Design and evaluation of a flexible travel training environment for use in a supported employment setting

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ABSTRACT

This article describes the user centred design and development of a virtual environment (VE) to support the training of people with learning disabilities to travel independently. Three separate implementations were built on top of an initial design. Two of these environments implemented intelligent agents to scaffold learners using virtual environments; the third took stakeholder experiences to redesign the initial environment in an attempt to improve its utility.

1. INTRODUCTION

Many of the issues around travel training for people with learning disabilities (LaGrow 1990, Bourland 1996) and virtual reality (Brown 1997, Steed & Frecon 1999, Standen *et al* 2001) have been previously identified. Brown *et al* (2002[2]) report on a number of VEs developed to support people with learning disabilities in extending independent travel skills. Building on this experience, we describe the design and implementation of a three dimensional virtual environment for improving travel skills of people with learning disabilities, and on two approaches to incorporating virtual tutoring agents into such an environment. The travel training VE formed part of a larger "Invest to Save" project (LBS 2004) established by the London Borough of Sutton. Its aims are "to help adults with learning disabilities move into employment by training them in relevant subjects, offering support and helping them to find work".

Stakeholder meetings were held to set the initial design requirements for the VE, and from these meetings, storyboards were created and agreed upon. An initial environment was then built, implementing a limited sub-set of the stakeholder identified features in order to obtain feedback on a working design as soon as possible. This VEs development was then forked, allowing work to proceed in two areas:

1. An investigation of the application of virtual tutors as a means of scaffolding a trainee's experience within the 3D environment.

2. The development of a customisable environment enabling trainees to practice navigating a specific route and the hazards encountered along it.

Alongside the VE implementation, the Traverse project sought to incorporate handheld computers in support of its travel training programme. This was to be achieved by using *TouchSpeak*, the commercial result of a research project from the ACE Centre (2003), who developed a Portable Communication Assistant for People with Acquired Dysphasia (PCAD), a "hand-held augmentative & alternative communication device with a dynamic colour display, a built-in microphone and digitised speech output. It is designed specifically for non-speaking dysphasic and brain injured users".

2. PACKAGE DEVELOPMENT - PHASE 1

2.1 Specification of the Package

Before any design began, informal context meetings were held with trainers and service users to identify the elements important to the two principal stakeholder groups. These meetings sought to address three aspects of the design:

1. How the travel training software was likely to be used

2. What usability issues were likely to be encountered

3. Define an initial set of interactions

These issues were discussed separately with the trainers and also with trainers and learners in facilitated sessions. These sessions defined the initial content and design outline.

2.1.1 Intended Use of the Travel Training Software. The trainers identified their primary requirement for the software as to provide an environment where the users could practice real-world skills in a naturalistic manner. The trainer would then intervene where the learner exhibited unsafe behaviour or had difficulty in remembering the procedure for a particular task. This would allow the trainers to continue the principal method of their real world (RW) travel training procedures while working with the simulated environment.

2.1.2 Usability Issues. A technical limitation was in place at project inception; that implementation was to be using standard PC hardware. Given this constraint, the principal usability concern was the method of avatar control in the virtual environment. A variety of avatar viewpoints were planned and a range of control devices supported (keyboard input, mouse control and joystick control). On screen representation of control state was also considered as potentially useful. This variety of approaches was decided upon in order to test which were most usable and should be employed in subsequent development.

2.1.3 Initial Set of Interactions. The following elements were identified as an appropriate set of tasks that the environment should support.

Road Crossing	Public Transport
Normal road*	Bus journeys, principally, catching the bus.
Normal road with island	Recognise a bus stop.
Zebra crossing*	Wait for a bus – look the correct way.
Zebra crossing with island	Allow trainer to configure bus number (with
Pelican crossing*	destination?) and bus colour.
Pelican crossing with island	Add possible decoy buses.
One-way roads	

Additional aspects: More than one lane, Parked cars*, Straight & curved sections*

Only a sub-set of these elements (marked*) were selected for phase 1 implementation, namely, a selection of the road crossing interactions.

2.1.4 The Role of Touchspeak. Touchspeak was hoped to support the learner's real world communication in a similar manner to its use with dysphasic adults. There were also hopes that it could support learners in remembering the tasks and duties required of them by their employer.

2.2   Package Development

The phase 1 environment was given an urban setting, and included a user controlled avatar and traffic (parked and moving). A simple figure '8' road layout was developed, as it provided a simple environment in which a variety of road crossing elements could be implemented, and in which traffic could naturally flow. A park was included as a safe practice area to develop avatar control skills. Traffic density was variable and three crossing types were created at various locations around the scene. A number of predetermined tasks were incorporated into this environment, by defining start and end points for the avatar. A variety of control methods and viewpoints were included.

The three different control systems were:

▪ on screen buttons, allowing mouse or touch screen control
▪ keyboard control (using the arrow keys), also allowing for use of a simplified "concept" keyboard
▪ joystick control, also allowing the use of other analogue controllers such as a steering wheel

The three different viewpoints were:

▪ 1st person (avatar not visible) - Default
▪ 3rd person-fixed (avatar permanently in centre of view)
▪ 3rd person interpolating ("follow" camera)

Additionally, the cursor was necessary for a specific interaction (pelican button press), and so was changed to a large hand with two states, open hand (normal) & press (indicating an active area).

All configuration options were presented on the initial screen, and this screen was returned to whenever the simulation was exited. This screen offered 7 pre-set routes, plus an 8th manual option, with which start and end points could be set by the trainer. A cylindrical "hot area" identified the completion point of a task,

this could be made visible (a yellow cylinder) or not in the virtual environment. Activation of the end point triggered a random congratulatory audio file. Settings for (parked and driving) traffic density were provided and the initial camera viewpoint.
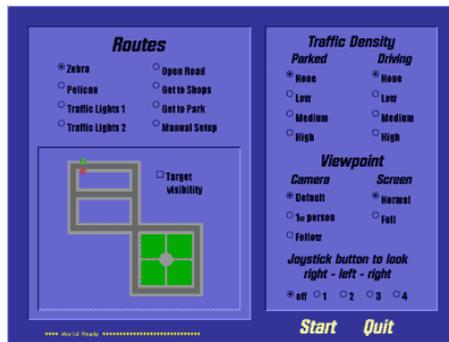
Figure1. *Phase 1 - the initial screen.* **Figure2.** *Phase 1 in use, follow camera.*

2.3   Iterative Evaluation and Refinement

Once a working environment had been developed, user testing was conducted with a number of the client group trainees. This diagnostic evaluation identified a several of usability problems and potential areas for improvement.

Control of the avatar was found to be the main usability issue. Most users found that mouse control (by clicking on the directional buttons) was difficult because of the need for fine control and mouse clicking. Most users had much more success using the standard keyboard or a joystick. Turning was noted to be a problem with users frequently over steering. A suggestion from the trainers was to modify the method of avatar control by implementing "stepped" turning; this was implemented as a switchable option and improved the capacity of many of the trainees to control the avatar.

Looking to look up and down the street for oncoming traffic was found to be awkward since the avatar had to be turned to the left and right to bring the street into view. A camera action to look right, left, right was developed and bound to the space bar. This was also made available to be configured onto any of the first four joystick buttons.

A previous VR travel project (Lewis *et al* 2000) suggested that a first person perspective was an acceptable viewpoint for a similar group of users, so this was made the initial default. It very rapidly became apparent that the fixed 3rd person perspective was the preferred viewpoint, so the system default was changed to this.

An additional traffic density of zero was added, to allow for users to practice avatar control in the environment without any traffic. (The park was intended as a safe area to practice, but the trainers found that avatar control practiced in the park did not transfer too well to the street.)

Other improvements arose which were noted for consideration during the second development phase. The trainers were also interviewed to discover their experiences using the environment as part of their travel training programme and to determine those elements that they felt were important for inclusion in the second development phase.

3. INTELLIGENT AGENTS - PHASE 1

On completion of the first phase of development, two implementations of intelligent agents were developed for the environment (Chuang 2003, Penter 2003). These intelligent agents seek to scaffold the trainee's introduction to and use of the 3D environment. A baseline analysis of students and tutors (Chuang 2003) using the phase 1 environment without an agent suggested the principal activities of the tutor in supporting a user of the travel training software (and so those required of an agent) were to:

- Introduce the control devices
- Introduce the tasks
- Support route finding
- Provide problem solving whilst performing the tasks
- Monitor performance

These principal activities comfortably agree with the activities identified by the trainers at the package specification stage (2.1). This analysis of trainees using the environment helped to define the characteristics an Intelligent Agent requires; four characteristics were identified as being necessary (Chuang 2003):

- **Deductive Character** – The agent should introduce goals and learning objectives, and assist the trainee in mastering the control system.
- **Monitoring Character** – The agent should observe the student's progress, giving additional instruction, support and demonstration where the student is having difficulty or gets into a hazardous situation.
- **Motivational Character** – Successful achievement of goals should be rewarded with positive feedback, however, since some safety issues may have arisen from the student's behaviour despite a successful result, the agent may need to direct the student to repeat a task until no safety issues arise.
- **Solution-address Character** – The agent should provide incidental advice and guidance on request or in response to the breaking of a rule.

An interesting observation was that combination of two (successfully completed) simple tasks into a more complex task resulted in double the number of tutor interventions. Learners rapidly forgot the instruction previously given, and had to be prompted by the tutor; "[r]eminding users to do important tasks regarding safety issues should be included in IAs".

The Intelligent Agents were then implemented, incorporating these four characteristics, with two differing approaches, one using an active, animated 3D figure, and the other a static 2D representation of a tutor. Evaluation was conducted by observation, recording the duration and frequency of trainer interventions and user errors with and without a virtual tutor. Trainer assistance, task completion and user satisfaction were all noted to be enhanced in the environments augmented by an intelligent agent (Chuang 2003, Penter 2003). A set of design guidelines for the implementation of intelligent agents for people with learning disabilities were developed from these studies (Chuang 2003):

- Use simple and short language and avoid long sentences
- Consistent layout or controls for the Agent
- Use plain background for the speech balloon
- Use step by step instructions to guide users
- Provide positive feedback
- The speech of the text should be recorded by native speakers, or use text-to-speech techniques
- Provide dismissible functions while they are not essential
- Limit length of the animation
- Agent behaviour cannot be too complex
- Avoid use of voice input
- Minimize distraction from learning, for example give reminders without requiring learner's full attention

These guidelines build upon previous work by Brown *et al* (2001, 2002[1]) and Standen *et al* (2002).

4. FLEXIBLE TRAVEL TRAINING - PHASE 2

4.1   Refinement of Phase 1 Design

The design methodology planned for the project had always intended to undertake a radical overhaul of the prototype after the completion and evaluation of the work undertaken during phase 1. The rationale for this decision was that both the user group and the trainers, the stakeholders informing the design process, would be in a much better position to comment and suggest ideas after the experience of the phase 1 design cycle.

4.1.1 Stakeholder Input. The learners were very encouraging about the way in which they could practice tasks over and over again, building up confidence in their own abilities. There was a discernable view however that the lack of variety in the available tasks was making repeating the exercises a little monotonous. Users sometimes wanted to visit other parts of the environment, however because the crossing type they were learning to use was not located there they had to continue working in a specific area of the world. The trainers suggested that this could begin to effect the motivation of the users.

There was also a view from the trainers that the transfer of skills from the simulation to the real world could be made more reliable if the users were enabled to experience the same task in different contexts. It was suggested that by only exposing a user to a crossing type in one specific place, that its value as a generic

skill may not be as effective as it could be. The trainers had fears that the skills required to understand how to use a crossing may be context specific e.g. *"this is what I do at the crossing outside McDonalds"* rather than the generic *"this is what I do at a pelican crossing"*. It was felt that if a particular task could be placed in different locations within the environment that the adoption of generic skills could more easily be achieved. The trainers suggested that the most important aspect to consider for this was the route following aspects of the users' experience. This was closely followed by the need for the users to associate parts of the journey with landmarks along the route.

A proposal was therefore made to overcome the limitations of the fixed VR world by developing a world builder with which the trainers could develop customised environments. This approach would allow the VE to reflect the sequence of actions and situations that a learner encounters along each of the routes that they are being trained on (as well as allowing the exploration of other, unfamiliar routes). The phase 2 design was therefore based on creating a set of 3D assets which could be combined into a world that went some way towards simulating the real world environment that the user would have to navigate their way around.

4.2   Implementation

The implementation of this idea was a tile based VE built from a variety of road tiles incorporating bends, crossroads, T-junctions, cul-de-sacs and straights, utilising both single and dual carriageways. The tiles were developed as a kit of interchangeable pieces which could be arranged to create a flexible customised environment that could be assembled to much more closely resemble the real world environment which the user would have to navigate their way through. Following the assembly of the road layout the trainer can populate the environment from a set of road safety interactions; zebra, pelican and puffin crossings can be dragged onto any road tile as can pieces of street furniture etc. This interface allowed any number of road and crossing configurations to be built by the trainer, enabling a varied presentation of various crossing types to be experienced by the user and also allowing the development of routes specific to the trainee's anticipated journey(s).
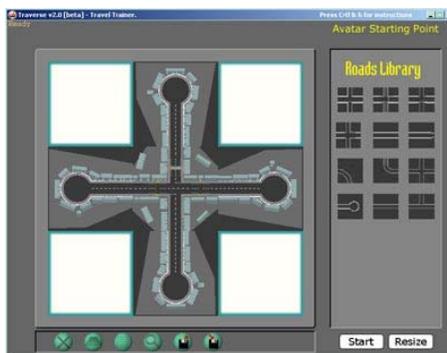
Figure 3. *The World Builder.*   **Figure 4.** *Adding Interactions to the World*
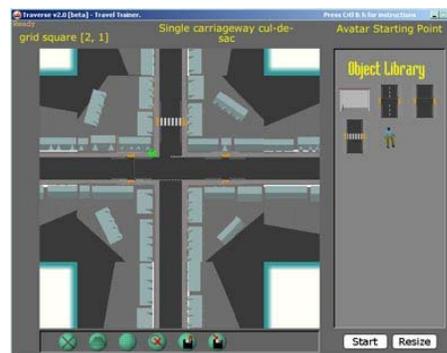
4.2.1 Navigation Issues – Bridging the VE/RW Gap. The configurable environment seemed to enable generic skill acquisition and make a major contribution towards context specific route learning. However it was clear that the VE alone could not produce the infinite variety of real world situations, in which landmarks are features utilised by the users in navigating their way around. To tackle these issues the *Touchspeak* package was enlisted as a portable memory aid. The trainers together with the users surveyed the route noting the landmarks and decision points especially where they seemed to hold particular significance for the user. This survey was used to construct a hierarchy of photographic images and vocal and text prompts within *Touchspeak* that could be used by users throughout their journey, both in the simulation and in the real world.

At first the results of this were encouraging, however the trainers found the hierarchical nature of *Touchspeak* awkward to program and use, and the extremely flexible decision tree arrangement of the software was unnecessary for the linear progression of a journey. The approach was refined to use Microsoft PowerPoint to hold a slideshow of the same types of media, this time arranged in a linear fashion. The trainers found this approach much easier to develop for the users, and there was a suggestion that the users found this easier to use.

Whilst use of handheld computers seemed to offer much promise, several significant drawbacks were identified. There was some concern that the need to ensure that the units were kept charged could impact upon their usefulness - particularly where people with a learning disability took the units home. There were also concerns that somebody with a learning disability travelling alone with a handheld computer on prominent display could place themselves in a position where they were a target for theft. Indeed, the prominent display of valuable items such as handheld computers is contrary to police advice. Finally the user group expressed a view that in outdoor situations the display was very difficult to see - the problems of lack

of brightness and reflections from the LCD screen were exacerbated by the relatively small size of the display itself.

Following these trials the value of a portable memory aid was confirmed, the problem was perceived to be with the technology. After discussion with the users it was decided that a laminated paper based set of pictures and instructions was the most appropriate way of tackling the need for users to have reminders of decisions and actions whilst in the field.

4.2.2 Technical Refinement of the VE. Phase 2 offered the opportunity to solve a number of technical issues identified during the testing of the first phase. One of the most significant of these involved the complete reworking of the control system of the environment. Collision detection in the first environment was implemented through a system of ray casting. When this approach was first tested on the avatar it appeared to be a satisfactory solution, however once cars were introduced into the environment significant drawbacks emerged. The most critical instance of this problem was where a collision between avatar and car could go undetected. This was because ray casting was a frame-based test that became increasingly unreliable at the slower frame rates experienced on less powerful computers. This was exacerbated by the fact that the ray casting method could not detect partial collisions between geometry untested by the ray.

The solution to this was to implement the VE with a physics simulation. This simulation was used to monitor events within the environment and provide the control systems for both the avatar and the cars. Cars were given route finding and decision making routines, allowing them a degree of freedom to decide where in the world they would go, within the constraints of their rule set. To solve the collision issues experienced in phase 1, the physics simulation conducts collision tests 4 times between each frame draw, using low polygon versions of the VE geometry.
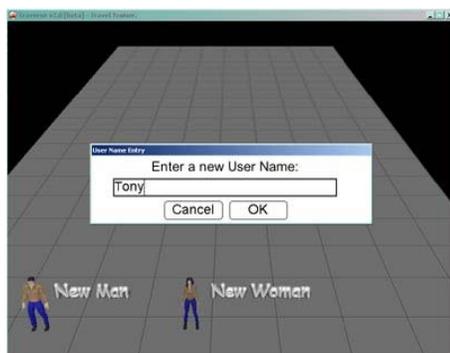

Figure 5. *The Lobby*   **Figure 6.** *Customising an Avatar*

The generic avatar used in phase 1 was always intended to be replaced, and discussion with the trainers and project management established that they required avatars to represent both sexes and a variety of races and ages. This was achieved by developing a male and a female avatar with customisable clothing, skin and hair colour. Implementing customisable avatars enabled the implementation of a simple log-in system. A 3D lobby was built, populated by the default male and female avatars (for new users) and any customised avatar used on the system. It was hoped to link this system up to user profiles containing personalised rotes and performance data. Observation of users demonstrated that they enjoyed being able to customise their avatar, a feature seeking to enhance identification of the trainee with the action taking place within the virtual environment.

A further refinement suggested by the trainers was to trigger puffin and pelican switches by walking the avatar into the control box. Implementing and testing this indicated that the former approach of using a hand cursor to represent pressing the crossing button was more useful, being more comprehensible to the learners and a more positive representation of the real world action. An additional usability issue was requested, to indicate when the avatar was correctly positioned at a zebra crossing - a visual cue was developed, however, we have reservations about using an on-screen indicator to give feedback to the user in this way, as such cues do not exist in the real world.

Figure 7. *The phase 2 VE*

5. CONCLUSIONS

The software was only one element within a general programme of life, employment and travel training skills. Because of this it is difficult to detach the contribution towards travel training made by the software, from the impact made by the trainers in the real world. Anecdotal evidence from the trainers suggests that the incorporation of V.R. training into a programme of travel training does have beneficial results. The skills learned in the V.R. environment appeared to transfer to the real world. There were indications that this skill transfer reduced the overall time taken to teach a user all of the skills required to enable them to travel independently.

Contrary to our initial expectations and implementation, the learners all preferred a 3rd person perspective for avatar control. Many users also found unmediated turning caused control problems; stepped turning appears to be a satisfactory method of addressing this.

Incidental outcomes identified by the trainers included a significant increase in the users confidence in using computer systems. There were also suggestions that the motor skills and co-ordination of users in operating mouse and keyboard were also improved.

Virtual tutors have been shown to improve the time taken to achieve a task in both of the tutor studies. However, it has not been demonstrated that such an improvement in one performance parameter associated with computer use leads to an equally effective transfer of skills from the VE training environment to the real world.

6. FUTURE WORK & LONGITUDINAL EVALUATION

The focus of this project was on the development of the travel training software following a user centred design methodology. Due to this, the focus of work was on the evaluation of the design from a usability and utility viewpoint. It is clear that there is a need for an extensive study to substantiate the anecdotal evidence of skill transfer to the real world and reduced overall training time.

There is also a particular need to look at the effects the software has on the users perceptions of hazards in the real world. This particularly applies if the software is to be used without of an observing trainer. A wider range of potential traffic hazards is planned for the simulation including emergency vehicles, reversing vehicles and parked cars moving off. A tendency to experiment with hazardous behaviour in the simulation has been noted, particularly where the user perceives this behaviour to have been "rewarded" because it generated a system response. There is a very real danger that inappropriate responses from the environment or an agent could desensitise users to real world hazards and it is essential to thoroughly evaluate this risk.

Work is ongoing to extend the range of tasks covered by the software, notably to incorporate the skills required to enable travel using buses and trains. There is also a desire to increase the set of tiles available to extend the range of environments and road shapes. This could enable urban, suburban and rural environments to be assembled to more closely match the needs of users. Extension of the user profiles to allow personalised routes and the collection of performance data is envisaged.

An additional area of interest raised by this project is the potential for exploring contemporary technology, notably 3G phones and GPS, as a means of augmenting travel training programmes. This is a

wide open field that could use ideas such as a portable and usable mobile phone based slide-show tool to aid navigation or a bus timetabling system such as Nottingham's NextBUS (Bargiela 2004).

Funding for these activities is currently being sought. In the meantime a user survey questionnaire is being developed to give the trainers a subjective method of recording their opinions on how useful the travel training environment has been to their students. To widen the range of this feedback the software has been made freely available. It is available for download at http://traverse.isrg.org.uk. The user survey questionnaire will be circulated to users who have downloaded and registered their use of the software.

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