Designing virtual learning environments for people with learning disabilities: usability issues

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ABSTRACT

The Virtual Reality Applications Research Team (VIRART) has been developing communication and experiential Virtual Learning Environments (VLEs) for people with learning disabilities since 1991. As a human-factors-based research group, we have always been aware of usability issues and the importance of consideration of user needs and abilities in any design development process. However, the infancy of VR for use by the general public and lack of VE applications, particularly for special needs users, has meant that there are few examples of usability studies and a general lack of design guidelines. This paper outlines design considerations in development of virtual learning environments and highlights usability issues identified via observation of users with learning disabilities. Specific usability problems were identified relating to communication, navigation and interaction. Examples are given and recommendations for VE design guidelines are suggested.

1. INTRODUCTION

There is a general lack of guidance in terms of how to go about the development of a VE and any specific design principles that should be adhered to (Hix et al., 1999; Wilson, Eastgate, & D'Cruz, In Press). Design rules can be found in the field of Human-Computer-Interaction (HCI) that act as specific instructions intended to be followed by the designer. However, many design rules developed within general HCI are not relevant to virtual environment design because of the different features and objectives of VEs as compared to graphical user interfaces (GUIs) or more traditional computer interfaces (Kaur, Maiden, & Sutcliffe, 1999). The defining features of VR are that a user can freely navigate and interact with objects within a virtual environment in real time. Where these VEs are intended to replicate real world places and activities, there is potential that the user should be able to interact with the virtual environment intuitively, much as they would with the real world (Wilson, 1997). The extent to which this is true will be determined by; the individual (their experience and perception of using VEs), the purpose of the VE (determining any instructions they may have received) and will be shaped by VE design. It has been suggested that by developing a VE that represents reality, providing features common to real world scenarios, such as collision boundaries placed along walls and floors, users will be able to apply knowledge- and skill-based rules acquired in the real world, thus providing a more intuitive experience (Eastgate, Nichols, & D'Cruz, 1997). However, there has been relatively little research conducted to define and evaluate the amount and form of cues required to achieve this.

From the point of view of the VE programmer, decisions concerning amount and quality of objects and interactions constructed within the VE will have a direct impact upon the time required for its development and the speed at which it will run. Wilson et al. (In Press) describe two approaches. One is to model a VE as accurately as possible to its real world counterpart, however, this may result in a VE that is overly complex for its purpose, which could result in slow running speed and unclear cues as to what to do within the VE. The other is to develop a VE containing a crude representation of salient characteristics of the real world. If chosen correctly, this would produce a VE that is meaningful (not necessarily 'realistic') to the user and provides adequate and appropriate cues for interactions required to complete the relevant tasks (Wilson, 1997). However, there is a danger here that this may result in a simplistic VE containing insufficient information or detail for effective application use. The design choice, whether to represent reality, or some abstraction of it, is true for both navigation and interaction. However, defining appropriate levels of VE design complexity is not straightforward.

Recommendations for the design of computer interface systems for users with special needs and learning disabilities include reducing cognitive barriers, simplifying language in task instructions, making displays simple and consistent, providing on-line help and supporting selection techniques (Edwards, 1995). Cress & Goltz (1989) recommend that the visual and audio complexity of the output display should be minimised, and that the system should include on-line memory aids and help screens.

These guidelines, developed for traditional computer interfaces, may not be wholly appropriate for the development of VEs. As already stated, the way in which information is presented within a Virtual Environment is often designed to represent some real world situation and therefore navigation and interaction should be somewhat intuitive and understandable. A VE developed for special needs education, that has been made to look realistic, would probably not provide any additional on-line help. A realistic environment may require a lot of detail and this will not always result in a 'simple' display. Thus, the problem remains; how can we design virtual learning environments with sufficient detail to offer learning of real-life tasks and yet not resulting in complex environments which may be difficult to navigate and interact with?

An evaluation study which examined the effectiveness of VLEs in terms of how well they support constructivist theories of learning in children with learning disabilities (reported in Neale, Brown, Cobb, & Wilson, 1999), reached some conclusions concerning the impact of VLE design on users with learning difficulties:

1. *Use of the virtual environment*

   Use of the virtual environment should be made simpler. Not by oversimplifying its representation, but by subdividing the goals of a given task, to suit the needs of the user.

2. *Interaction*

   Tasks should not be more difficult in VE than the real world. Interaction with a virtual environment is not the same as in the real world and so it is important that the interface doesn't actually make it more difficult, and therefore unusable. This is itself can cause confusion, and lead to misinterpretations.

3. *Efficacy*

   If a VE doesn't convey the real world behaviour in a realistic way, then the students may be picking up the wrong cues and information and make the wrong assumptions about the real world.

4. *Navigation*

   The use of navigation devices can make it difficult to actually move around the VE. Some users find this very difficult and this leads to frustration and some disincentive to use it.

This paper examines the success of these design guidelines as applied to the development of the Virtual City (Brown, Neale, Cobb, & Reynolds, 1999). Further recommendations for the design of virtual learning environments for users with learning disabilities are proposed.

2. USABILITY EVALUATION OF THE VIRTUAL CITY

The Virtual Life Skills project was developed to teach basic life skills to children and adults with severe learning disabilities. This was a community-based project comprising a team of specialists in health care, special needs education, social workers, and representatives of the intended user population, and took a user-centred approach to design and evaluation of the virtual environments. The project, its design and evaluation processes, and virtual environments created have been described in detail elsewhere (Brown, Kerr, & Bayon, 1998; Brown et al., 1999; Cobb, Neale, & Reynolds, 1998; Meakin et al., 1998) and will only be briefly summarised here.

Four components of a 'Virtual City' were completed during this one-year project; a virtual supermarket, a virtual café, a virtual house and a virtual transport system (see Brown et al., 1998). A user group of 16 adults and their support workers specified the contents of each virtual environment and the learning scenarios they wanted in each one (Meakin et al., 1998). The users reviewed the development of the virtual environments and a testing programme involved another group of representative users to 'try out' the virtual city. Evaluation focused on usability (could the users interact with the virtual environments?), enjoyment (did they want to?), learning (demonstration of understanding of skills) and transfer of skills learnt from the virtual environment in to the real world (see Cobb et al., 1998).

Several methods were used for the analysis of usability, producing a form of methodological triangulation to provide richer, more meaningful results than could be obtained from a single data source (Breen, Jenkins, Lindsay, & Smith, 1998). Observational analysis was used to record the levels of support given whilst the user performed tasks in the real world and the equivalent tasks in the virtual environment. Reports of any difficulties faced were also recorded in the form of questionnaires and interviews with both the tester and the support worker.

Each component of the Virtual City was broken down into a number of tasks representing specific learning objectives; each learning objective was then broken down into a list of procedures. Observation checklists consisted of these tasks and sub-tasks, so that problems experienced with certain tasks and specific areas of the VLE could be identified. For example, in the Virtual Café, task 2, ‘find a table’ could be broken down into a number of basic components:

- Understand instruction ‘find a table’ – understanding/communication
- Move to table – navigation
- Click on table to sit - interaction

For each task component the level of support provided by the support worker was recorded. This ranged from no support given, through verbal, visual and physical prompts, to support worker does task. The importance of this measure in this situation was that it allowed a comparison between the support given in the VLE and support given to carry out the same task in the real world. If a higher level of support is required in the VLE than the real world, then this may indicate that the task is more difficult to complete in the VLE than the real world and this may be due to the design of the Virtual Environment. It is important to ensure that the training tool used is not more difficult to use than to carry out the task in the real world.

Support workers were asked open-ended questions, allowing them to make comments about each of the task components in the VE with respect to usability and training strategies. Testers, representing the target user population, were also asked questions related to enjoyment and usability of the VE.

3. RESULTS

Usability reports were created for each of the main areas of the Virtual City. The reports combined task information (broken down into basic components) with evaluation results compiled about this task. These included; levels of support required to carry out task, researcher notes, participant and support worker comments and questionnaire answers.

Tables 1 and 2 show example scenarios where difficulties of use were highlighted by the evaluation study. In Table 1 the tasks represent difficulties relating to navigation within the virtual environment and table 2 highlights interaction difficulties. In both cases, the problems encountered were not because the tester did not know what they were expected to do (they had successfully achieved these tasks in the real world trials), but because they could not use the VLE effectively to achieve their goals.

The usability problems experienced from different tasks within the Virtual City were compiled and theme based content analysis was performed (described in Neale & Nichols, In Press) which allows the grouping of similar types of problems experienced across the four sub-components of the Virtual City. This analysis indicated specific usability problems in:

1. *Communication*, specifically in reading text instructions
2. *Navigation*, particularly getting through doorways and other small spaces
3. *Interaction*, a variety of difficulties were identified here including; unnatural interaction metaphors used such as ‘bump into table to sit down’, users unsure of the effect of actions, difficulty interacting with objects, and insufficient cues provided in the VLE.

Individual usability reports and the content analysis matrix were discussed with a focus group of experts from the fields of human factors, VE development and special needs education and used to make informed decisions regarding design refinements and prioritisation of modifications.

Recommendations for design improvements for each of the usability problems areas are shown in Table 3.

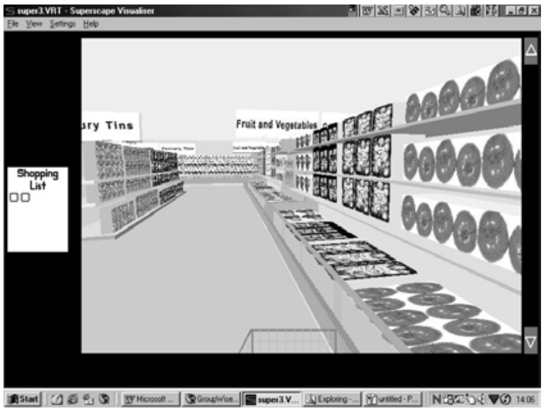

Figure 1. *Enlarged products on shelves.*

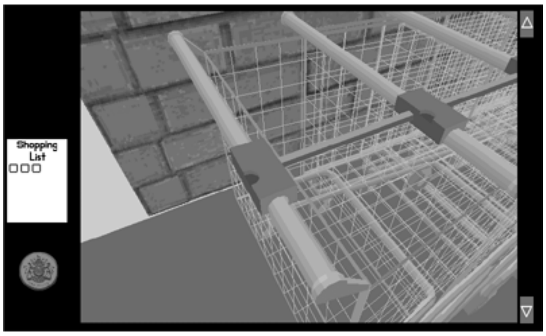

Figure 2. *Fixed viewpoint.*

Figure 3. *Exaggerated size of door and stairway.*

4. DISCUSSION

Constraints from the Virtual Reality System and the Virtual Environment software used means that we may never be able to present a truly 'realistic' experience in a VE. VE designers need to adopt strategies that distort the design so that a realistic appearance is substituted for naturalistic interaction. For example, when representing the shelves in a virtual supermarket to scale, the food on these shelves may appear to the user of a VE to be very small and it may be difficult to differentiate between objects. This is partly due to the users' viewpoint in the VE, they need to be able to see the trolley, the aisle, the shelves etc and all of this must be represented on the screen making each item appear smaller than it would in a real supermarket. To make it easier for users to identify objects within the virtual environment, it may be necessary to make them larger than they would realistically be. Figure 1 shows food in the virtual supermarket larger than it would be in a real supermarket. In the virtual supermarket it is also possible to interact with items that are a long way away. In the real world, when shopping, one may use their peripheral vision and a number of other senses in order to detect the types of items on sale and would walk up close to the shelves in order to examine the items. When using all senses in the real world it is also easy to understand the impact of an action, for example, when picking up an item from the shelf, you will see the item has been moved to your trolley, you will hear the item being picked up, you will feel the item in your hands.

Another way, in which we can design to compensate for the differences between the virtual experience and the real experience, is to set an automatic viewpoint so that the object takes up most of the user's display or to colour the object so that it immediately stands out from its surroundings. In the virtual supermarket an automatic viewpoint was implemented after users had problems locating the area they needed to select. The user must first collect their pound coin, then move towards the shopping trolleys. When the user is close enough to the trolleys they are moved to an automatic viewpoint (shown in figure 2) so that they can see the area where they need to place their coin in order to release the trolley.

When designing a Virtual Environment, it is important to identify its primary objective. In the case that we have described, learning daily life skills, the focus is on teaching procedures required to carry out these skills and providing information about the social and practical consequences of actions (for example, explaining why the bathroom door should be locked and the shower curtain pulled across when the shower is being used). Physical interaction provided by a desktop VR system used with a joystick and mouse as input devices is not representative of the real world. Therefore the aim of the VE is not to simulate and teach physical navigation and interaction with objects, and so these actions should be made as easy to do as possible, and not prevent the user in any way from carrying out procedural tasks.

Again, by distorting the VE to make it less realistic looking we increase the naturalistic experience in the VE. In the case of navigation we found that this was problematic when travelling in and through confined spaces. Figure 3 shows a recently developed VE, which has an enlarged staircase, hallway and doorframes that should make navigation simpler.

5. CONCLUSIONS

VE design and development guidelines provided by previous research studies are by no means comprehensive and the authors themselves recognise that they may not be at all suitable for all types of user groups. They may also be difficult to implement, for example, even if a VE design represents the real world as accurately as possible, the experience may not be perceived by the user in the same way as its real world counterpart, as the VR system will not provide the user with the same sensory powers that they would hold in the real world. The VR system will primarily rely on visual and audio stimuli for communication and the users' visual display will be less detailed with a limited field of view. Therefore it may be useful to build in some exaggeration or manipulation of object and interaction representation in the design of the VE in order to make virtual objects or interaction effects at least as obvious as they appear in the real world. In the cases that have we described, the VE was designed to teach specific life skills, therefore users interact with a series of structured scenarios where attention is drawn to particular objects within the VE. Distortion of reality when representing objects may be necessary in order to make objects appear more obvious when designing for a learning-disabled population. These steps, whilst they may appear contrary to the desire to *replicate* the real world, allow us to *represent* the real world in a way that is still meaningful to the user. Furthermore, these recommendations aim to minimise usability problems and to maximise the potential that VEs offer for learning.

This paper has highlighted usability issues and presented design recommendation appropriate to a specific user population for an application with specific learning objectives. Without further evaluation of usability of these environments, it is difficult to comment upon generalisability of the design guidelines suggested. Further work aims to evaluate usability of these environments on a wider scale and to apply these design guidelines to other user populations using VLEs for different purposes (e.g. social skills training in adults with Asperger's Syndrome, (Parsons et al., 2000)). It is also important for any design guidelines that are developed to be practically useful for VE developers. Considerations as to how they are displayed and information provided would be an essential part of this.

Acknowledgements. We would like to acknowledge all partners and participants in the Virtual Life Skills project, especially the user group and support from the Virtual Reality Applications Research Team at the University of Nottingham.

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Table 1. *Difficulties relating to navigation in the VE.*

Task	Evaluator observation notes	Tester questionnaire	Support worker questionnaire	Coded assistance
Entering supermarket doors	*The view on the screen often makes it difficult to distinguish between the glass doors and glass panels between the doors and the tester sometimes gets frustrated. Support workers often have to provide assistance getting through the door. This is an activity which none of the testers would have a problem with in the real world.*	*Q: What was the most difficult task to do in the supermarket?* *S1: Getting through the supermarket doors*		
Entering bathroom doors	*The doors close automatically. 4 out of 5 testers need no help to do this in the real world, but needed some support to do this in the VLE.*	*Q: What did you not like about using the Café VE?* *S2: Using the toilet and getting stuck in the door* *Q: What was the most difficult task to do in the café?* *S3: Getting through the toilet door*	*"The toilet doors should be made a different colour from the walls - to make it clearer when entering and leaving."* *"The only problem was negotiating these doors."*	Student 101 - more prompts in VE than real world

Table 2. *Difficulties relating to interaction in the VE.*

Task	Evaluator observation notes	Support worker questionnaire	Coded assistance
Locate specific product on shelf	*Difficult to see & identify some items - especially if from a distance or if walking along an aisle and looking at items from a steep angle [they are pasted flat textures]. The tester does not want to stop and turn to look at them at each step - this would take a lot longer - especially if the tester has some difficulties using the joystick.* *Occasions were observed where the product has been mistaken for something else - this did not happen in real life.* *Sometimes support worker required to find the exact location of the product - this did not happen in real world.*	*testers find it difficult to recognise products*	More prompts required in VLE than real world for tester numbers 103, 104, 111, 118 and 120
Put £1 in trolley slot	*"Tester often needs support worker help to click on the trolley slot. These tasks are often frustrating for the user."*		More prompts required in VLE than real world for tester numbers 103 and 104

Table 3. *Recommendations for design improvements.*

Usability category	**Design guideline**	**Recommendation for refinement to VLE design**
Communication	Use a **consistent** format throughout the programme	Display information /instructions using - Audio (have a 'replay' button) - Text (simplified) - Pictures or symbols (in this case Makaton) Standardise symbols and positions on screen for user responses 'yes', 'no', 'move on' and 'replay'
Navigation	Unless the VE is intended to teach navigation skills - **simplify navigation**	- Widen doors, corridors and allow extra space for navigation.
Interaction	Task design should be **realistic,** equally as **complex** as in the real world, and **flexible** (allowing users to carry out sub-tasks in any order). Metaphors used to interact with objects should **reflect** real world behaviour Representation of objects in the VE must be **obvious** Use **set viewpouints** to focus attention to object **Highlight** objects to indicate interactivity	- Include **all** steps and sub-steps of a task. Allow users to carry out **sub-sections** of tasks. Do **not** include any **extra steps**. - E.g. clicking on the menu in the café brings the menu closer to view, representing 'picking up' the menu to read it. - **Enlarge** objects to make them recognisable. - E.g. change view to see coin slot in trolley when close enough - E.g. place a red border around object to be interacted with.