Access to virtual learning environments for people with learning difficulties

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ABSTRACT

An evaluation of virtual learning environments, developed to teach independent living skills to people with learning difficulties, found that individuals differed in the amount of support required to use the input devices. This paper describes the employment of a user-centred design methodology to design, develop and evaluate a virtual environment hardware interface for people with learning difficulties. Central to this methodology is 'usability', a crucial factor in the production of a successful human-computer interface. The completion of this study should result in the production of a virtual environment interface for people with learning difficulties, which satisfies ISO 9241 (the British Standard giving guidance on usability).

1. INTRODUCTION

There have been some interesting developments in the specification of training and education environments for people with special needs, including the Virtual City: a set of virtual environments developed to teach independent living and social skills to people with learning difficulties (The Shepherd School, 1998). In an evaluation of the Virtual City, it was found that individuals differed in the amount of support required to use the input devices: joystick for navigation tasks; mouse for interaction tasks (Cobb et al, 1998). Studies on the most appropriate methods of virtual environment control for people with learning difficulties have been conducted. Hall (1993) concluded that a joystick, limited to two simultaneous degrees of freedom, had the greatest utility in navigation. A further study evaluated a set of interaction and navigation devices, from a range of affordable and robust devices commonly used in special schools (Brown et al, 1997). In this study, the joystick was found to be more suitable for navigation tasks than the keyboard and mouse. The touch-screen and mouse were assessed for interaction tasks but neither of these devices rated best, although the touch-screen was found difficult to calibrate. From this research, it is clear that there is a need for further investigation into virtual environment access for people with learning difficulties.

2. INPUT DEVICE EVALUATION

2.1 Aims

- to evaluate the usability of the joystick for navigation tasks and the mouse for interaction tasks within virtual environments, for people with learning difficulties
- to obtain any usability guidelines for future virtual environment input device development

2.2 User Group

A user group was selected from the pupils who attend the Shepherd School in Nottingham. The user group attributes were as follows: size of group - 14; gender - 7 female and 7 male; age range - 8 to 19; cognitive ability - 2 moderate/severe and 12 severe learning difficulties; physical ability - co-ordination, gross-motor and fine-motor difficulties. 6 students had previous experience with virtual environments, 6 had used the joystick and 5 had used the mouse before.

2.3 Environment

The evaluations took place at the Shepherd School, in the 'Cyber Café' room. For some of the evaluations, the room was quiet and mostly free from distraction. During the majority of the evaluations, other students would come and go from the room, but would not attempt to disturb the subject.

2.4 Equipment

A colour computer monitor was used to display the virtual environments and a standard 2-button mouse was used for interaction tasks. 10 students used the Axys joystick (Suncom Technologies) and 4 students used the Wingman joystick (Logitech) for navigation tasks. The stick on the Wingman joystick is much taller and wider than the Axys joystick and is shaped to fit the hand.

2.5 Task

Each student was asked to complete navigation and interaction tasks, using the joystick and mouse respectively, within a virtual factory, café or supermarket. A demonstration of the devices and tasks was given before commencing the evaluations.

2.6 Assessment Measures

- Misuse of device: non-task related movement, harshness, pressing the wrong buttons, any other points
- Support required: spoken instruction, physical assistance, any other points
- Physical ability: sufficient strength, able to grip properly, any other points
- Workplace: able to reach, any other points
- Attention: on task, on device, on other
- User comments/reactions: positive, negative

2.7 Results

When performing navigation tasks with the joystick, 7 students showed controlled use of this device and 6 appeared to be holding the stick comfortably. The difficulties, which some of the students experienced with the joystick are listed in Table 1. The main usability problems experienced with the joystick were found to be: random movement; left/right movement causing too much rotation in the virtual environment; trying to use the device for interaction tasks and difficulties in gripping the joystick.

For interaction tasks, 6 students used the mouse quite well, with 7 gripping the device properly. Some students rested their hand on top of the device when using it, instead of gripping around the sides. As was found with the joystick, random movement of the device occurred and 3 students repeatedly pressed the mouse button, rather than just pressing it once and releasing it. One student required the evaluator to hold the mouse still, so that he could press the button and interact with the virtual environment. These, and further usability difficulties, which were observed are listed in Table 1.

Details obtained from the other assessment measures, i.e. support required, which were considered to effect the usability of the system are also listed in Table 1. Additionally, this table lists some suggested design guidelines for future virtual environment input device development, which have also been summarised in Table 2. Examples of these design guidelines are:

- Clear, understandable operation
- Consider the physical abilities of the user group
- Ergonomic design

These requirements highlight the importance of considering the cognitive and physical attributes of the user group when designing a product to meet their needs. In user-centred design, product developments are driven from user requirements, rather than from technological capabilities (USERfit, 1996). Therefore, it was decided that a user-centred design methodology should be employed, in order to design, develop and evaluate a virtual environment interface for people with learning difficulties.

Table 1. *Usability factors identified in the Input Device Evaluation and suggested design guidelines for future virtual environment system development (in italics).*

Navigation Random movement of device, disorientation - *Clear, understandable operation* Too much left/right rotation, spinning - *Device more resistive to movement (may help to prevent some disorientation)* Trying to use for interaction tasks - *Functional clarity for achieving navigation and interaction tasks* Button misuse - *Not easy to press buttons by mistake* Base held still by evaluator - *Ensure that base of device remains stationary during operation* Physical help with some tasks, alignment guidance - *Able to use the device independently* Used two hands, tight grip - *Ergonomic design of device* **Interaction** Random movement of device - *Clear, understandable operation* Frequent pressing of buttons, pressing wrong button - *Not easy to press buttons by mistake* - *Only possible to press buttons which are required* Physical help with some tasks, held still to press button - *Able to use the device independently* - *Consider physical abilities of the user group* Not gripping around the sides of the device - *Ergonomic design of the device*	**Further assessment measures** Prompting as to which device to use for a task - *Functional clarity for achieving navigation and interaction tasks* - *Only have one input device for navigation and interaction tasks* Encouragement, some distraction/distracted - *The device gives rewarding feedback* - *The device is motivating to use* Weak grip, shaky hand/arm - *Consider physical abilities of the user group* Desk too high - *Adjustable workstation* In Major Buggy - *Consider accessibility to the workstation* Fidgets in seat - *Workstation helps to engage the user* - *Integrated workstation* Some distraction/distracted - *Develop interesting, motivating and age appropriate virtual environments* Attention on devices when using them - *Device doesn't distract attention for the VE* - *Device is transparent* Attention on devices when switching between them - *Only have one input device for navigation and interaction tasks* - *The user does not have to keep locating a device* Frustration with tasks - *Ensure virtual environments are age appropriate*

Table 2. *Summary of the suggested design guidelines for future virtual environment system development*

- Clear, understandable operation of the device
- Functional clarity for achieving navigation and interaction tasks with the device
- The device is more resistive to movement (may help to prevent some disorientation)
- Only have one input device for navigation and interaction tasks
- Not easy to press buttons by mistake
- Only possible to press buttons which are required
- The device can be used independently
- Ensure that base of device remains stationary during operation
- Ergonomic design of device
- Consider the physical abilities of the user group
- The device gives rewarding feedback
- The device is motivating to use
- The device is transparent, i.e. doesn't distract attention from the virtual environment
- Adjustable and accessible workstation
- Workstation helps to engage the user
- Develop interesting, motivating and age appropriate virtual environments

3. USER-CENTRED DESIGN

3.1 Introduction

Central to this design process is usability, a crucial factor in the production of a successful human-computer interface. The usability of a product is defined in ISO 9241, part 11 (the British Standard giving guidance on usability) as 'the extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use'. According to the ISO 13407 standard (human centred design processes for interactive systems) the key activities in user-centred design are:

- understand and specify the context of use
- specify the user and organisational requirements
- produce design and prototypes
- carry out a user-based assessment

In user-centred design, an iterative design process is employed, with the cycle of activities being repeated until the usability objectives have been attained (Daly-Jones et al, 1999).

3.2 Understand and Specify the Context of Use

This activity can be achieved by conducting a Usability Context Analysis (UCA), which involves the following research:

- User analysis: the product should be designed with reference to the characteristics of the end-users. Important factors to identify include the physical, cognitive and perceptual abilities of the user group.
- Task analysis: this should be carried out to identify the major productive goals, which a user can achieve, using the product.
- Environment analysis: it is important to understand the environment in which the product will be used, and how that environment should be constructed, so as to facilitate rather than impede the use of the technology (USERfit, 1996). This study involves an analysis of the organisational, technical and physical factors of the environment in which the product will be used.

3.3 UCA – Virtual Environment Input Device for People with Learning Difficulties

The UCA guidelines, available from Serco Usability Services, were utilised for this research. These guidelines include a 'context questionnaire', which covers the user, task and environment analysis. Initially, a 'Usability Team' was formed to advise and monitor the project development. This multi-disciplinary team included: project advisors; the design engineer; human-computer interaction and special needs experts; a usability specialist and an occupational therapist. To date, the User Analysis stage of the UCA has been completed and is described in the following section.

4. USER ANALYSIS

4.1 User Group

A user group of 21 students was selected from pupils who attend the Shepherd School in Nottingham. 14 of these students had previously participated in the Input Device Evaluation (see section 2). Students were selected who seemed to enjoy using computers and showed an understanding of how to use the virtual environments. The students ranged from age 7 to 19, with 5 primary, 8 secondary and 8 from the 16+ department of the school (9 of the students were female and 12 were male).

4.2 Skills and Knowledge

Details of the students' experience, with input devices, virtual environments and computers in general, was obtained through the Input Device Evaluation (see section 2) and the students' annual monitoring forms:

- Input devices: some of the students could use the joystick, mouse, trackball and keyboard and the majority of the user group could use a touch-screen and switch.
- Virtual environments: 6 students had previous experience.
- Computers: 4 students can switch on the computer and load a program and most of the students are motivated when working on a computer.

4.3 Cognitive Abilities

In order to gain some understanding of the cognitive abilities of the user group, two established assessment tests were used:

- The BPVS-II (British Picture Vocabulary Scale): a test of receptive English vocabulary, which correlates highly with verbal intelligence.
- The MAT-SF (Matrices Analogies Test – Short Form): a test of non-verbal reasoning.

4.3.1 Results. From the BPVS-II, 19 of the user group achieved in the extremely low score range for receptive English vocabulary, with two of the students scoring slightly higher and bordering the extremely low to moderately low score range (female aged 8:04, male aged 16:11). From the MAT-SF, 18 of the students achieved in the extremely low score range for non-verbal reasoning. In this case, 2 students scored in the low score range (female aged 8:06, male aged 8:06) and 1 student achieved an average score for his age (male aged 7:05). These measures are indicative of the students' cognitive abilities and in have shown that the students in the user group are generally in the moderate/severe level of cognitive functioning.

4.4 Physical Abilities

Details of the gross and fine motor abilities of the user group were obtained through the QNST-II (Quick Neurological Screening Test) and the students' annual monitoring forms. The tasks on the QNST-II provide an opportunity to observe the students' skill in controlling gross and fine muscle movements and their motor planning and sequencing abilities.

4.4.1 Fine-Motor Ability. 11 students were observed to have a good pen grip when writing and drawing and 15 showed good finger dexterity. A clumsy pen grip was noted in 10 students, with 1 student displaying hand tremor, which enhanced her difficulty in writing and drawing. Further fine-motor difficulties, which were observed, are listed in Table 3.

4.4.2 Gross-Motor Ability. Most of the user group members are independently mobile and over half showed good upper extremity movement and ability to reach. 3 of the students walk with an unsteady gate and 1 is normally in a special chair or using a walker. Co-ordination, motor planning and balance difficulties were observed in the majority of the students. Further gross-motor difficulties, which were observed, are listed in Table 3.

4.5 Perceptual Abilities

Details of the perceptual abilities of the user group were also obtained through the QNST-II, with further input from the students' educational files:

- Visual perception: all members of the user group have normal vision, though 7 are required to wear glasses to achieve this.
- Auditory perception: most of the students have normal hearing, though 6 have a history of ear infection or hearing difficulties.
- Visual-motor perception difficulties: there were many difficulties observed during the QNST-II, which can be categorised under this heading. The main difficulties experienced were with spatial awareness, ordering and sequencing, mixed laterality and bilateral tasks.

4.6 Further User Attributes

4.6.1 Communication. All members of the user group use Makaton signing, in order to communicate with other students and their teachers. There is a wide range of communicative ability within the group. A few of the students have good verbal communication, whereas others are limited to signs, gestures and some vocalising.

4.6.2 Behaviour and motivations. Almost half of the students displayed distractibility and a few showed a lack of self-confidence. The virtual environment system should aim to gain the full attention of its user and to build his or her confidence. A list of activities, which the students enjoy, was also obtained, e.g. music, art, sport and writing.

Table 3. *The physical attributes of the user group*

Fine-Motor Ability	Gross-Motor Ability
Good fine-motor ability - Good pen grip: 11 - Can isolate finger press: 15 Fine-motor difficulties - Clumsy pen grip: 10 - Motor planning difficulties: 19 - Motor tension: 4 - Slight hand tremor: 1 - Limited wrist movement: 6 - Wrist dip (muscle hypertension): 6 - Weak grip: 1 - Finger dexterity difficulties: 6	Good gross-motor ability - Independently mobile: 20 - Good upper extremity movement: 11 - Good reach ability: 15 Gross-motor difficulties - Unsteady gate: 3 - Uses a walker: 1 - Unsteady arm movement: 2 - Rigid arm: 1 - Difficult to fully stretch right arm: 1 - Co-ordination: 14 - Motor planning: 18 - Balance: 16

5. CONTINUED RESEARCH

Following the completion of the UCA, the user requirements for the input device will be identified. These will then be translated to design objectives to produce a 'product design specification'. The suggested design guidelines, identified from the Input Device Evaluation (see section 2) will also be incorporated into the design specification. A review of existing computer interface technology, including assistive computer access methods and virtual reality interfaces, will be conducted to identify any existing devices, which with adaptation could provide a potential solution and to identify technological opportunities for satisfying the design requirements in novel ways. The design specification will be used to guide both concept and prototype design, by checking the developing input device(s) against the design objectives, and established techniques for concept and prototype development will be employed. Storyboards of the concepts will be reviewed by the Usability Team, in order to modify the design before commencing to the prototyping stage.

In a usability evaluation, the User Group will test the prototype(s) with appropriate virtual environments. The results from this user based assessment will be continually fed into concept design, until the design objectives, outlined in the design specification, have been attained, see Fig. 1. The completion of this study should result in the production of a virtual environment input device for people with learning difficulties, which satisfies ISO 9241 (the British Standard giving guidance on usability).

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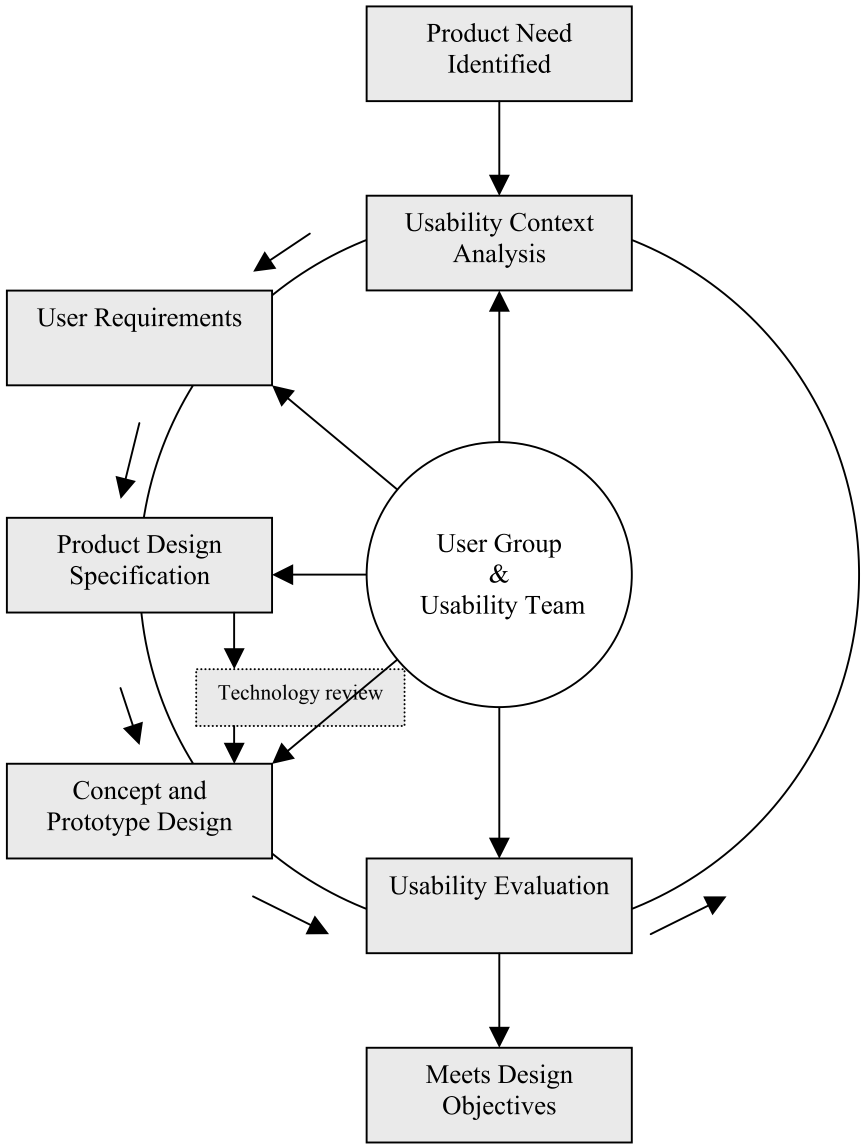

Figure 1. *The user-centred design cycle*