

Design, development and manufacture of novel assistive and adaptive technology devices

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ABSTRACT

The aim of this research is to design, develop, evaluate and manufacture an assistive/adaptive computer peripheral to facilitate interaction and navigation within Virtual Learning Environments and related learning content for people with physical learning and disabilities. The function of the device will be software specific; however the most common primary functions are those of selection, navigation and input.

1. INTRODUCTION

This research project has been developed within the Portland Partnership Project which has been funded under the first round of the European Equal Call. The holistic aims of the project are to develop Virtual Learning Environments (VLE) to teach basic skills to young people with severe physical and associated cognitive disabilities.

The Portland Partnership is led by Portland College (PC). The VLE is being developed by North Teeside University (Tee), with the embedded Flash based learning materials being developed by Cambridge Training and Development Ltd (CTAD). The aim of the research described in this paper is the design, evaluation and manufacture of a switch based device to provide control (scanning and selection) of the VLE and embedded learning materials by a group of people with a wide and heterogeneous range of physical and cognitive abilities.

This development of the assistive/adaptive device is being carried out in a partnership approach itself between the Nottingham Trent University (NTU), Nottingham University (NU) and Traxsys. These partners have the following roles in the design, development, evaluation and manufacture of the device:

NTU: Parallel Products Review of existing switch based devices to identify potential design solutions; User Group and Usability Group work to drive the contribution to design by people with a physical and cognitive disability and professionals in the field; Usability Study to inform the development of the Design Specification Document; Development of Automatic Data Capture Software for baseline and prototype evaluation studies; Prototyping of the assistive/adaptive device.

NU: Baseline Evaluation of existing switch based devices with prototype basic skills software developed by CTAD; Evaluation of Prototype with the same software for comparison with baseline; Identification of Modifications to prototype device based on comparative analysis, and Recommendations to Manufacturers.

Traxsys: Contribution to Usability Group and Design Specification Document via experience and manufacturability metrics; Manufacture of the assistive/adaptive device.

It is intended that the device will not only facilitate navigation (scanning) and interaction with the VLE and Flash based learning materials, but also contribute to the assessment of the user group by being mountable on other hardware and allow the determination and assessment of their individual switch based needs. The feasibility of the development of a bespoke piece of software to assess the switch based needs of

all learners is currently being investigated. The target population represents a heterogeneous group of users, with the definition of a universal design unlikely. Where the best design solution identified and manufactured as a result of this research does not fit a learner's abilities, the assessment software linked to a contemporary database of other existing solutions could be used to match a best fit.

It is worth noting that the choice of Macromedia Flash to develop the embedded learning materials raises several issues. The first is that it eases the development of the data capture software to automatically capture evaluation results, significantly aiding the task of the evaluation researcher. The second is that its use as a development tool has shown positive results in motivating the learning activities of young people at risk of social exclusion and that its presentational format (animation driven) is ideal for young people with a cognitive disability who will have associated literacy difficulties (Brown et al, 2002).

The project is now at the stage where the Parallel Products Review is complete, the User Team and Usability Team are running and providing design assistance, advice and storyboards, The Baseline Assessment of existing devices with prototype CTAD software is proceeding and the Usability Study is now being collated from complete User, Task and Environmental analyses. In addition to these design components, the advice from device manufacturers Traxsys will complete the Design Specification.

2. DEVELOPMENT METHODOLOGY

The development methodology is based on one developed and evolved over a series of earlier related studies (Hall, 1993; Brown et al, 1997; Soos, 1998; Lannen et al, 2002 and Standen et al, 2002). Its application to this project is now described.

2.1 Parallel Products Review

Evaluation of existing technologies has been undertaken to provide a Parallel Products Review to determine the reusability of existing solutions in the research. The properties of an extensive range of switch based devices should be examined against the requirements of control (scanning and input), cost and the Portland Partnership Technical Specification. The results of this review will contribute towards the Design specification Document.

2.2 Usability Study

A user-sensitive design will be employed to meet the needs of users and beneficiaries. In user-centred design, product developments are driven from user requirements rather than from technological capabilities. Central to this design process is usability, a crucial factor in the production of successful human-computer interfaces. Usability is defined in ISO 9241, part 11 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:

“Understanding and specifying the context of use, specifying the user and organisational requirements, producing designs and prototypes and carrying out a user-based assessment.”

An iterative process is employed with the cycle of activities being repeated until the design criteria have been attained. The first activity can be achieved by conducting a Usability Context Analysis (UCA), which involves the following stages:

- User analysis: to describe physical, cognitive and perceptual abilities of the user group. Physical Ability: Quick Neurological Screening Test II.
- Task analysis: to identify the major productive goals, which a user can achieve, using the product.
- Environment analysis: to describe the organisational, technical and physical factors of the environment in which the product will be used.

2.3 Baseline Evaluation: Within Subjects Design

A within subjects design is being utilised to collect performance data on existing and devices, which can be compared in later analysis with new prototype devices to identify performance enhancement. To reduce the effect of learning on performance, participants will be allowed several practice sessions with the currently

used devices before data collection starts. Data collected at each stage will be used to inform the design of the final prototype or any subsequent alterations.

Data will be captured automatically using the bespoke software capture suite designed and currently implemented at NTU. This will considerably speed up, and make more accurate, the process of data capture. This in turn will allow a greater amount of data to be captured for comparative analysis.

2.4 Data Collection method

Data collection will take place within Portland College. The Evaluation Researcher will sit alongside participants to give assistance and encouragement. The order in which they will work through the VLE will be the same for each participant starting with those environments which require fewer functions from the control devices.

Each session will be recorded on videotape, the camera positioned to view both the participant and the researcher sitting next to them. The videotapes will be analysed using a method established in an earlier author led study which yielded measures of help given by the researcher, user engagement, unproductive actions and user comments (Standen et al, 2002).

The researcher will also keep a diary to record any other information that might be useful but that would not be picked up by video analysis or the bespoke data capture software.

3. PROJECT PROGRESS

3.1 Project Management

A multi-disciplinary team was formed to advise and monitor the project development. To aid this process a website (Portland.isrg.org.uk) has been developed to provide an on-line reference project management and dissemination tool. The team includes a design engineer, human-computer interaction and special needs experts, a usability specialist, learners, an occupational therapist and a representative from industry (Traxsys).

3.2 Parallel Products Review

A survey of existing input and assistive/adaptive devices has been carried out to identify devices, features and components that will inform design and reusable components for the project. This, in conjunction with an over-arching Technical Specification provided by Portland Partnership, has raised the possibility of the development of an additional software solution to assess all learners' switch-based needs and to point to a variety of existing best-match solutions, where the device developed by this research does not fit their needs. This eventuality is possible due to the heterogeneous nature of the target population. The conclusions from this review were as follows:

Essentially all assistive switches are the same, really only differing in ergonomics and aesthetics. In order to interface with a computer system successfully, the switch needs to be used in conjunction with a suitable connector.

The Technical Specification provided by Portland Partnership has dictated that this connector be of the USB type. This factor, considered in conjunction with the requirement of being compatible with existing VLE and learning software developed in the project thus far, suggests the use of either a Don Johnston pro 5, Sensory Software JoyCable or Joybox Interface.

Whilst the Don Johnston pro 5 can be used without the instillation of an additional software solution, in comparison with the Sensory Software Joybox and JoyCable, it is not as adaptable. Recognised by windows as a switch controlled USB joystick, the Joybox and JoyCable devices can be used with any software that supports joystick input extending functionality.

The Joybox allows up to 12 switches to be connected via the USB port (see Figure 1), giving an advantage over the JoyCable. However, the JoyCable could possibly provide the optimal solution, dependant upon the outcome of the device's input requirements; i.e. 2 switches or less.

For software that does not support joystick input, a driver is provided to allow the switches to control the keyboard or mouse. This allows the switches to be used with any Windows software (and Windows itself), thus resulting in full switch interface functionality.

As previously stated all switches are very similar and in function provide an output in the form of a true or false signal dependent on the switch's state. At base level the technology used in all switches is the same. On triggering, an electric current is shifted to another circuit, providing a signal state.

The main differences are factors such as size, shape, colour and physical feel. Some developers have also added additional functionality such as the ability to alter trigger activation parameters. Another popular trend is the provision of auditory feedback.

At this stage it has been decided that a sample of approximately 10 switches should be tested with the users in order to obtain a good baseline evaluation of present switch technology. This outcome forms deliverable 1 of the project to inform the Product Design Specification Document in terms of reusability of existing design solutions and features.



Figure 1: Sensory Software JoyBox

3.3 User-based Development Team

A user-based development team has been formed to work in conjunction with the design engineer. The team consists of around six sixteen – nineteen year olds spanning four main levels of ability (pre-entry to prevocational), with additional potential access to users within the Portland College's Employment Department. Those within the Employment Department have less disability and more life experience and thus provide good additional user representation, however the main focus is to address the greatest challenge - "include the excluded".

These users will help to inform the design of the adaptive/assistive device through consultation using an interactive storyboarding method first developed by the team for use in the design of VLE-based life skills learning software (Brown et al, 1999) and enhanced in recent studies and this research to develop navigation devices for the use of VLE by people with a cognitive disability (Standen et al, 2002). This methodology places users at the centre of a rapid prototyping development cycle that allows them to effect changes to the device design and quickly see the results of such action. This rapid turn around is important for people with a cognitive disability in order to maintain their interest and active involvement in the design process. Figure 2 shows this process in action for the development of the navigation device for people with a cognitive disability using VLE in a recent EPSRC sponsored study.



Figure 2: Development of interactive storyboards for EPSRC Study

The interactive storyboarding process for the switch-based device developed within this project started with an explanation of the storyboarding process using 3D based CAD. This explanation was given to the User

Team by the Design Engineer (NTU) and Portland Partnership Project Manager (PC) demonstrating 3D imagery in combination with manipulation of the real life counterpart object.

A mug (large cup) was held up in front of the User Team and rotated whilst its counterpart 3D computer generated image was rotated simultaneously on screen. Members of the User Team were then asked to choose their favourite colour. These colour settings were then applied to the electronically generated mug to illustrate the relationship between the two sets of objects in a concrete way. The User Team could then readily understand how the interactive storyboards represented real world objects and how they could contribute to modifying their properties to express their own design preferences.

The User Team was then shown a range of commonly used switch-based devices to gain their feedback on design preferences (on preferred colour, shape and textures). Figure 3 illustrates the method of describing the iterative prototyping process to the User Team, which contributes to Deliverable 2 to inform the Product Design Specification Document.

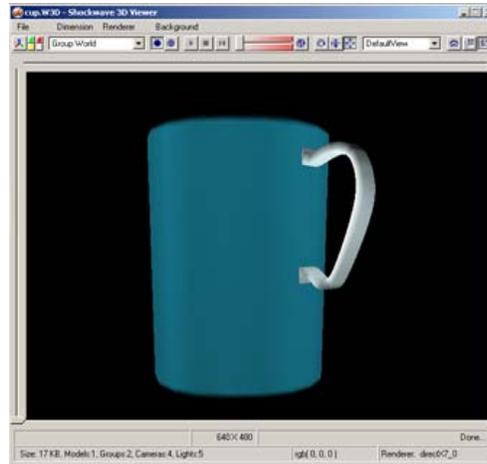


Figure 3: *User Team Design Preferences*

3.4 Usability Team

The Usability Team has a dual function within the project. Its first main task is to provide a steering committee (meeting six times) to effectively manage the project, monitor deliverables, provide dissemination and provide expert advice to contribute towards the Design Specification Document. To this end the overall Portland Partnership Manager (PC) provided visioning storyboards of the switch based assistive/adaptive device based on an expert knowledge of the target user group abilities, the Portland Partnership Technical Specification and a situated analyses of the environmental factors and tasks expected to be performed. These storyboards contribute to deliverable 3, as a component of the Design Specification Document.

3.5 Baseline Evaluation

Twenty six (26) students have been recruited to the baseline evaluation study who experience a range of physical and cognitive abilities described by the User Analysis (section 3.6.1). This evaluation study is currently being carried out by the Evaluation Research (NU) using the following commonly used devices (and also shown to the User Team to examine their design preferences): Big Red, Standard Jelly Bean, Spec, Palpad, The Handy Switch (Wobble Switch) and Churchill.

The baseline evaluation study (Deliverable 4) will contribute towards the Design Specification Document in two ways; by providing data for comparative analysis with the final prototype developed, and by the identification of usability problems users experience with currently existing and commonly used switch based devices when using the Flash based learning software developed by CTAD and embedded within the VLE. This evaluation study is using the bespoke designed data capture software and an established set of usability metrics.

3.6 Usability Study

3.6.1 User Analysis. Thirteen (13) male and thirteen (13) female participants, aged 16-22 years at recruitment, consented to take part in all phases of switch evaluation. They completed verbal Intelligence Tests (BPVS) and Motor Skills Assessment in QNST2. Most participants have limited vocabulary and varied

methods of communication including speech, eye gaze, head movements and the use of communication devices. Most participants would be able to use a switch with one or both hands but are limited in reach, strength and motor control. Therefore position, size and texture of the switch developed needs to be explored.

3.6.2 Task Analysis. Given that a tutor has set up the session, the tasks that a student will have to perform within the VLE and embedded learning materials, with a relevant degree of support from the tutor, are:

- Log in to the VLE using relevant input device.
- At the earliest project development milestones (M1-3), when they click on 'learn' they will go straight into the activity (no choice).
- At later milestones (M4-6), they will have a choice of 2 items (if set up by the tutor in this way, although the tutor may choose a linear presentation of the materials) e.g., a video (to provide context) and an activity (learning object, which will include a test game at the end, with the score being passed back to the VLE database). The video and the activity will be represented on screen by thumbnail images or icons.
- At later milestones (M7-8), they will have a choice of 4 items.
- At Entry level, the VLE may appear more like a traditional VLE with a wider choice of items.

In terms of how these choices are presented, there is a menu presented to the students. For the early prototypes CTAD have developed a "cheese" icon as a means of selection as an interim measure. As their understanding deepens of the tasks to be performed within the embedded learning materials and how these are linked to the VLE, the use of this icon will need to be reviewed. It may be that the cheese icon is not the best metaphor as it is perhaps not versatile or flexible enough. It may be better to have a thumbnail or other icon for each activity; however, there is a need to balance this against the fact that learners have liked using the cheese.

At the end of a session using the VLE, it is important for the learner to have a summarized printout as a hard copy record of what they have achieved in the session (as well as a progress indicator in the VLE itself).

In conclusion, the task analysis has revealed that students will need to use a combination of scanning and selection (with choice) to navigate and interact with the VLE and embedded learning materials.

3.6.3 Environment Analysis. There are a range of technical and physical factors that form the environmental analysis. Technical factors that will exert an influence on the Design Specification Document have been supplied in the form of the Portland Technical Specification Document and can be summarized as following to be:

- wireless
- compatible with existing hardware (Discover switch, Joy Box, standard USB PC *etc.*) or better than this hardware in terms of functionality
- compatible with existing software and also any materials produced by the Portland Partnership
- potentially be used as an assessment device (in terms of being adjustable in specification (surfaces, mounting *etc.*)
- flexible in terms of physical attachments
- accompanied by a system which allows for the base unit to be moved within a specified range (45 cm)
- capable of adhering to the technical specifications as advised by the technical group of the Partnership.

Physical factors identified within the environment that may exert an influence on the Design Specification Document are:

- Many users use wheelchairs, and hence their switches will be used on wheelchair trays, rather on a desk. This may exert constraints of size and fixture abilities on the device.
- The time of day at which the switch and VLE will be used, as many students are more tired at end of day and the device may have to attempt to compensate for this.
- The use of the device and VLE may coincide with other therapies (such as physio) which may exert an influence on their motor skills abilities, and therefore their ability to control the VLE.
- Typical rooms in which the device and learning materials are used are quite warm, with adequate lighting levels. Any device should be temperature tolerant.

The analyses of the physical and technical factors that may exert an influence of the Design Specification Document have been identified through consultation and observational case study. Together they form the environmental analysis, which in turn helps to develop the Usability Study (deliverable 5) alongside the task and user analyses.

3.7 *Distillation of Design Criteria*

The distillation of design criteria to form the Design Specification Document is nearing completion. The criteria are evolved from The Parallel Products Review (reusability of existing design solutions and features), The User Team (interactive storyboards), The Usability Team (expert design storyboards), the Baseline Evaluation (identification of usability problems of existing switch devices with prototype VLE and learning software) and the Usability Study (design considerations from user, task and environment analyses).

Earlier work on the assessment of assistive/adaptive devices for people with a physical disability using VR (Brown et al, 1997) defined a list of key desirable features for any proposed input device. These key features were that any innovative device should be robust, modifiable, adjustable, reliable and affordable. This study considers the necessity of an additional feature; its 'manufacturability' (especially in terms of cost, including the expense involved in developing a completely new production line for a potentially low volume sales product). Whilst it is imperative that this new target feature does not stifle creativity and innovation, its consideration is none the less vitally important if any new assistive/adaptive device is to reach the market and hence repay the research investment (e.g., funders and user's with disabilities expectations that their research effort is not wasted).

Traxsys will provide input to the Design Specification Document to satisfy this requirement that any proposed switch-based device should have sufficient attention paid to its manufacturability.

4. INITIAL CONCLUSIONS

An ideal outcome of this research would be the identification of a design solution for as many people with physical and associated cognitive disabilities as possible. However, they represent a heterogeneous group of people (as observed in the User Analysis) and vary in abilities along many dimensions, for example, vision and hearing abilities, gross and fine motor abilities, cognitive abilities, understanding and use of language. Neither does it follow that just because someone has low ability on one of these dimensions that they hold a similar position along one of the other dimensions.

It is highly likely that there is no single functional solution for such a large heterogeneous user group, but with the possible addition of bespoke assessment software and a contemporary database of existing switch based product information, a solution can always be recommended, if not immediately provided.

The best fit solution for the majority of the target user population will be however identified in the Design Specification Document, and this represents the distillation of all of the design stages of a proven and tested methodology to develop peripheral devices for people with a disability using VLE. The imminent prototyping and re-evaluation of this device will facilitate its comparative analysis with existing solutions to identify performance gain (against an established set of usability metrics and baseline study) and design modifications before final manufacture and distribution.

A bespoke piece of software may also be developed for the purpose of assessing users' assistive/adaptive device need. This additional software solution will be used in conjunction with the assistive/adaptive switch-based device to greatly increase its potential application, and ensure all users are able to access the VLE and learning materials.

The investigation of the use of blue tooth technology, as a means to provide user recognition and automatic calibration, as well as wireless capability appears feasible. The importance of the peripheral's aesthetic design, a theme all too commonly neglected in the development of assistive/adaptive devices, has also been highlighted. The role of users in determining these design parameters is vital and a priority in design. A novel iterative and inclusive storyboarding process to facilitate these user sensitive design processes has been developed.

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