Virtual environment for assessment of rehabilitation equipment

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ABSTRACT

Selection of assistive equipment for use in the home can be difficult. In many cases a variety of alternative designs may be available and it can be hard to determine the most appropriate one to select for a particular patient. The Derby Disability Equipment Assessment Centre (DEAC) provides a needs-led evaluation programme for the assessment of assistive equipment designed for older people and people with disabilities. The primary criteria for each equipment evaluation vary for each project, but often include safety, ease of use, aesthetics and ease of cleaning, as appropriate. DEAC consider the views of the people who use the equipment to be an essential aspect of product evaluation, however, it is not always practicable to have patient representatives visiting the hospital to review alternative product designs. Taking a variety of products to users' homes for assessment can also be problematic from the point of view of manual handling, set up and travel for therapists. Visualisation in a virtual environment presenting raiser combinations with different furniture was proposed to as a potential alternative, speeding up the assessment process and minimising manual handling risks. A feasibility study was conducted jointly between DEAC and the Virtual Reality Applications Research Team (VIRART) at the University of Nottingham to evaluate the effectiveness of a VE as a tool for rehabilitation equipment assessment, taking into account usability and acceptance of the tool by rehabilitation therapists and disabled or older people. This paper presents the findings from a case study example of a chair raiser evaluation and a comparison of results in product selection preferences between real and VE viewing conditions.

1. INTRODUCTION

The Derby Disability Equipment Assessment Centre (DEAC) at the Southern Derbyshire Acute Hospitals NHS Trust, Derby, UK is one of three centres in the UK evaluating equipment for the Medical Devices Agency (MDA) on behalf of the National Health Services and Department of Health under the Disability Equipment Evaluation Programme (MDA, 2002). An example of a typical evaluation study conducted by DEAC is the recent study of chair raisers. Rising from a chair unassisted is a prerequisite to independent living (Chan et al., 1999), and a combination of movement strategies and furniture modification can facilitate easier sitting to standing. Fitting raisers to chairs is a relatively inexpensive method of furniture modification, and is suitable for elderly and disabled people, and those recovering from surgery such as hip replacement. However, forty different types of chair and bed raisers have been identified making selection of the most appropriate raiser difficult.

The selected criteria for product appraisal were stability, safety, aesthetics and ease of cleaning. Technical tests of stability and safety were applied in the laboratory and raisers were marked as either pass or fail with respect to British Standards Guidelines. In addition to these technical tests, the views of the people

who use the equipment were felt to be an essential aspect of product evaluation. In particular, it has been found that aesthetic appeal is an important consideration affecting user confidence of use (Alexander et al., 1996). Users were therefore invited to visit the laboratory to review a range of chair raisers on one of two types of chairs – either a castor chair or leg chair. They had the opportunity to sit on the chairs with the raisers fitted. Then they were asked to assess their perceptions of the raisers' comfort, convenience, safety and aesthetics. However, the problems with this approach were twofold, firstly it was difficult for elderly and disabled participants to make the journey to the laboratory (based in Derby City General Hospital). Secondly, the manual handling operations involved in manoeuvring the raisers on and off the chairs required two people, had safety risks and were time consuming for evaluators.

It was considered that virtual reality (VR) may provide an alternative review medium and an opportunity for participants to assess a larger number of chair and raiser combinations. Desktop VR has been found to be a useful tool to support co-operative design, where users are involved in product or workplace specification early on in the design process (Davies, 2000; Eastgate, 2001). Obviously there is a trade-off here in that Virtual Environment (VE) participants do not have the opportunity to physically sit on the chairs, and the visual quality of a virtual model will inevitably be less than of a real model. Therefore one of the aims of this project was to assess how differences between the real and virtual environments might affect patient judgement. It was also important to take into account acceptability and usability issues of VR technology, particularly for elderly users although studies have demonstrated that elderly people can successfully use desktop virtual reality (Stanton et al (in press); Rose et al, 1999; Rizzo, 2001; Karlsson et al, 2000).

This paper presents a feasibility study conducted to assess whether virtual reality is an appropriate tool for assessment of rehabilitation equipment, specifically to allow elderly and disabled individuals to evaluate chair raisers for the home. Measures of success included quality of representation of the real product and design of the virtual environment interface (reviewed by Occupational Therapists), usability and acceptability of the VR system particularly for elderly users, and comparison of results in user selection preferences between real and VE evaluation settings.

2. VE DESIGN

A Superscape VRT desktop Virtual Environment was developed to allow visualisation of different raisers when placed on different types of chairs. The VE was modelled on the room at Derby City General Hospital that is currently used for patient assessment and rehabilitation, and was used for the laboratory based review of the chair raisers. The requirements of the VE were that it should allow the Occupational Therapist to select chair and raiser combinations to present to the user. The user should then be able to view these from different angles, close up and from a distance, navigating freely around the VE if required. An iterative user-centred design process was employed when designing the VE, involving a number of meetings between VE designers and rehabilitation therapists and ergonomists.

Figure 1 shows screenshots of the VE. The interface comprises a window into the VE room that contains two different types of chair, one with rectangular legs, and one with castors (see figure 1a). The two-dimensional overlay (see Wilson, Eastgate & D'Cruz, 2002) around two edges of the screen contains a number of icons that allow the user to select chair and raiser combinations and view them from different angles. On the right hand side of the screen the user can select a chair and raiser type to examine in close detail (see figure 1b). The icons below the screen are used to change the user viewpoint and rotate the chair. These icons were included to allow users who have little or no experience of VE navigation to easily view the chairs from a number of different angles.

3. PRODUCT ASSESSMENT

3.1 Product selection

A search of the product literature and the DLF Hamilton Index (2000) identified over 40 different varieties of chair and bed raisers available on the UK market. Of these 24 were sold as chair raisers. These were grouped according their main design features, i.e. whether they were linked or individual. Two armchairs were purchased, one on legs and one on castors. Twelve chair raisers were selected to fit these chairs:

- Six to fit the chair on legs, and six to fit the chair on castors
- Six were individual raisers and six were linked raisers.

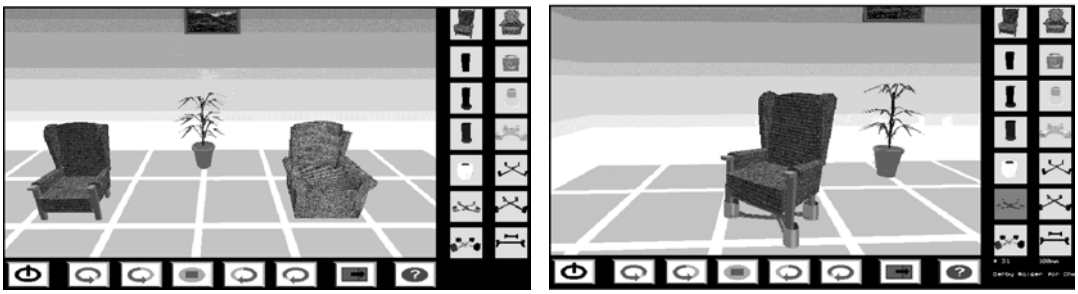

Figure 1. *Screenshots showing an overview of the two chairs (a) and a close up view of chair with linked raisers attached (b).*

3.2 Technical tests of chair raisers

Technical tests were conducted to assess each of the chair raiser designs on the appropriate style of chair for:

- stability
- safe hoist access
- moving
- measurements
- mass

Mechanical tests of stability and safety were applied in accordance with the stability overturning tests for chairs described in BS EN 1022:1997, and a modified impact test for chairs, adapted from BS EN 4875: Part 1: 1985, Strength and stability of furniture - methods for determination of strength of chairs and stools, Section 7.7.1 Back impact test. The results from these tests were recorded and are presented as either "pass" or "fail".

4. USER EVALUATION STUDY

4.1 Participants

53 participants were recruited who were either aged over 70 years, had a disability or had used raisers either currently or the past. 36 participants viewed the raisers in the VE, and 17 in the laboratory. Of the participants who took part in the VE trials, 67% had not used a computer before.

4.2 Materials

The participants were required to rate the chairs on three aspects after having viewed the raisers in either the laboratory or virtual environment during a semi structured interview.

1. Participants were asked how safe they thought they would feel with sitting on or standing from the chair with the particular chair/raiser combination viewed, from "very safe" to "very unsafe".
2. They were also asked to rate how convenient they felt the raiser/chair combination would be for cleaning, and responded on a scale from "Very convenient" to "Very inconvenient".
3. They were asked to explain their comments and reasons for giving ratings
4. The participants' use of and reaction to the VE was observed.

4.3 Procedure

4.3.1 Laboratory trials using raisers fitted to chairs. Seventeen participants sat in and stood from the chairs fitted with the raisers. A semi structured interview, video and observation were used to gather a variety of data about safety when sitting and standing, perceived ease of cleaning around chairs with raisers fitted and personal acceptability.

4.3.2 Trials using the Virtual Environment. The portable desktop Virtual Environment (VE) was taken into day centres where 36 participants viewed the raisers from all aspects on either a laptop screen or a large screen.

A semi structured interview, video and observation were used to gather a variety of data about perceived safety when sitting and standing, perceived ease of cleaning around chairs with raisers fitted, personal acceptability and ease of use of the VE. Participants were invited to control the VE themselves, but if they did not feel confident to use the input device then the facilitator controlled the VE for them.

5. RESULTS

5.1 Usability and acceptance of VE by older people

78% of participants in the VR trials found the system easy to use, and this was supported by observational data that illustrated that although some participants were initially reluctant to use the computer, once they did they enjoyed the experience and were pleased they had been able to use the VE themselves.

Generally the mouse was the preferred interaction device, although some participants thought that it was easier to find a better view within the VE using the joystick. The main problems observed when using the controls were: positioning the cursor (overshooting), following the cursor on screen and using the device to select (positioning and clicking simultaneously). Generally the large screen projected display was viewed in preference to the small lap top screen as the image was easier to see, although some participants used the small (laptop) monitor when operating the interaction device.

5.2 Comparison of results in user selection preferences between real and VE settings

5.2.1 Safety when sitting and standing from a chair. The ratings of perceived safety of the chairs when either sitting in them or standing from them were compared using a Mann Whitney U test. For ratings of safety when sitting, three raisers yielded significantly different ratings – raisers 1, 2 & 7 (raiser 1: $U=3$; $N=5,6$; $p<0.05$; raiser 2: $U=2$; $N=3,6$; $p<0.05$; raiser 7: $U=2$; $N=4,6$; $p<0.05$). In all cases the raiser was rated as more unsafe when viewed on the VE compared with the rating obtained in the laboratory. For standing from the chair, the ratings for only one raiser – raiser 2 – were significantly different for the VE and laboratory ($U=2.5$; $N=3,6$; $p<0.05$).

In the mechanical testing trials raisers 1, 2, 8 & 10 failed to be passed as safe. In the laboratory trials, these were ranked as 3rd, =6th, 12th and =4th respectively (where 1st is the raiser perceived as being the most safe), and in the VE trials, they were ranked as 12th, 11th, =5th and =8th. Therefore there is some indication that the judgements of safety in the VE matched the results of the technical testing more closely than when the raisers were viewed in the laboratory. Table 1 summarises the comparison between these three types of evaluation.

Table 1. *Comparison of assessments of chair/raiser combination safety from laboratory, VE and technical evaluations*.

	Raiser no.											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Safety ranking from laboratory	3	=6	2	11	=9	=4	1	12	=6	=4	=9	8
Safety ranking from VE	12	11	=8	=1	=1	=5	4	=5	=5	=8	10	3
Pass/fail technical test	X	X	√	√	√	√	√	X	√	X	√	√

5.2.2 Cleaning. The responses to the rating questions were compared for each raiser viewed either in the laboratory or virtual environment. The significance of the differences between the ratings were also compared. There was no significant difference of the rating of ease of cleaning for any of the raisers between the laboratory and virtual environment. However, overall, the ratings for the two modes of viewing were not correlated (Spearman's $r = 0.282$, $N=12$, $p>0.05$), indicating that there was some difference in the rank order of the raiser/chair combinations in perceived ease of cleaning. In general, the chair raiser combinations were rated as being slightly more inconvenient to clean when viewed in the VE compared to the ratings given when viewed in the laboratory.

6. CONCLUSIONS

Almost all of the participants were able to study the VE and form an opinion on the raiser from the image displayed, however many participants did not use the interactive capabilities of the VE in order to make their judgements. Some also requested further information about the raisers in order to formulate their opinions (e.g. what material it was made from, size, colour, etc.).

It was commented that the VE would be a useful tool to help narrow down a choice of raisers to trial in real life. The VE alone would probably not be sufficient to make a final choice.

On examination of the characteristics of the particular raisers for which the ratings differed, an interesting hypothesis can be formed. The raiser for which perceived safety ratings differed for both sitting and standing was raiser 2, a wooden block with indentations that is designed to be placed on the legs of the chair. As this raiser is made from wood, compared to the others that are predominantly plastic or metal, it is more aesthetically pleasing, and is likely to complement the décor of a house and appear less intrusive. The "wooden" appearance of the block would have been more noticeable when viewing the real block compared to viewing the virtual block. Therefore it is possible that the pleasant aesthetic quality of this raiser may have made participants biased towards it, and thus reluctant to rate it as unsafe. This is analogous to general findings in product design and consumer behaviour. However, it does suggest the possibility of artificially altering details of objects to be assessed in a VE in order to deliberately bias judgements from users.

7. IMPLICATIONS FOR FUTURE DEVELOPMENT

The study presented in this paper does provide an illustration that VR may be a useful tool in the context of rehabilitation equipment assessment. The VE allows users to switch between raiser types quickly, so different types of raisers can be easily compared. The VE is also displayed via a laptop and small projector, so is portable, avoiding the need for participants to travel to the hospital. This should enable rehabilitation therapists to access a wider population sample. Potential extensions to the relatively simple VE used in this project could be to allow images of participants' own homes or furniture to be rapidly included, to make the equipment appear in more familiar surroundings. The observational and subjective response indicated that the population used in this study, despite their relatively low level of familiarity with the technology, were happy to use the VR equipment, although some felt that they would have liked their conclusions to be reinforced by viewing the real objects.

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