INTERNATIONAL CONFERENCE ON ENGINEERING DESIGN
ICED'05 MELBOURNE, 15 – 18 AUGUST 2005

ARE USERS NECESSARY FOR INCLUSIVE DESIGN?

C Cardoso, S Keates and P J Clarkson

Keywords: accessibility, user trials, self-observation, exclusion analysis, assessment methods

1 Introduction: people excluded from everyday interactions

The growing older adult population, and also people of all ages with diverse impairments, are frequently disabled by many existing mainstream design solutions [1]. This 'disablement' is typically caused by a mismatch between the user and the products demands, usually due to the product surpassing the users' level of physical and psychological capabilities. Such mismatches can lead to minor inconvenience and frustration, human error, accidents [2] even absolute exclusion [3].

Despite the existing wide range of usability and accessibility evaluation approaches [4-8], a large number of designers refer to their personal experiences and professional intuition when assessing their designs. This approach, typically termed Self-observation or Self-modelling [9], is frequently adopted by designers to cope with the time and cost imposed upon the design process, which prevent them from working directly with real users.

This paper discusses the implementation of an evaluation method that designers could use to estimate the number of users affected by particular product interface features, without relating to the users directly. To illustrate the implementation of the method, a case study on the assessment of the ease of use of domestic central heating control units is briefly presented and discussed.

2 Case study: assessing product accessibility demands

One of the main concerns when assessing the usability and accessibility of a particular design interface is the importance of ranking in order of severity any existing problems. Typically, the impact of a usability or accessibility problem can be identified if a large number of representative users are involved, for instance, in User Trials. However, such approaches are usually time consuming and are expensive to organise.

The case study presented here explores the implementation of an assessment approach - *i.e.* Exclusion Analysis – to help designers predict and prioritize potential accessibility problems in everyday interfaces without directly referring to the users, thus reducing the overall cost of the assessment.

In order to compare the efficiency and effectiveness of the method suggested, three different assessment methods have been employed to assess the ease of use of eight domestic central heating control units, of which three are presented here (Table 1): (1) User Trials with 48 older and disabled users; (2) Self-observation, and (3) Exclusion Analysis*,* performed sequentially by a group of seven designers.

2.1 User Trials

The trials took place in a laboratory setting, where the participants were provided with a set of instructions guiding them through a sequence of activities with each device. Feedback from the users on the devices' ease of use was questionnaire-based.

2.2 Self-observation assessment

Self-observation, or Self-modelling [9], is a commonly employed assessment method whereby designers consider themselves or a colleague as the user and act out the interaction process. Designers use their daily experience and intuition to try to predict how users will use the device and what type of difficulties they might encounter.

One of the main advantages of this approach is that it is usually a low-cost and quick method, which does not involve the use of special resources. It can be easily implemented throughout the design process, being particularly suitable when the time and budget available for a project are limited.

The Self-observations involved seven designers assessing the ease of use of the same heating control units. Designers were observed and videotaped while performing the evaluations. They were also encouraged to 'think aloud' [5] while they were exploring and evaluating the devices.

2.3 Exclusion Analysis assessment

Exclusion Analysis benefits from the use of statistical demographic capability data [10], and it takes the form of a systematic approach to product accessibility assessment. This tool provides a set of five physical capability scales particularly relevant for the assessment of user-product interaction, namely: locomotion, reach/stretch, dexterity, vision and hearing [11].

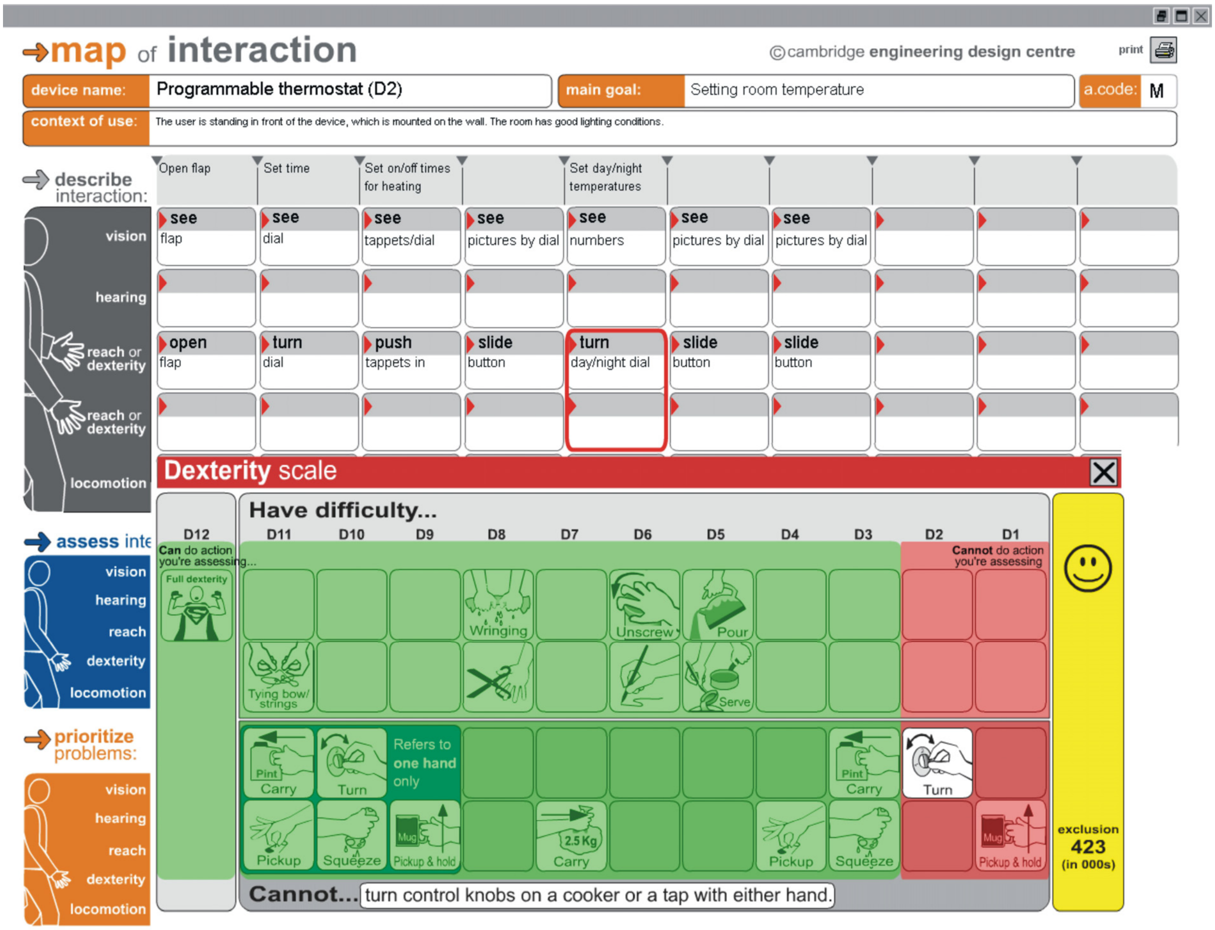
Each scale is subdivided into different levels of capability describing actions or activities that people *can do*, *have difficult with* and *cannot do*. Each of the scales range from *low capability* (severely disabled), through *medium capability* (moderately disabled), until *high capability* level (mildly disabled) and, ultimately, fully able-bodied (no disabilities). Every single level on all five scales can be statistically mapped with an estimate of the number of people in the population of Great Britain (age 16+) experiencing the capabilities (or disabilities) described [10].

One of the advantages of these scales is the potential to use the scales' descriptions to assess and quantify the capability demands of everyday products and, hence, translate the results into how many people could be affected by a particular design solution. Additionally, the fact that the scales give examples of the users' actual range and level of capabilities, instead of their medical conditions, makes it simpler to map this information to the capabilities demanded by the product features. This kind of information on what users *can do* (*i.e.* their level of capability) is less ambiguous and thus easier to incorporate into design decisions. In fact, designers are more receptive to learning about possibilities when dealing with less familiar areas, rather than vague and obscure terminologies or constraints [12].

The original capability scales were not, however, designed to be used as an assessment tool, but to update information on the number of disabled people in Great Britain [11]. Therefore, several case studies were conducted with industrial designers to explore the practicality of the scales for the assessment of product accessibility. Results and feedback from the designers during those case studies suggested that the written format in which the scales were presented were ambiguous and complex to visualise as an assessment tool.

Therefore, the written descriptions for the capability scales were 'translated' into pictograms, which in turn were contained within a graphic structure. The development of this tool was based on designers' feedback and on the intuitively obvious claim that designers are visual people [13, 14] or that design students [2] or even engineers and design professionals [15, 16] have a preference for pictorial forms of information. The outcome is a framework for the assessment of design exclusion, which takes the form of a prototype software tool (Figure 1).

Figure 1. Screenshot of the Exclusion Analysis assessment tool being used to assess a domestic central heating control unit.



The assessment framework is divided into three main stages:

- (1) Describe the interaction – which can be accomplished using a procedure similar to task analysis;
- (2) Assess the interaction – where the capability scales are presented in a pictorial format, yet supported by the original written descriptions;
- (3) Prioritise problems – since prioritising problems merely based on the number of users excluded, may be too simplistic in many circumstances [3], it is also important to take into account the *frequency* of the problems identified and the *relative importance* of the interface element or constituent actions being carried out (and in a real life design project, the time and budget available for any design change).

The software tool does not calculate how many people could be excluded from performing the tasks being assessed. Instead, it provides comparative information (in pictorial and written form) on the numbers of people experiencing difficulties while carrying out a wide number of everyday tasks. Ultimately, it is up to the designer to interpret the information described and to make judgements on the number of people prevented from performing particular steps of the interaction with the products being assessed.

3 Results

The results from the User Trials (UT) were used to identify the widest possible number and type of problems that the interfaces presented. The study then compared the number and type of problems highlighted by the designers through their Self-observation and subsequently Exclusion Analysis assessments.

It was important to find out whether Exclusion Analysis evaluation would allow the same group of designers to identify additional problems to those potentially pointed out during their Self-observation assessments. More importantly, it was of particular interest to find out if the Exclusion Analysis approach enabled the designers to identify the most critical problem with each device – *i.e.* the highest priority to redesign – highlighted by the users during the trials. The results on the number of problems encountered through the different assessment approaches are presented in Table 1. The results from the User Trials correspond with the sum of all the users experiencing problems in performing particular constituent actions with each device. The results from the designers' Self-observation and Exclusion Analysis are shown individually.

The stages of the interaction (*i.e.* constituent actions) during which the users experienced the most severe problems are presented in Table 2. It is important to specify that while only the most problematic constituent actions of use are shown in Table 2, both users and designers actually identified other problems with the devices (especially with the first device, Table 1).

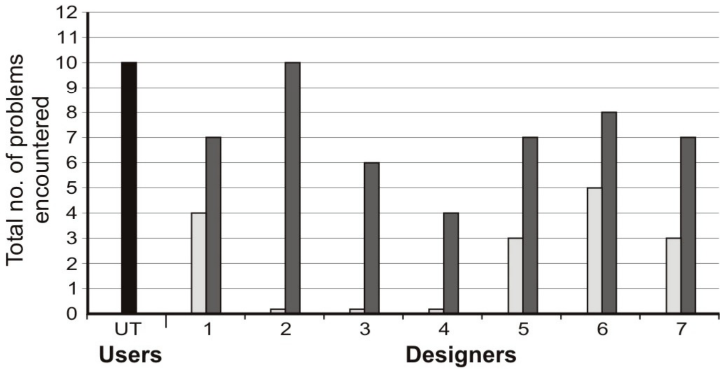
The problems presented primarily relate to the motor (particularly dexterity and reach/stretch) and sensory (mainly visual) demands that the devices may have imposed upon the users. Problems ranged from high to low level of user exclusion and were categorised in terms of: (1) *highest* priority, (2) *second* priority and (3) *third* priority to (re)design. However, in general designers did only identify what they considered to be the *highest* priority to (re)design, thus any other problem identified by them was categorised as an *undetermined* priority (Table 2).

Results from the designers' assessments show that once they underwent the Exclusion Analysis evaluation there was a significant increase in the number of problems identified for the first device (Table 1). The results show that the Exclusion assessment tool prompted the designers to identify more problems than their previous Self-observation evaluations. This is noticeable for all designers, but particularly for Designers 2, 3 and 4, who identified no problems during the earlier Self assessments.

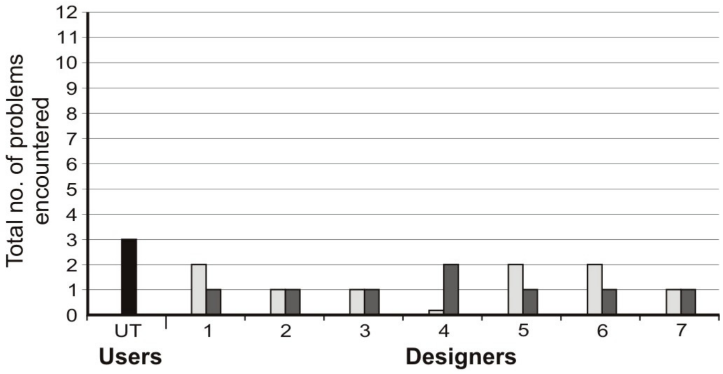
Conversely, the number of problems identified through Self-observation and Exclusion Analysis for the second and third devices were almost identical, with practically no additional problems found during the second evaluation. However, these two devices also presented very few problems for the users during the trials. Two of the designers (5 and 6 for the second device) even seemed to have found fewer problems during the second assessment phase.

Table 1. Number of problems encountered through User Trials, Self-observation and Exclusion Analysis assessment.

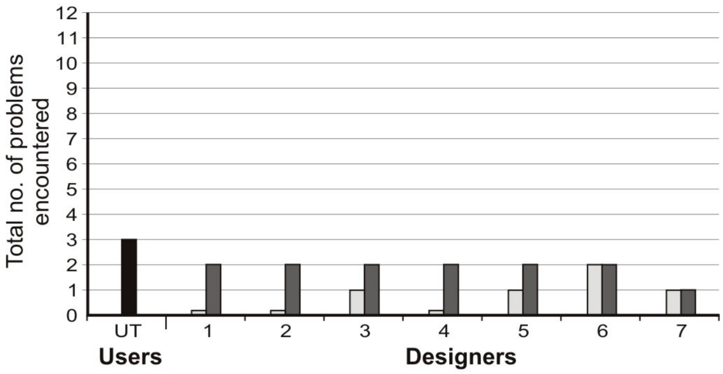
Device 1 (programmable thermostat)



Device 2 (room thermostat)



Device 3 (radiator valve)



Legend: ■ User Trials □ Self-observation ■ Exclusion Analysis

The most obvious impact of the Exclusion evaluations was on the identification of the stages of the interaction (*i.e.* constituent actions of use) that could potentially disadvantage, or even exclude, a greater number of people (Table 2). For instance, during Self-observation most designers missed what could be potentially considered as the worst problems and thus the highest priorities to (re)design (highlighted in red italics, Table 2: first device, Actions D, H and J; and second device, Action A).

Table 2. Problem prioritization, results from User Trials (UT), Self-observation and Exclusion Analysis assessment.

Constituent actions:	UT	Self-observation							Exclusion Analysis						
	48	1	2	3	4	5	6	7	1	2	3	4	5	6	7
Device 1 (programmable thermostat)															
A. Opening the flap	3												1		
B. Reading PROG button	2									1		1			
C. Pressing PROG button	2	1					1				1				1
***D**. Reading info on display*	1					1				1		1		1	
E. Pressing (+) and (–) buttons	2	1					1				1				1
F. Reading time on display	3														
G. Reading (**Λ**) and (**V**) markings	2														
***H**. Read temperature on display*	1					1				1		1		1	
I. Reading +HRS markings	2									1					
***J**. Reading +1HRS on screen*	1					1				1		1		1	
Device 2 (room thermostat)															
***A**. Reading temperature markings*	1					1				1	1		1	1	1
B. Turn dial to set temperature	2	1					1	1				1			
C. Seeing temperature indicator	3														
Device 3 (radiator valve)															
A. Bending to reach for valve	2									1	1	1	1	1	1
B. Reading markings	1														
C. Turning valve	3						1								

Legend: **1** Highest priority **2** Second priority **3** Third priority ▢ Undetermined priority

On the other hand, when performing the Exclusion assessment all designers identified those problems. Three of the designers ranked these problems as the highest priority to change for the first device, and five designers defined it as the highest priority for the second device. Whereas Designers 2, 4 and 6 seemed to have successfully identified the visual demands imposed by the first two devices as the critical parts of the interaction, the remaining designers highlighted the first device's dexterity demands as the worst problem. Designers 2, 4 and 6 based their judgments on the higher levels of people excluded by this device's visual demands. Conversely, Designers 3 and 7 considered that whilst not being able to read the device would have a severe impact on its operation, not being able to use the buttons would prevent the users from using the device (*i.e.* absolute exclusion).

It is complex to assess whether problem prioritization solely based on the levels of people excluded (the approach taken by designers 2, 4 and 6) is favourable to judgments made on frequency and importance of particular instances of the user-device interaction (the approach adopted by designers 3, 5 and 7). All these issues related to prioritization should be thoroughly considered. Ultimately, they will also be constrained by the allotted time and budget for any given design project. Interestingly, during the Exclusion Analysis evaluation of the third device almost all the designers pointed out "bending to reach for valve" (Action A) as the most difficult action, and hence the highest priority to (re)design. However, this problem was, according to the User Trials, of secondary importance. This may have to do with the physical capability profiles of the users selected for the trials, which were more severely affected by the difficulties in reading the markings on the device than the problems in bending to reach for the valve. However, the number of people in the wider population of Great Britain who would experience problems in bending to pickup something from the floor is greater than the ones experiencing dexterity problems [10]. Hence, designers almost unanimous decision (supported by the information comprised within the Exclusion Analysis tool) in pointing out this action as the worst problem presented by this device.

4 Discussion

On the whole, the results from this case study suggest that there might be obvious limitations on designers' Self-observation evaluations regarding the assumptions they make about the capabilities of the wider and heterogeneous population. Designers' experience and creative input is extremely valuable to the design of innovative solutions. However, designing truly usable and accessible solutions, is a complex process that involves taking into consideration too many test issues and influencing factors [17]. Therefore, in the same way that it is not possible to, for instance, commit to memory all the users' anthropometric measurements, it seems unlikely that it will be possible to memorise the users' wide range of physical and psychological capabilities. In order to achieve realistic results (and assuming that the aim is to extend the market for the product) designers would have to be familiar with a wide diversity of user capabilities and behaviours. A large number of users exhibit unique capability characteristics, which may result in unexpected behaviours or even prevent them from using certain products.

Self-observation may enable designers to succeed in terms of enhancing user-product interaction for those who could already use a certain product (typically the able-bodied consumer). However, it is likely to lead designers to continue excluding large numbers of consumers who do not possess the 'required' capability profile. Therefore, the informality and possible incompleteness of designers' usual Self-observations could lead to subjective decisions that may result in problems at the interface level of the interaction between users and products (Norman, 1993). On the other hand, Exclusion Analysis has the potential to provide designers with more objective information on "non-able-bodied" people's capabilities. Such information could be used to estimate the numbers of people experiencing problems with a wide range of typical everyday human interface elements. However, this method should not be implemented as a replacement for the real user. Instead, it is a supplementary assessment approach that could enhance typical Self-observation techniques, prompting designers to consider issues of design exclusion based on capability data.

5 Conclusions

It is likely that direct user participation during the design process will always be necessary for the achievement of genuinely inclusive design solutions. Methods such as User Trials or User Observations, provide unique insights into a wide range of peoples' behaviours, needs and preferences, which are unlikely to be identified without their direct involvement. However, typical time and budget restrictions imposed during real-life design projects prevent designers from adopting such evaluation practices. As a result, many designers end up referring to their own perceptions about possible problems with the products they develop. Whereas this might be the most practical approach to counter for the absence of the real user, it is also likely to be inadequate when taking into consideration the wide range of user's of psychological and physical capabilities. A supplementary and more systematic assessment method – *i.e.*

Exclusion Analysis assessment – has been explored through case studies on the evaluation of the accessibility of everyday interfaces. This method, which places emphasis on pictorial and graphical representations, takes the form of a software tool that incorporates statistical demographic data on older and disabled people's physical capabilities. Hence, potentially enabling designers to prioritise accessibility problems, in a practical and less costly manner, based on an estimate of the number of people affected and the frequency of occurrence of particular problems during user-device interaction.

References

[1] Coleman, R., (2003) *Living longer*, in *Inclusive Design: Design for the Whole Population*, J. Clarkson, et al., Editors. Springer: London. pp. 120-141.

[2] Porter, S. and Porter, J.M., (1999) *Designing for Usability; Input of Ergonomics Information at an Appropriate Point, and Appropriate Form, in the Design Process*, in *Human Factors in Product Design: Current Practice and Future Trends*, W.S. Green and P.W. Jordan, Editors. Taylor & Francis: London. pp. 15-25.

[3] Keates, S. and Clarkson, J., (2003) *Countering Design Exclusion: an Introduction to Inclusive Design*. 1st ed. London: Springer-Verlag. 227.

[4] Jordan, P.W., et al., (1996) eds. *Usability Evaluation in Industry*. 1st ed., Taylor & Francis: London.

[5] Nielsen, J., (1993) *Usability Engineering*. London: Morgan Kaufman.

[6] Drury, C.G., (1995) *Evaluation of Human Work*, J. Wilson and N. Corlet, Editors. Taylor & Francis: London.

[7] Stanton, N.A. and Young, M.S., (1999) *A Guide to Methodology in Ergonomics: Designing for Human Use*. London: Taylor and Francis. 127.

[8] Poulson, D., Ashby, M., and Richardson, S., (1996) *Userfit: a Practical Handbook on User-Centred Design for Rehabilitation and Assistive Technology*. European Commission TIDE/USER project: Brussels-Luxembourg.

[9] Hasdogan, G., (1996) *The Role of User Models in Product Design for Assessment of User Needs.* Design Studies, Elsevier Science Ltd, Great Britain. 17: pp. 19-33.

[10] Grundy, E., et al., (1999) *Disability in Great Britain: Results from the 1996/97 Disability Follow-up to the Family Resources Survey*, Department of Social Security, Charlesworth Group, UK: Huddersfield, UK.

[11] Martin, J., Meltzer, H., and Elliot, D., (1988) *The Prevalence of Disability Among Adults*, Office of Population Censuses and Surveys, Social Survey Division, HMSO: London. 75.

[12] Porter, S., (1995) of Conference *The use of Ergonomics Software in the Education of Industrial Designers*. In *2nd National Conference on Product Design Education*.

[13] Muller, W., (1989) *Design Discipline and the Significance of Visual-Spatial Thinking.* Design Studies. 10: 12-23.

[14] Tovey, M.J., (1992) *Intuitive and Objective Processes in Automotive Design.* Design Studies. 13: 23-41.

[15] Henderson, K., (1999) *On Line and on Paper: Visual Representations, Visual Culture, and Computer Graphics in Design Engineering*. Cambridge, MA: The MIT Press.

[16] Hanington, B., (2003) *Methods in the Making: a Perspective on the State of Human Research in Design.* Design Issues. 19(4): 9-18.

[17] Kwahk, J. and Han, S.H., (2002) *A Methodology for Evaluating the Usability of Audio-visual Consumer Electronic Products.* Applied Ergonomics. (33): 419-431.

Carlos M C Cardoso, Engineering Design Centre, University of Cambridge, Trumpington Street, Cambridge, CB2 1PZ, United Kingdom, Tel: Int +44 1223 766 959, Fax: Int +44 1223 766 963
E-mail: cmcc3@eng.cam.ac.uk, URL: http://www-edc.eng.cam.ac.uk/people/cmcc3.html