

Simeon Keates

Pragmatic research issues confronting HCI practitioners when designing for universal access

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Abstract Many HCI products exclude potential users unnecessarily. Such exclusion often arises because of a mismatch between designers' perceptions of the wants and needs of the end-user and their actual wants and needs. Sometimes the mismatch originates from the designer being unaware of the need to design inclusively, or of methods for implementing inclusive design. Other times the mismatch comes from the commissioner of the design, for example the client of a design consultancy. If the design commissioner specifies a target socio-economic group, but does not explicitly recognise that the group consists of users of varying functional capabilities, then the designers will often be given a design brief that overlooks the need to address the wider range of users, beyond simply the able-bodied. In either case, for universal access to be achieved effectively, information is required to identify the need for inclusive design and thus to generate demand, and design guidance is needed to help designers make inclusive design a reality. Currently, that information is largely unavailable to designers in an appropriate off-the-shelf format. This paper investigates methods for researchers to provide the kind of information that HCI designers need to design for universal access. It focuses on the profiling, recruitment and selection of users, along with the interpretation of the data gathered. In many instances, the HCI designer may also be the person performing the research, where specialist researchers are not available.

1 Introduction

Philosophies such as universal access and inclusive design are becoming increasingly high profile, being driven by:

- legislation, e.g. the 1990 Americans with Disabilities Act [1] and the 1995 UK Disability Discrimination Act [8];
- standards bodies, e.g. the new BS7000-6: Guide to Managing Inclusive Design [16]
- purchasing policies, such as Section 508 of the Workforce Investment Act [35]; and,
- social forces, such as the ageing of the baby-boomer generation [6].

All the above recognise that it is unacceptable to discriminate against potential users on the grounds of their capabilities.

However, while the motivations for adopting inclusive design and the like are now well established, many designers are not adequately equipped for putting those philosophies into practice [9]. Partly this is due to lack of training, as many designers are not trained explicitly in gathering user data or in interpreting it. Other common causes include time and financial constraints placed on the designers during the development process. So, to optimise the amount of creative time available for the design, designers often find themselves having to short-circuit the investigation of the user aspects to meet those constraints. One of the most common methods for achieving this is to assume that the users are fundamentally similar to the designers. A common justification for this is "I am a user of this product, so if I design it for my needs, I must therefore be designing it for the needs of other users."

This line of thinking had led authors such as Cooper [7] to make the assertion that, unless told specifically to do otherwise, most designers will design for themselves.

However, while this line of argument is open to question even for so-called 'mainstream' products, i.e.

S. Keates
IBM TJ Watson Research Center,
19 Skyline Drive, Hawthorne,
NY 10532, USA
E-mail: lsk@us.ibm.com
Tel.: +1-914-7847565
Fax: +1-914-7847455

those products not designed for universal access but for principally the able-bodied market, it is clearly unsatisfactory when considering products that are to be used by users with impaired functional capabilities.

The reason for this is that as there are comparatively few designers with noticeable functional impairments, but many who can broadly be considered able-bodied, the default design approach is to design for the able-bodied users. Any users with impairments that are able to use the product have often only been included by good fortune rather than by design.

To design inclusively, or for universal access, requires the designers to design for the wants, needs and aspirations of a diverse range of users, many of whom will differ significantly from the designers' experiences.

Consequently, the designers need to be given methods of support for distilling the wants, needs and aspirations of the users into a form that they can understand and work with.

Throughout this paper, the term 'product' is used to denote the complete HCI system under consideration. It goes beyond the usual image of the standard graphical user interface (GUI) to encompass the input/output devices and also the environment of use.

2 Information provision in inclusive design

Having recognised that information is vital to the success of inclusive design, it is tempting to imagine that simply providing designers with more and more data about the end-users will be sufficient to ensure an inclusive product is designed.

However, there is a real danger that, unless the information provided is carefully screened to ensure that it is relevant to the use of the product being designed, the designer may be overwhelmed by the sheer volume of data that could be provided about the end-users.

2.1 Identifying the knowledge requirements

There is a need to understand the knowledge requirements of designers and design commissioners, both in terms of content and format. Knowledge requirements include information about the end-users and also the tools and techniques for developing more inclusive solutions. This is an important element of the broader goal of delivering complete, appropriate and validated information to those who can deliver products and services that are designed to include the needs of the whole population. Inclusion will be achieved through both the improvement of mainstream design solutions and the effective integration of assistive technologies and devices.

Presently, the data needs of information-users are met either by the designers having to obtain the data from first principles for each project, or else by comprehensive approaches where large volumes of data are

provided, but most of it is irrelevant for the case in hand. Examples of the latter approach include common anthropometric texts, such as *Adultdata* [25], which has 266 anthropometric dimensions and 28 strength measurements.

The ideal solution for information-users is to have sufficient data available on hand when it is needed—a kind of data 'just in time'. The need for sufficiency is key—the data needs to contain all the necessary information, but no more, to avoid information overload.

3 Types of user information

As discussed above, both insufficient and too much information about the users can impair the effectiveness of designers in developing inclusively designed products or services successfully. Consequently, it is necessary to understand which information about the users is of most use to designers, and then to find ways of presenting that information in an easily usable format.

As would be expected given the wide variety of possible information sources about users and the different data requirements of designers, there is no single ideal format for the representation of such knowledge in all circumstances. However, there are techniques available that enable the necessary information to be identified, gathered and packaged to meet the needs of designers.

The ultimate purpose of finding successful data representations is to support the designer in developing products that are both socially and practically acceptable [23], through developing the necessary understanding of the end-users to accommodate their wants and needs proactively during the design process, and obviating the need for retrospective adaptations.

3.1 Designing for social acceptability

Social acceptability, as defined by Nielsen [23] and used in this paper, is achieved when the product meets the expectations and aspirations of the end-user. For brevity, this paper shall refer to these as the 'user wants'. Social acceptability addresses issues such as:

- product aesthetics;
- user trust towards the product;
- potential user stigmatisation; and,
- overall interest of the user in the product.

This list is not exhaustive, merely indicative of the type of attributes associated with social acceptability. When considering the design of assistive products in particular, it is also important to add the avoidance of stigmatisation to the list of attributes.

In other words, a socially acceptable product must be one that the user is happy or content to use. Some commentators go so far as to suggest that the only successful products are those that the users want to use

[7]. While this may be true for most mainstream commercial products, it does not necessarily apply to so-called assistive or rehabilitation products, which are often bought on behalf of the user by an intermediary, such as a health authority.

Designing for social acceptability requires the designer to be provided with information about what constitutes a socially acceptable product for the users, and then using a suitable design approach that is responsive to those requirements. Obtaining and interpreting those requirements needs specialised approaches.

As would be expected, it is not possible to provide a single definition of what a user wants from a product or service. For example, some people want a product that draws attention to itself, such as a memory aid or prompt to take medication, while others would prefer something more discreet, especially for a product to be used in public. Consequently, it is often necessary to dedicate some effort to finding those wants for at least each product domain, and sometimes for each product variant.

Many designers are not trained to identify user wants. Traditionally, defining the user expectations for a product has been the remit of market researchers, or other specialist professionals, such as ethnographers. This does not necessarily need to change, as long as researchers can provide sufficient information about user wants to the designers in a format that they can understand and use. The following list represents a summary of typical methods used by researchers to elicit user wants [28, 30]:

- questionnaires—a series of pre-prepared questions asked either in writing or orally;
- interviews—either pre-structured or free-form;
- user observation—watching the users perform the task, either using an existing product or a prototype;
- focus groups—discussion groups addressing a specified topic; and,
- ethnographic methods—use of cultural probes, such as cameras, diaries, etc.

Each of the above methods can be effective in eliciting the user wants, but they also have their potential limitations. For example, questionnaires are only as useful as the questions that are on them. If the wrong questions are being asked, then the information obtained will be of limited use. Also, if the questionnaires are mailed out (as compared with being completed in the presence of a researcher), then they often suffer from low response rates.

Interviews are time-intensive, requiring one-on-one time between the interviewer and the interviewees, so are only really practical for small samples.

Similarly, user observation is also time-intensive, and often requires the use of specialised equipment for recording and analysing the observation sessions. The observers also have to be aware of the need to not interfere in how the user performs the task, to avoid influencing the data collected.

Focus groups are a current favourite among market researchers. They offer feedback from many users in a short time, and so are considered good value for money. However, the principal weakness of focus groups is that they can be hijacked by a small vociferous minority who impress their opinions on the other participants.

Ethnographic methods rely on providing the users with recording media, such as cameras, diaries and tape recorders. The users then use the media to keep a record of what they consider to be important over a period of between a few days and a week. The strength of this approach is that the user is left at complete liberty over what to record, thus preventing the researcher from influencing the outcome. However, the weaknesses are that the user may not record anything that is relevant and also that the data collected needs to be interpreted, and this is in turn subjective, depending of the individual researcher performing the analysis.

All of the above methods are discussed in more detail in many usability textbooks [24, 36]. As when considering any technique or approach developed originally for the mainstream market, there are additional considerations that need to be borne in mind when adapting to designing for the whole population.

Designing for social acceptability is what most product designers try to achieve. As such, inclusive design does not require the application of new skills or techniques. Instead it requires the designer to modify his or her perception of what the user really wants.

The encapsulation and presentation of the user wants needs to include additional factors such as the effects of age, experience and impairments, so that the designers can respond to them.

As this information can be quite complex, it is obviously difficult to provide exactly the right amount of data to the designer. Common approaches often focus on providing inspiration to the designers, encouraging the right frame of mind, rather than a list of specific requirements. For example, the provision of anecdotes or vignettes about the life of a target user is a popular method, and contributes to design by story-telling, an approach adopted by companies such as IDEO [21].

Another possible alternative is simply to expose the designers to the end-users. This is the approach used for empathic design [11], and also in the content of the annual design business association (DBA) inclusive design challenge organised in conjunction with the Helen Hamlyn Centre of the Royal College of Art. In the DBA Challenge, design teams are provided with access to critical user groups throughout the design process [3].

3.2 Practical acceptability

Having considered designing for the goal of social acceptability, the subsequent step is to consider practical acceptability. Nielsen's [23] definition of practical acceptability is divided it into:

- cost;
- compatibility;
- reliability; and,
- usefulness.

Of these, usefulness is further subdivided into utility and usability, where utility is the provision of the necessary functionality by the product or service to perform the desired task. Usability is defined as including:

- ease of learning;
- efficiency of use;
- ease to remembering; and,
- low (user) error rates.

The traditional concepts of utility and usability need to be extended to include a third factor to consider—that of accessibility when designing inclusively [17]. For brevity, the objectives of utility, usability and accessibility will be referred to as the ‘user needs’ in this paper.

There are many approaches to defining the functional requirements that a product has to meet, such as task analysis, functional analysis and competitive analysis [23]. The fundamental application of these techniques is not different from the typical ‘mainstream’ design process, and so will not be discussed in detail in this paper, with the caveat that they need to be applied with sensitivity to the wider range of end-users associated with designing for universal access.

4 Extending the user definitions

If it is true that designers typically design for themselves, unless explicitly directed to do otherwise, then the default user in a typical design process is a clone of the designer. When considering designing inclusively, this is unlikely to be a satisfactory description of the users.

If designers follow the usability practices recommended in the traditional usability literature, then the definition of the users should be broadened to include people with different experience, backgrounds, knowledge and skills. While this definition is an improvement, it still only represents variation of ‘mainstream’ users, i.e., those with no functional impairments.

In practice, though, for successful inclusive design, the definition of the users needs to move away from just the ‘mainstream’ to embrace users with different functional capabilities.

However, this raises interesting issues for HCI methodology, because extra dimensions need to be added to the user profiles when deciding which users to target and also to involve in the research and design activities. These extra dimensions arise from the need to know the levels of functional capabilities of the users for all of the capabilities needed during the interaction process. In other words, if the interaction requires vision, hearing and dexterity, then users should be selected in light of the levels of impairment

(or otherwise, if unimpaired) of those capabilities that they possess.

4.1 User capabilities

There are many sources of capability data available, each tailored for different purposes. As such, the capability data available often needs to be selected and synthesised carefully to be usable for design research. Traditionally, HCI research tends to focus on accommodating single, primarily major, capability losses. The reasons for this are two fold.

First of all, single major impairments are often the most noticeable, and therefore are the easiest to inspire motivation to address. This is particularly true in the case of visual impairment, which dominates much HCI research into designing for universal access. Second, such impairments are the easiest to understand and are comparatively easy to compensate for, as there are no complex interactions with other capabilities. However, many people do not just have single functional impairments, but several. This is especially true when considering older adults. Consequently, there is a need to make designers aware of the prevalence of not only single, but also multiple capability losses.

Estimates of the prevalence of disability derived from any study depend on the purpose of the study and the methods used [20]. Since disability has no ‘scientific’ or commonly agreed upon definition [26], a major problem lies in the confusion over terminology. However, the international classification of impairments disabilities and handicaps (ICIDH) [33] and the subsequent international classification of functioning, disability and health (ICF) [34], represent a rationalisation of the terminology frequently used. They identify impairment, disability and handicap as consequences of diseases, and present a classification for each. Further, the definitions also recognise the continuum of disability, whereby the severity of disability (loss of capability) ranges from very slight (category 1) to very severe (category 10).

The ICIDH/ICF definitions of disability have been used widely for both disability research [12, 20] and design research [27].

The Survey of Disability in Great Britain in the 1980s [20] and the 1996/97 disability follow-up (DFS) to the Family Resources Survey [12] extended the ICIDH/ICF definitions by identifying 13 basic types of functional impairments that affect an individual’s ability to participate actively in society. Of those 13, 7 are potentially applicable when considering HCI, and namely:

- locomotion;
- reach and stretch;
- dexterity;
- vision;
- hearing;
- intellectual functioning; and,
- communication.

These impairments can be clustered under the more general classes of motion (locomotion, reach and stretch, dexterity), sensory/perception (vision, hearing) and cognitive (intellectual function and communication). The 1996/7 DFS estimated of the prevalence of each level of these impairments throughout the population of Great Britain [12], and therefore provides a good starting point for discussing the issue of sampling users.

4.2 Sampling users by condition

There are many possible approaches for identifying and sampling potential users. The most obvious is to identify users based on their medical condition. The advantage of this approach is that someone's medical condition is a convenient label for identifying potential users. Not only are most users aware of any serious condition, especially one that affects their functional capabilities, but it also makes locating users easier. For example, many charitable organisations are focused on specific medical conditions, such as cerebral palsy, muscular dystrophy or Parkinson's disease.

The disadvantage of this approach is that many of these conditions are highly variable in terms of their impact on the user's functional capabilities, and so a degree of user capability profiling is still required.

4.3 Sampling users by capability

The alternative approach to sampling users is not to focus on their medical condition, but to look instead at their capabilities. The advantage of this approach is that the accessibility of the resultant product should then be independent of the medical condition. The disadvantage of this approach is that more user capability profiling, e.g. finding out the levels of each of the seven capabilities discussed in Sect. 4.1, is required at the outset to establish where each user sits in the capability continuum.

The first choice to be considered is whether to aim for a homogeneous user group, or a heterogeneous one. A homogeneous group offers a greater likelihood of generating statistically significant data when compared to a similarly homogeneous control group, and the results are thus more likely to find favour within the research communities. However, the weakness of this approach is that it needs to be repeated at potentially many different points in the capability continuum to provide a wider view of the general population. There are also practical difficulties in finding the required number of users with very similar profiles to participate in the experimental sessions.

The heterogeneous user approach argues that ideally the users sampled for participation in product research and design should represent the full range of end-user capabilities that can reasonably be expected in the

intended target population. However, to achieve statistical significance at all possible levels of capability across the target users would require a large number of participants. For example, if the capabilities involved in an interaction are vision, hearing and dexterity (as discussed above), and each of these have 10 levels of severity, and there need to be five users at least (7 or 8 would be a more typical minimum) [23] for each level, then 150 participants are required. If it is considered that there may be interactions between the capabilities and the ability to interact with the product, then this number could increase exponentially, as 10×3 levels of severity becomes 10^3 and so potentially 5,000 participants could be required. Therefore, methods of reducing the number of users are needed.

The most popular approaches to sampling are to either find users that represent a spread across the target population, or else to find users that sit at the extremes of that population. The advantage of working with users that represent a spread across the population is that they ensure that the assessment takes the broadest range of needs into account. The disadvantage, though, is that there is not much in depth coverage of users who may experience difficulties in accessing the product.

The advantage of working with the extreme users is that the user observation sessions will almost certainly discover difficulties and problems with the interaction. However, the disadvantage is that there is a real danger of discovering that particular users cannot use the product, and little else beyond that. For example, giving an instruction book to a user with complete sight loss yields the obvious difficulty arising from the inability to read the text. However, subsequent questions about the content of the instructions are not possible because of the over-riding difficulty of reading. This is of only limited value in an assessment such as this, as the difficulties encountered by the extreme users are comparatively predictable and provide little information about how many other users may or may not be able to use the product. It could also be argued that such users may reasonably be expected to make use of assistive technology to help access particular products.

Therefore, it is more useful to identify users who are likely to be 'edge-cases', those who are on the borderline of being able to use the product, and who would commonly be accepted as able to use the product [7]. Going back to the example of someone with a visual impairment attempting to read an instruction book, while someone with complete vision loss would certainly not be able to use the instructions, someone with only partial sight loss may be able to do so. Even more interestingly, that person might be able to read some bits and not others, and thus it is possible to begin to infer a wide range of very useful data from such a user. On top of that, if the user cannot read the instructions, then it may be inferred that any user with that level of sight loss or worse will not be able to use them, automatically encompassing the users with complete sight loss in the assessment of product exclusion.

Figure 1 summarises the different approaches to sampling the users. The implication of this is that whichever group of users participates in the assessment, it is important that their capability profiles are known, so that it is known how many users share the same characteristics.

4.4 Finding users

Having decided which types of users should be included in the product assessments, the next stage is to find suitable participants. For traditional usability assessments, the users would typically be customers or employees, and would often be readily to hand. However, when considering users with a wide range of capabilities, it is often necessary to commit explicit effort and resource to seeking out potential participants.

Good sources of users include charities specialising either in helping older adults or people with functional impairments arising from specific medical conditions. Social clubs are often a good source of more active older adults, whereas residential homes often house less capable potential participants. User groups can be found in most towns and cities, but effort does need to be expended in trying to find them, and then to identify candidate users who match the user sampling profiles.

4.5 Working with users

As with all usability testing, the participating users need to be treated with respect and courtesy at all times. When dealing with users with more severe impairments, it is especially important to be sensitive to their needs. For example, such users will often tire more easily than the person supervising the assessment may normally expect.

One of the other major issues to consider when working with users, especially for assessments, is the presence of coping strategies [10]. Many people with functional impairments find strategies for compensating for their impairments—sliding heavy objects that were designed to be lifted, using two hands instead of one,

making customised alterations to products to make them easier to use.

Identifying coping strategies can be difficult for someone who is not familiar with the nature of functional impairments. Users will often perform the coping strategy as if it was second nature to do so (through practice) or, alternatively, may actively disguise any such strategies to avoid drawing attention to any functional restrictions that they may have.

However, even when coping strategies have been identified, finding the cause of them is not always straightforward. For example, performing a one-handed operation with two hands may be a coping strategy for manoeuvring an object that is too heavy, but it is also a strategy for increasing accuracy.

4.6 The application of statistical analyses

It is important to note at this stage that practical limitations, principally involving the variable availability of individual users and the small sample set, can restrict the usefulness of detailed statistical analysis. HCI research in the field of universal access often requires years of intensive research, very often with weekly experimental sessions. It cannot be emphasised enough how the difficult circumstances surrounding this form of experimental work can influence the outcome. The users can experience changes in their capability over time, and may require medical treatment such as surgery during an experimental series. They become fatigued easily, despite extremely high motivation, and sometimes cannot complete trials or conditions. Only users who are already used to interacting with computers are suitable due to capability ‘floor’ effects. In other words, users who are unfamiliar with computers may report problems arising from their basic lack of familiarity, rather than issues with the interface being studied.

Like other voluntary users on a long-term study, they often choose not to attend experimental sessions, because of other commitments, such as medical appointments, or simply a need to take a break. It is necessary for experimenters to run the trials on a long-term basis, and to develop a working relationship with the users and to keep experimental conditions constant. Because of the small number of users available, repeated measures designs should generally be employed. Obviously, these practical difficulties make the systematic varying of conditions in pilot studies difficult and give rise to missing data problems resulting from incomplete conditions, caused by the loss of levels and factors from designs. For example, ANOVAs are commonly used to establish whether a statistically significant relationship or difference exists between two conditions. To use ANOVAs, there must be the same number of controlled independent variables, e.g. the size of a target and the distance to it, for the groups of data being compared (the factors) and the different values ascribed to each of those factors (the levels), e.g. distances of 128, 256 and

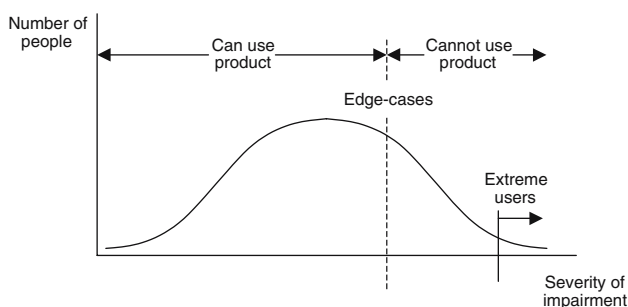


Fig. 1 The different approaches to sampling the users

512 pixels. Ideally, each factor should have the same number of levels for each user (or group of users), but that often requires the users to be available for the same number of sessions. If not, then some of the levels and even the factors may be missing. The data analysis then has to be based on either a subset of the data collected or on an extrapolation of the existing data. Both of these options are less favourable than a complete set of levels and factors across all users (or user groups) being studied.

In addition, the increased range and skewed variability resulting from the range of motor deficits leads to increased noise and violation of the assumptions of statistical tests. Where statistical tests are possible without violation of standard assumptions, such as normality of distribution or homogeneity of variance, they should be carried out. However, even if the power of these experiments was unknown because of the reasons outlined and the small sample size, the effect sizes may still be large because of the sometimes radically different behaviours that are associated with different functional impairments. For this reason, some statistical results that do not appear significant should be analysed in terms of statistical power ($1-\beta$: the probability of rejecting a false null hypothesis) [5], and estimates of effect size given [4].

If all else fails, experimental evidence should be presented as primarily qualitative, allowing the experiments to be used as pilots for retrospectively estimating effect sizes and power, enabling a continued effort to increase the effectiveness of the experimental series. At the very least, the researcher can use the argument that “*this* user had *this* (very real) difficulty”. While the immediate response to an assertion like this is that it offends most accepted scientific principles, when dealing with real people in the absence of large sample groups, this very pragmatic approach may be persuasive to the commissioner of the research. This is especially true if the commissioner subscribes to the ‘top-down’ design principle whereby if the design can be used by the least able users, then the design should also benefit more able users [16].

5 Packaging the user data

Having discussed the issues that HCI researchers and practitioners have to consider when aiming to design for universal access, it is helpful to look at ways of packaging the user data in a succinct format.

There are two basic approaches for providing user information:

1. generalised information about the population; and,
2. detailed information about individuals.

Most common ergonomic and anthropometric texts focus on providing information at the population level e.g. [25]. However, much of this information focuses on

the 5th–95th percentile ranges. When considering universal access, it is often those users outside of this range that are of interest. Of course, the methods of providing population data can also be replicated for subsections of the population, as the underlying data formats are still valid. However, the resultant data collections still end up being a similar size to those for the complete population. For example, anthropometric texts describing the characteristics of older adults [29], have a similar number of tables and charts as those for all adults [25]. This makes sense, because there are similar numbers of body attributes to report. So, while texts such as *Older Adults* help the designers and researchers obtain more specific information about older adults, the overall problem of sheer volume of data is not reduced.

So the second approach, that of carefully chosen, in-depth information about a limited range of users, is arguably more relevant for universal access. However, the issue of sampling arises again (see Sects. 4.2, 4.3), with the question of how to decide *which* users to describe in detail.

Looking at this second approach in more detail, there are a number of methods of packaging the user information for designers. For example, short videos of target users—perhaps depicting their lifestyles or using or talking about particular products—provide designers with greater insights into the needs and aspirations of users. Such dynamic illustrations can be effective in inspiring designers to formulate inclusive solutions.

Multimedia snapshots supplement imagery—illustrations, photographs and videos relating to targeted users, their needs, aspirations and use of products—with short textual descriptions and other complementary information. This is often presented in the form of text-based stories, scenarios or storyboards representing different users interacting with a particular product or service.

Such accounts offer immediate means of assessing a variety of ways and situations in which a product/service will be used or accessed. It can be a powerful technique if care is taken when building up user profiles based on actual user data or amalgams of individual users constructed to represent the full range of target users and contexts of use.

Anthropometric or accident data, or data gathered from the ‘knowing your user’ activities can be encapsulated using graphs, charts and tables. These can be effective for revealing trends and relative values, and for communicating more vividly what may be perceived as overly ‘dry’ information in designer-friendly formats. Reference tables and other conventional data formats are particularly suited to showing absolute values, but these may not inspire designers or be readily understandable to them.

These are all examples of methods of packaging the information for general product design purposes. However, for HCI, because of the resolution of detail of information that can be recorded about the interaction process through data-logging facilities in computers,

there are two notable additions to the repertoire of available methods: user models and claims.

5.1 Cognitive user models

Cognitive models describe interaction as a series of discrete component steps that are combined to achieve a target. They are powerful tool for designers, because they are quantitative in nature and thus support optimisation techniques for refining interface designs.

Their application to users with functional impairments has a somewhat chequered history. Horstmann [13] proposed that simple models of interactions could be used to model single switch letter scanning and predict communication rates. This was subsequently expanded to the modelling of communication rates for alternative and augmentative communication (AAC) both with and without word prediction technology [14]. The conclusion of this research was that cognitive modelling techniques offered a powerful method for addressing the numerous trade-offs that occur in AAC. A key result of the modelling exercise was the identification of the importance of cognitive loading on the users, and led to further research on the effects of cognitive impairment on human-computer interaction [19].

However, cognitive models have also been criticised for their application to motion-impaired users, for instance by Newell et al. [22] and Stephanidis [31]. The principal argument against their application has been that the models aim to capture the general behaviour of user populations, which runs contrary to how the critics view the purpose of AAC. They maintain that it is the individual differences between users that are most important and that trying to make users fit generalities will inevitably result in sub-optimal solutions for them. It is this view that has held most sway in recent years, resulting in relatively little research into the use of user models for motion-impaired users.

While it is true that the aim of AAC is to avoid forcing users to comply to stereotypes that are not necessarily ideal, the assertion that cognitive models therefore are of little or no use is false. The assertion assumes that the only purpose of modelling is to generate one model that applies to everyone and then use that model as the basis for interface design. Under those conditions, modelling would be detrimental to the interaction for those who deviate significantly from the generalised model.

However, cognitive models can serve a wider purpose than just to provide one description for all users. For instance, there is no reason why only one user model should be generated to describe the population. There could easily be several models and different flavours of the same basic interface offered to users based on the model that most closely matched their capabilities.

Also, cognitive models are not simply a tool for helping to design interfaces. They also offer a practical method for splitting the interaction into discrete sepa-

rate entities. These entities, or steps, can be calibrated for different user capabilities, to provide relative user performance and also identify where the key differences are between users. For example, one of the most straightforward models for understanding interaction is the model human processor [2].

The Model Human Processor is a very straightforward cognitive science model that segments the interaction process into three broad function types:

- the time to perceive an event, τ_p ;
- the time to process the information and decide upon a course of responsive action, τ_c ; and,
- the time to perform the appropriate response, τ_m .

The model states that each of these steps (perception, cognition and motor functions) occur in sequence. So the total time to respond to an event can be determined from the following equation:

$$\text{Time taken to respond, } T = x\tau_p + y\tau_c + z\tau_m \quad (1)$$

where x , y and z are integer values. For a simple response time to a single stimulus, x , y and z are all equal to 1 for able-bodied users. However, evidence suggests that for users with significant motion impairments additional cognitive (τ_c) steps may be inserted into the response [15]. Thus, the value of y should be modified by a function of the severity of impairment, $f(i)$:

$$\text{Time taken to respond, } T = x\tau_p + (y + f(i))\tau_c + z\tau_m. \quad (2)$$

So for some users, the simple response time is no longer $\tau_p + \tau_c + \tau_m$, but instead $\tau_p + 2\tau_c + \tau_m$ or even $\tau_p + 3\tau_c + \tau_m$.

Using sources of prevalence of impairment data, such as the DFS data set [12], the different variations of the model can be mapped to actual numbers of people in the general population, offering a powerful tool for designers and researchers alike.

5.2 Claims

Where quantitative data is not available, another method of packaging the user information is that of claims. This idea was originally proposed by Carroll [32] and recognises that there are often conflicting requirements when designing an interface that can lead to design compromises being sought. This is particularly true when considering functional impairments and capability losses. For example, if an on-screen button is hard to press, then a claim could be made that increasing the size of the button would make it easier to operate. Increasing the size would also benefit users with low vision, as the button would be easier to see. However, the drawback is that more screen real estate is occupied, leaving space for fewer buttons and supporting information. Whether the reduced number of buttons and information on the screen is a good thing or a bad thing depends on the particular circumstances under consideration. Thus

the theory of claims also stipulates that each claim must identify the user and the situation.

This approach was used in a recent study into the accessibility of digital terrestrial television (DTV) set-top boxes (STBs), commissioned by the UK department of trade and industry (DTI) [18]. The study involved user observation sessions with 12 older adults interacting with two different STBs. The usability and accessibility problems identified during the sessions were recorded as a series of claims. Table 1 shows one of the problems encountered, namely that the STB only responded to part of the input from the user via the remote control, for example when the user was slower at pressing the remote control's buttons than the STB expected.

Table 1 An example of a claim for a DTV set-top box

Symptoms
STB only responds to part of the input from the user
Encountered
When changing channel, ending up on channel 04 instead of channel 40
Result
Impairment of ability to change channels Tendency to end up on wrong channel Reinforces concept of DTV 'being difficult'
Causes
Principal cause Time-outs almost certainly based on model of young, able-bodied user Exacerbated by Checking the screen to see that the previous input has been recognised (e.g. showing "4-" when trying to go to channel 40)—even further exacerbated if this involves a change in spectacles from reading to distance pairs Finding the next button to press (e.g. the '0' on the STB1 remote is not in the standard position) Deciding on the next button to press (e.g. the OK/SELECT button—see problem 1)
Possible fixes
Extend time-out periods to allow for 'slower' users Counter claim: extending time-outs may affect faster users adversely. Use of warning-style dialogue boxes before dropping a user out back at the start of a process ("You have not selected an option—do you wish to do so or leave the menu?"—then press appropriate button) Counter claim: this may get annoying if the user keeps encountering it Use of buttons such as the "-/=" button on remote controls for specifying "I am doing a two-digit input now" Counter claim: not many users understand what this button does Reducing the 'exacerbating' features—e.g. having an LCD display on the remote control show the user the input created (saves having to swap between the TV and the remote control) Counter claim: increased cost of remote control

This method of summarising problems, their potential fixes and the opposing counter claims proved very popular with the people in the DTI who had commissioned the project.

6 Conclusions

This paper has discussed many of the issues to be considered when involving users in research and design activities.

While many of the widely-accepted methods of performing user studies often require large homogeneous sample sets, this is not always possible when considering design for universal access. In real, practical circumstances where there is limited time, money and user availability, researchers and designers may be required to tailor their data collection methods to meet those constraints. It is particularly important, therefore, that any user involvement is designed carefully to ensure that the maximum amount of useful information is obtained and then packaged in the most effective manner.

Researchers, who typically obtain this data, and designers, who typically use it, need to work together to ensure that these goals are achieved.

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