SIMULATING VISION LOSS: WHAT LEVELS OF IMPAIRMENT ARE ACTUALLY REPRESENTED?

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Capability loss simulators give designers a brief experience of some of the functional effects of capability loss. They are an effective method of helping people to understand the impact of capability loss on product use. However, it is also important that designers know what levels of loss are being simulated and how they relate to the user population. The study in this paper tested the Cambridge Simulation Glasses with 25 participants to determine the effect of different numbers of glasses on a person's visual acuity. This data is also related to the glasses' use in usability assessment. A procedure is described for determining the number of simulator glasses with which the visual detail on a product is just visible. This paper then explains how to calculate the proportion of the UK population who would be unable to distinguish that detail.

Introduction

As the population of the developed world ages, there is a growing awareness of the need for more accessible and inclusive designs. Products and services need to be usable by people with a wider range of capabilities and characteristics. To do this, designers need more and better information about people's capabilities and capability loss and their impact on usability. However, written methods of presenting such information can often seem dry and difficult to relate to real-life product use.

An alternative is the use of capability loss simulators. These simulators give designers and other stakeholders a brief experience of some of the functional effects of capability loss for themselves (Nicolle and Maguire, 2003; Cardoso and Clarkson, 2006). A functional effect is the effect of a medical or other condition on a person's physical or sensory capabilities, such as the ability to see fine detail. Thus simulation can be achieved through wearing equipment that restricts one's motion or reduces one's sensory capability. This ranges from whole body suits such as the Third-Age Suit (Hitchcock *et al.*, 2001) to individual sets of gloves or glasses (e.g. Goodman-Deane et al, 2008). Some authors also advocate using simple techniques to reduce capability in a rougher, more approximate manner, such as taping buttons onto knuckles or smearing glasses with petroleum jelly (Nicolle and Maguire, 2003). Alternatively, simulation software can be used to show how things would appear or sound to someone with a sensory impairment (e.g. Goodman-Deane et al, 2008).

Simulators can encourage greater empathy with users with capability loss, and provide a more personal understanding of impairment. Designers can also wear simulators while using products and prototypes to give them some insight into the effect of capability loss on product use and to identify usability problems.

Simulation does have limitations, as it provides a constrained experience of capability loss. It does not convey the frustration, social consequences or coping strategies involved in living with an impairment day-to-day. It is also usually not possible (or not ethical) to simulate the pain and other symptoms associated with an impairment. As a result, simulation is not intended to be used on its own. Rather, it should be used in combination with user involvement and expert appraisal methods. It can supplement these by helping a designer to internalize information obtained through other methods. It can also provide initial usability feedback to help correct some of the major issues before designs are taken to users.

Calibrating simulators

Another limitation of simulation is that it is often difficult for designers to tell what levels of impairment simulations correspond to, and thus whether they affect many of the target user group or just a few. This is particularly problematic for the rough-and-ready simulation techniques, but can also affect pre-produced simulators. For example, the Third-Age Suit reduced visual acuity, increased glare sensitivity and added a yellow tint, to simulate some of the effects of aging on vision. However, it did not specify what level of these effects were used (Hitchcock *et al*., 2001).

Other simulators do cover a range of impairment. This is particularly common with software simulation where levels of vision or hearing loss can often be manipulated through interface controls (e.g. eclipse, 2012). However, software simulators lack the immediacy and immersiveness of wearable simulators or their ability to be used while examining products directly.

Wearable simulators can also cover a range of capability loss. In vision simulation, sets often contain multiple pairs of glasses that mimic different levels of vision loss (e.g. Zimmerman Low Vision Simulation Kit, 2012). However, these are often designed for education purposes and thus only cover higher levels of impairment, with simulated vision typically starting at about 20/60 or worse (affecting less than 0.8% of the population). They thus do not help designers to understand the lower levels of impairment that can cause many people problems with mainstream designs. Furthermore, the basis for stating that a certain pair of glasses simulates a certain level of impairment is also often unclear.

This study address this issue by calibrating the level of visual acuity loss simulated by a set of simulator glasses covering both lower and higher levels of vision impairment (Engineering Design Centre, 2011). Waller et al (2008) calibrated an earlier version of these glasses using a self-report vision capability scale. Their purpose was to demonstrate how such data could be presented and used, rather than to give an accurate calibration. The current study takes this further, using a standard vision test with 25 participants to give more reliable data, and comparing the results with data on visual acuity in the wider population.

The Cambridge Simulation Glasses

The study used the Cambridge Simulation Glasses, which restrict the ability to see fine detail and perceive contrast differences (Engineering Design Centre, 2011). The glasses are made from a thin, lightweight material so they can be layered to simulate greater levels of impairment (Figure 1). Gloves are also available that restrict the functional ability of the hands. The two can be used in combination to help designers understand the impact of a range and combination of impairments.

Figure 1: Cambridge simulation glasses

The glasses and gloves were developed from a previous toolkit by Cardoso and Clarkson (2006), which was adapted by Waller et al (2008). The glasses in this paper were further developed to make them cheaper to manufacture and to make it easier to wear multiple pairs on top of each other. The glasses examined in this study were the “Level 2” glasses from the kit, which contain two sheets of filter material. Level 1 pairs, containing a single sheet, were not available at the time of the study. Furthermore, using Level 2 glasses meant that the range of the glasses could be examined while keeping the length of the study manageable.

Calibration of the simulators

Method

Participants’ visual acuity (VA) was measured using the Landolt C chart from Test Chart 2000, with 8 possible orientations of the C. This eye test is a standardised and reliable method of measuring visual acuity. It was chosen because it is faster to run than EDTRS letter charts, yet produces a reliable measure. Speed was an important consideration as each participant's eyesight was measured multiple times.

Participants wore their usual vision setup (e.g. glasses or contact lenses) for all the tests. A participant's VA was first measured with three pairs of the simulator glasses (in addition to their usual vision setup). It was then measured with two pairs, a single pair and finally no pairs of simulator glasses. This last was defined as the participant's base visual acuity (base VA).

Sample

Twenty-seven staff and students of the authors' research centre took part in the study. This recruitment strategy was used because the study depends primarily upon participants' levels of eyesight, rather than other participant factors. Two of the participants were removed from the analysis as their base VA was very low and would skew the sample. It was 0.3 LogMAR (Snellen 20/40) or worse, which is generally considered to impact the ability to drive. The remaining 25 participants had base VA varying from 0.22 to -0.12 LogMAR (mean 0.07, S.D. 0.10).

Results

The results are summarised in Figure 2, which shows the effect of wearing different numbers of simulator glasses. The effect is calculated as the difference between a person's VA when wearing the glasses and their base VA. The three peaks on the graph correspond to the results with one, two and three pairs of simulator glasses.

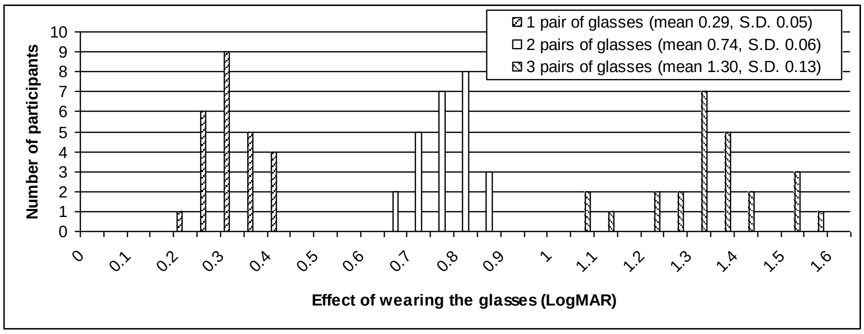

Figure 2: The effect of wearing the simulator glasses. Scale points on the x-axis correspond to 0.05 LogMAR bins (0-0.05, 0.05-0.1 LogMAR, etc).

Analysis

The effect of wearing one or two pairs of glasses is not correlated with the participants' base VA (r = 0.05, p>0.05; r = -0.12, p>0.05). However, there is a strong correlation between base VA and the effect of wearing three pairs of glasses (r = -0.54, p<0.01). The better a participant's visual ability (lower LogMAR), the larger the effect of the glasses. The regression line is modelled by: *effect with 3 pairs = 1.34 - 0.67 * (base VA).* However, it should be remembered that this only accounts for about 29% of the variance in the results.

The actual VA experienced when wearing one or two pairs of glasses can be estimated by adding the wearer's base VA to the mean effect of those glasses. For three pairs of glasses, using a single mean value is not appropriate. Instead, the effect for the particular base VA can be calculated using the regression equation. The equations and resultant visual acuities for various base VAs are summarised in Table 1.

Table 1: Visual acuity when wearing different numbers of simulator glasses. Snellen 20/X figures have been rounded to the nearest whole number.

Base VA		VA with 1 pair of glasses		VA with 2 pairs of glasses		VA with 3 pairs of glasses	
LogMAR	20/X	LogMAR	20/X	LogMAR	20/X	LogMAR	20/X
x		*x + 0.29*		*x + 0.74*		*x + 1.34 – 0.67*x*	
0.2	20/32	0.49	20/62	0.94	20/174	1.41	20/514
0.1	20/25	0.39	20/49	0.84	20/138	1.37	20/469
0	20/20	0.29	20/39	0.74	20/110	1.34	20/438
-0.1	20/16	0.19	20/31	0.64	20/87	1.31	20/408

Using the simulators for usability assessments

The simulator glasses can be used to provide initial feedback on a product's usability and the levels of visual demand it places on a user. To do this, we propose the following "simulator assessment procedure". Designers first test their own eyesight, while wearing their usual glasses or contact lenses (if appropriate). This is, by necessity, a rough test as it is self-administered. Ideally, the designers would use the Landolt C test as in this paper, although a letter chart is also possible. The designers then put on three or more pairs of simulator glasses (on top of their normal glasses). With these on, they examine the product. For example, they may try to read some text on the product and distinguish some markings. If they cannot do this with all the glasses on, they remove one pair and try again. The "simulator demand level" is the number of glasses with which the feature is just visible.

For example, imagine a designer with 0 LogMAR visual acuity (20/20 vision). If he/she can distinguish the controls on a product with one pair of simulator glasses, but not two, then the simulator demand level is one pair of glasses. This corresponds to the controls being discernable by users with a VA of 0.29 LogMAR but not by those with 0.74 LogMAR (Table 1). Note that, in practice, users may employ other strategies to help them use products, so this evaluation method should not be used in isolation. Nevertheless, it gives an initial indication of a product's visual inclusivity.

Population figures

It can be helpful to relate these levels of visual acuity to population figures, to help designers understand how many people this would actually affect. Survey data can be used to calculate the proportion of a population that would not have the level of visual acuity required by a product feature and thus would be excluded from its use (Keates and Clarkson, 2003).

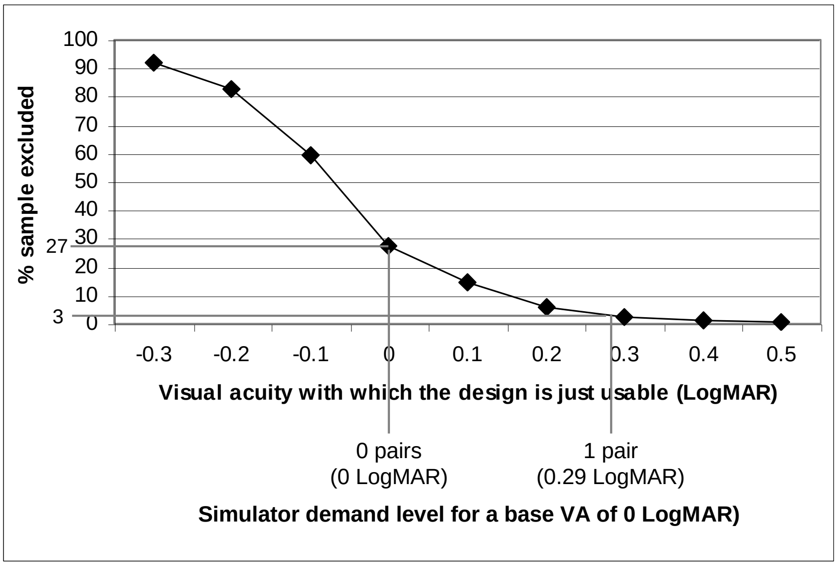

Figure 3: The percentage of the sample (from a 362 person survey) that would be excluded by a design that is just usable at different visual acuities. This graph was modified from one in (Goodman-Deane et al, in progress).

The graph in Figure 3 was constructed using this method with data from a survey of 362 participants in the UK (Clarkson et al, 2012; Tenneti et al, in progress). It thus gives the proportion of the sample that would be excluded rather than the proportion of the whole UK population. However, the survey was postcode sampled and weighted for age and gender and thus can give a good indication of exclusion on a wider scale. This data source was used because it covers a wide range of vision and other capability measures meaning that exclusion for other impairments and combinations of impairments can also be calculated (Keates and Clarkson, 2003; Goodman-Deane et al., 2011). In addition, the survey was a pilot and it is hoped that funding will be obtained for a full UK representative survey which will give more comprehensive results.

The survey tested visual acuity using LogMAR EDTRS letter charts. The results from these are generally comparable with the results from the Landolt C charts (Kuo et al, 2011), although some studies have found a small difference between the measures of between 0.01 and 0.1 LogMAR (e.g. Wesemann, 2002).

Some points are marked on the graph in Figure 3. They correspond to different values of the "simulator demand level" for a designer with a base VA of 0 LogMAR. For example, if that designer can just distinguish the markings on a product when wearing one pair of simulator glasses, then the graph indicates that about 3% of the UK adult population would be unable to see those markings.

The exclusion with different base VAs can be determined by examining Table 1. This table gives the visual acuity corresponding to different numbers of glasses (and hence to different simulator demand levels) with various base VAs. This visual acuity can then be matched to the x-axis in Figure 3, and the percentage exclusion can be read off the graph.

Note that the exclusion for two and three pairs of glasses are off the x-axis scale on the graph. They thus correspond to less than 0.7% exclusion. This level of exclusion is sufficiently low that it may be of little interest to designers designing for a general population. However, they should still consider that about 180,000 people in the UK are registered blind with 1.3 LogMAR or worse, roughly corresponding to three pairs of glasses (Action for Blind People, 2012). Using two and three pairs of glasses can still be a good check on a design, and is particularly valuable if designing with an older population or visually impaired population in mind.

The graph in Figure 3 raises another issue. The points for zero and one pairs of glasses are spaced quite far apart. It may be useful to have simulator glasses with smaller increments to provide more detail on visual inclusivity, and help designers to understand the effects of smaller changes in their designs. As mentioned above, this paper used the Level 2 glasses from the simulation kit. Since the study, Level 1 glasses have also been produced (Engineering Design Centre, 2011). These contain a one rather than two sheets of filter material. Thus they should be approximately half the strength of the ones used in this study. However, their precise effect on visual acuity has not yet been measured.

Conclusions and further work

The effect of the Cambridge Simulation Glasses on visual acuity was tested with 25 participants. The paper describes the visual acuity that a person has when wearing different numbers of these glasses, for people with different starting levels of visual acuity. The glasses can be used to examine the visibility of product features, and the results used to calculate the proportion of users who would be unable to distinguish these features.

The study has indicated the need for a finer level of simulation. Half-strength simulator glasses have been produced but further work is needed to calibrate them. Further work is also needed to use the glasses in practice to evaluate more products, and compare the results with usability findings from user trials and other methods.

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