Now you see it, now you don't

Now You See It, Now You Don't

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Abstract

This paper details a study that was conducted to determine the effect physical context of use, e.g. daily lighting levels and contrast, has on perception. The study was undertaken to further develop inclusive design analytical tools that assess the characteristics of a product against the capabilities of users. A total of four lighting levels were tested (equivalent to street lighting, in-house lighting, optimum and daylight), and four contrast levels (90%, 50%, 25% and 10% contrast). A random proportionate sample of adults aged 65 years and older was drawn from the population (N = 38, age range 65-87 years, mean age 74). The experiment revealed daily lighting levels to have a noticeable affect on visual acuity. Results showed that by increasing the lighting level from street lighting to optimum, there was an increase of up to 44% in the number of participants able to correctly read particular rows of letters. In 73% of cases the number of people able to correctly read each letter size decreased when its contrast was reduced. With certain letter sizes up to 50% more people were able to read letters at 90% compared to 10% contrast. Future work is being planned to see how these results relate to the general population and everyday products.

Keywords

Context, lighting, contrast, perception, population data, inclusive design

Introduction

Any form of product interaction always takes place within a context (context of use). This refers to a set of circumstances relating to the Users, Tasks, and the Environment (both physical and social aspects) in which a product is used [1]. The physical environment (lighting, temperature, weather conditions etc.) can vary greatly within a typical day. In particular, the ambient illumination in the real world is constantly changing. Lighting levels can reach higher than 100,000 lux on a bright sunny day, and drop as low as 0.001 lux at night. Anatomically, the human eye automatically adjusts itself to changes in ambient illumination. At low light levels the eye loses its ability to perceive detail and increases its ability to detect light. However, when it gets bright the reverse happens, and the eyes can detect detail around 10 times as fine in daylight as they can at night under starlight [2]. Visual acuity (the ability to see fine detail and shapes) is therefore a human capability that can improve or deteriorate as a result of ambient illumination. Therefore, the physical environment in which a product is used can significantly affect a user's ability to successfully perceive detail. This effect is even more noticeable with older adults whose visual acuity has already been reduced through aging and/or impairment.

The successful visual perception of detail can also be affected by contrast, i.e. the brightness and colour difference between the foreground and background colours of the detail being perceived [3]. The bigger the colour and brightness difference between the two colours the higher the contrast, the smaller the difference the less contrast. When the contrast between a visual target and its background is low, the target must be larger for it to be equally discriminable as a target with greater contrast [4]. Currently, metrics that detail the impact contrast has on visual acuity do not exist, which means uninformed design decisions have to be made by product designers about the inclusive merit of contrast levels used.

A number of inclusive design analytical tools that assess the characteristics of a product against the capabilities of users have been developed as part of the EPSRC i~design project. These tools quantitatively assess the inclusivity of different design decisions according to the number of potential users that would be excluded from using the product successfully. These types of tools have been found to greatly assist the implementation of inclusive design in business [5]. However, the tools do not factor in the effect such contextual and design factors have on users' capabilities; it is therefore not possible to truly calculate how inclusive products are in everyday circumstances.

The aim of the research study is to produce design guidance/measures that will allow designers to develop products that are appropriate and usable within everyday contexts.

The objectives of the study are to:

- Determine the extent daily lighting levels affect the readability of letters
- Determine the extent contrast affects the readability of letters
- Provide an insight into the number of potential users excluded as a result of daily lighting levels and contrast

Detailed within the remainder of this paper is the methodology adopted for the visual study, preliminary results and a discussion of what the results mean in relation to inclusive design.

Methodology

Test Charts

Letter charts are generally used to measure visual acuity. A number of such charts exist; however, there is a shift to using logMAR letter charts which have been regarded as the gold standard of vision tests [6]. Also, acuity results from logMAR charts can be extrapolated to any distance. LogMAR charts were therefore used for the purpose of this study. The charts were specifically developed to test acuity at a distance comparable to that when interacting with products, i.e. at a distance of 1 metre. The charts were developed based on the British Standard requirements [7] and the design principles detailed within one of the founding papers on logMAR charts [8]. The logMAR charts developed for the study are illustrated in Figure 1.

Scoring test charts

The aim of the study was to determine what size and at what contrast letters can be recognised correctly under different lighting conditions. Visual acuity was therefore scored using an alternative method to that typically used [8]. Each participant's acuity score was based on the smallest row of letters read correctly from start to finish, as opposed to the traditional scoring method which calculates threshold of visual acuity. Through using this scoring method it is possible to calculate the number of potential users excluded, i.e. unable to accurately recognise letters of a certain size and contrast.

Contrast levels

The charts were designed at four different contrast levels: 90% contrast (high level contrast), 50% (medium level contrast), 25% and 10% (two low level contrasts). Examples of two of the logMAR charts developed for this study can be seen detailed in Figure 1.

Figure 1: 90% and 25% logMAR acuity charts

Lighting levels

Four lighting conditions were chosen for the study. The conditions represented typical everyday environments where product interaction frequently takes place:

1) 7.5 lux (e.g., street lighting)
2) 150 lux (e.g., in-house lighting)
3) 6000 lux (e.g., optimum lighting)
4) 40,000 lux (e.g., daylight)

The light level used for the optimum condition is derived from past vision lighting studies [9, 10] , which define it as a state whereby a person has high visual efficiency–in other words they can rapidly and accurately discriminate detail without undue effort. Beyond this lighting level the law of diminishing returns applies [9]. This lighting condition was chosen in order to determine the extent of participants' visual capabilities. By comparing acuity scores from alternative lighting conditions to optimum, it was possible to establish to what extent visual acuity is affected by variation in everyday lighting levels. The optimum lighting condition is also representative of a typical everyday lighting condition, i.e. a cloudy day.

Sample

A random proportionate sample of adults aged 65 years and older was drawn from the population (N = 38, age range 65-87 years, mean age 74). Participants with cataracts, refractive error and age related macular degeneration were included in the sample as they are the major causes of sight problems within the elderly [5], but those registered as severely sight impaired or blind were not included in the sample.

Research design

A repeated measures research design was used. Each participant read four eye charts (90%, 50%, 25% and 10% contrast charts) and then the lighting condition was changed. Each participant was given sufficient time for their eyes to fully adapt when lighting levels were altered. A balanced Latin square was used to randomise the order of the charts and the lighting conditions. This counter balancing of the conditions mitigated against any order or carry over effects.

Results

The results in this section detail the preliminary findings from the study. The letter sizes detailed are equal in height and width. The sizes reported are related to a viewing distance of a metre; if the viewing distance were greater or smaller the letter sizes would have to be recalculated as they are proportional to the distance they are viewed.

Impact of lighting

In 58% of cases acuity improved as the lighting level increased. The mean acuity scores (i.e. the smallest size of letters 50% of the sample could correctly read), reported in Table 1, provides an overview of the extent to which acuity improved with lighting.

Table 1. Smallest letter size 50% of participants could read in all conditions

	90% Contrast	**50% Contrast**	**25% Contrast**	**10% Contrast**
Street lighting	2.9mm	2.9mm	3.7mm	3.7mm
In House	2.3mm	2.9mm	2.9mm	3.7mm
Optimum	1.8mm	1.8mm	2.3mm	2.3mm
Daylight	1.8mm	1.8mm	1.8mm	2.3mm

A noticeable improvement in mean acuity was observed between street lighting and daylight across all contrast levels. Lighting appeared to have the biggest effect on letters printed at 25% contrast, as on average participants could read letters 1.9mm smaller in daylight compared to street lighting. Mean acuity generally did not improve between the optimum lighting condition and daylight; the only improvement was recorded on the 25% contrast chart.

With the 90% contrast charts, it was found that by increasing the lighting level from street lighting to optimum, there was an increase of up to 44% in the number of participants able to correctly read particular rows of letters.

Impact of contrast

In 73% of cases, the number of people able to correctly read each letter size decreased as contrast was reduced. Figure 2 illustrates the extent to which correct letter recognition varied under in-house lighting as contrast was reduced.

For each letter size recognized under in-house lighting, the percentage of people able to correctly read them decreased as the contrast was reduced. When the contrast of a letter was reduced from 90% to 10%, on average, 40% fewer participants could perceive the letters correctly. When reduced from 90% to 25% contrast, on average 19% fewer participants could perceive the letters correctly. When reducing from 90% to 50% contrast, on average 10% fewer participants could perceive the letters correctly. Out of 32 letter size/contrast combinations, nine were unable to be read correctly. Letters unable to be read were generally 1.45mm or smaller and of low contrast (25% and 10% contrast).

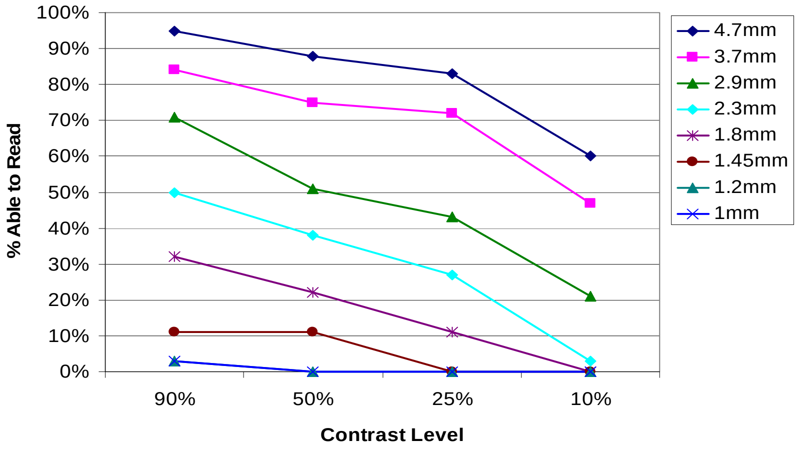

Figure 2. In-House Letter Recognition at Four Contrast Levels

Discussion

Through comparing the mean letter sizes across the lighting levels it is possible to get an indication of the effect everyday lighting levels have on visual acuity and readability of different sized letters. With all contrast levels tested, it can be seen that the mean readable letter size gets increasingly smaller as lighting increases. After lighting has reached a particular level (6000 lux in the case of this study) there is little if any improvement in visual acuity. These findings confirm what has been found in past vision lighting studies [9,10]. That is, visual performance increases rapidly as illumination increases from a low level; however, as illumination continues to increase, the improvement becomes smaller until eventually it ceases altogether. Lighting appeared to have the least impact on the high (90%) and medium level (50%) contrast charts: participants were generally able to read letters only 1.1mm smaller in daylight than under street lighting. Lighting levels had the biggest impact on letters printed at 25% contrast: on average participants were able to read letters 1.9mm smaller in daylight compared to street lighting.

Further analysis highlighted the impact lighting can have on the readability of letter sizes. In one particular case, the number of people able to read 90% contrast letters increased by 44% when the lighting changed from street lighting to daylight. This illustrates how variations in the physical context of use can lead to exclusion.

The contrast level of the letters has also been found to equally impact on the number of people who are able to read them. Results show that as the contrast of the letters is reduced, fewer people are able to read them. In certain situations letters became less readable by up to 50% of the sample. Again, this illustrates the extent contrast can affect the readability of letters and the inclusive merit of products.

Conclusions and future work

The results from this study show that the physical context of use, e.g. daily lighting levels, can have a noticeable impact on the readability of text. Failure to consider contextual data alongside capability data may result in users becoming unintentionally excluded from using products. By combining the data on contrast with letter size, designers would be able to make informed trade-offs between the two. For instance, if the buttons on a microwave had a letter size of 3.7mm at a contrast of 25%, approximately 70% of older adults will be able to read them at 1m. If the contrast were increased to 90% (e.g. background colour was made lighter and the figures darker) then letter size could be reduced to 2.9mm and it would still be readable by the same number of people. Further analysis of the data is needed to see how these results apply to the general population and everyday products. Future work will involve converting this experimental data into a usable form for designers.

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