THE IMPORTANCE OF CONTEXT IN INCLUSIVE DESIGN

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Capability data used in current inclusive design tools fail to take into account context of use. Two experiments were conducted with older users to determine what effect the physical environment has on two essential product interaction capabilities (vision and dexterity). For vision (n_1 = 38) everyday lighting levels were investigated, and for dexterity (n_2 = 14) warm (19°C-24°C) and cold temperatures (5°C) were investigated. Results from the vision study showed that when the lighting level decreased from daylight to street lighting, there was a decrease of up to 44% in the number of participants able to correctly read particular rows of letters. Findings from the dexterity study indicated that fine finger dexterity is significantly reduced ($p<0.05$) when exposed to average winter temperatures (5°C). Failure to consider the capabilities of users in these everyday contexts of use could result in products excluding or causing difficulties to those intended to be included.

Introduction

The ageing population has become such an issue that the UK Government along with Japan and the US are reviewing their strategies for meeting the challenges of our ageing society. In the UK alone there are more people aged 65 and over than there are children under the age of 16 years (HM Government, 2008). In relation to design this presents a problem, some may say a challenge.

As the human body ages, especially beyond the age of 65 years, there is a significant reduction in functional capability (motor, sensory and cognitive capabilities). Capability is one of the fundamental attributes a person needs to access and use everyday products. Failure to take account of this reduced functional capability in the design process results in users becoming excluded from product use. Inclusive design is the philosophy that aims to consider this reduced functional capability during the design process, with the aim of making products functionally accessible and usable to as many people as reasonably possible. However, designers have to understand users' capabilities and needs if inclusive design is to take place (Keates and Clarkson, 2004).

Two inclusive design tools have been developed in order to help designers achieve this. They are HADRIAN (Human Anthropometric Data Requirements Investigation and Analysis) (Marshall *et al*, 2002), and the Inclusive Design Toolkit (Clarkson *et al*, 2007).

For HADRIAN the capability of 102 older and disabled adults was measured in a laboratory environment (Gyi *et al*, 2004), whilst the exclusion calculator in the Inclusive Design Toolkit utilises data gathered from the 1996/97 disability follow up survey (Grundy *et al*, 1999). Data used in the Inclusive Design Toolkit was initially gathered to help plan welfare support, thus not intended to cover all aspects of product interaction such as context of use (Waller *et al*, 2008). Both tools are a big step forward in aiding the uptake of inclusive design in industry. However, one serious weakness with the data is its failure to consider capability in real-life everyday contexts of use. Designing a product to minimize exclusion requires knowledge of the demands made by the product on its users, knowledge of the range of capabilities of the target users and their prevalence, and knowledge of context of use (Clarkson, 2008).

Recent evidence suggests context of use can have a multi-faceted impact on product interaction (e.g. increasing or decreasing user capability, and/or increasing product demand) particularly with older adults who have significantly reduced capability due to their age (Elton *et al*, 2008). Thus, when a mismatch between context and a product occurs, it is unlikely that the benefits of a product will be realised (Maguire, 2001). In real world terms this could mean inclusively designed products in fact become unusable in everyday contexts.

The overall aim of this research is to understand the extent to which everyday contexts of use can exclude people from using products in their daily lives, especially those who are older or disabled and may already be working to the limits of their abilities.

Context of use and capability

A considerable amount of literature has been published on the subject of context of use. It is not the intention of this research to develop these definitions further. However, it is important to understand what is meant by it, before it is discussed.

Context is defined in the Oxford English dictionary (2000), as "*the circumstances that form the setting for an event.*" The British Standard BS EN ISO 9241-11 (1998) defines it in more detail as: users, tasks, equipment and the physical and social environments in which a product is used. Other disciplines such as computing and mobile communication consider context, expressing the same concept but with their own vocabulary or emphasis. Detailed in Table 1 are the main factors relevant to each of the identified context characteristics.

As can be seen from Table 1, context is vast and covers a wide selection of circumstantial factors. Identifying which of these characteristics are experienced on a frequent basis during product interaction and which are likely to have the greatest impact on capability is discussed in the following section of the paper.

Table 1. Context characteristics and their associated factors (adapted from Thomas and Bevan (1995)

Context characteristic	Associated factors
User (People intended to use the product)	Knowledge, skill, experience, education, training, personal attributes, physical, motor and sensory capabilities.
Task (Activities undertaken to achieve the goal)	Frequency, duration, flexibility, sub-tasks, physical and mental demands, goal/output, procedure, and criticality.
Equipment (Product/s used to achieve the desired goal)	What's used, where located, duration used, choice, anything not used.
Physical Environment (The external surroundings/conditions)	Visual conditions, atmospheric conditions, temperature, auditory conditions, vibration and the built environment.
Social Environment (The culture and people that surround the user)	Location, co-location of others, group working, assistance, number of people nearby, customs of users and surrounding people.

Product interaction capability

When interacting with a product, demand will typically be made on up to seven user capabilities (Waller *et al*, 2008). These capability categories have been identified by Clarkson *et al* (2007) as:

- Vision
- Hearing
- Thinking
- Communication
- Locomotion
- Reach and Stretch
- Dexterity

The demand placed on each capability is dependent upon the characteristics of the product being used and the task being accomplished. For example, making a mobile phone call requires a user to get their phone from their pocket/bag (reach), grasp the phone with their hand (dexterity), visually identify the buttons they need to press (vision), use their finger(s) to press the buttons (dexterity), and lift the phone to their ear (reach). During this process the user needs to recall a sequence of actions and numbers (thinking), and once this has been achieved the user then has to speak (communicate) and listen to the other person (hear).

Although demands are made on up to seven user capabilities, the vast majority of products make demands on the visual and dexterous (arm, hand and finger) capabilities of the user. For example, entering information into an electronic device (such as a computer, mobile phone, MP3, ATM), operating products around the home (kettle, toaster, vacuum cleaner, dishwasher), and using products outside the home (such as ATMs, gardening equipment, leisure equipment, devices for work) all require the perception of visual information and manipulation by hand for them to be successfully used.

Thus, identification of which everyday contextual characteristics frequently impact on these two capabilities will help to ensure products are usable in real world contexts of use.

Identification of relevant contextual characteristics

The Inclusive Design Toolkit (Clarkson *et al*, 2007) details the contextual characteristics that impact upon the seven user capabilities relevant to product interaction. For visual capability, ambient illumination and glare are identified as having an impact (Persad and Langdon, 2007). For dexterity, cold temperatures, sweaty/wet/lubricated hands, wearing gloves and vibration are identified as the contextual characteristics that can impact this capability (Persad and Waller, 2007).

Whilst glare is a significant factor that affects vision, it is mainly an issue on fixed surfaces/displays that cannot be moved. However, the ambient illumination is constantly changing from morning until night on a daily basis. On a bright sunny day lighting levels can reach 100,000 lux, and drop as low as 0.001 lux at night. The greatest variation in ambient illumination occurs outdoors; however ambient illumination can only be controlled to a degree when indoors, i.e. through lamps or mains lights that illuminate the room to a specific level. Detail on everyday products has to be perceived in both of these environments where the ambient illumination constantly varies. The issue is that 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 (Hopkinson and Collins, 1970).

A greater number of contextual factors are identified as having an impact on dexterity. For example, vibration can impair a person’s ability to make fine movements with their hands and fingers. Sweaty/lubricated/wet hands can require a person to exert a greater level of strength whilst gripping. Gloves can make it harder to operate controls on products, and the cold can reduce the flexibility and sensitivity of the hands and fingers (Persad and Waller, 2007). Although all of the aforementioned contextual factors could affect product interaction, it is only the ones experienced regularly that are of concern. Cold temperatures are experienced annually for up to 3-4 months at a time. Again, with products being used both inside and outside the home, it becomes a contextual factor relevant to a large number of product interactions. Furthermore, dexterity (both manual and fine finger) is significantly reduced due to physiological effects of the cold on the human body (Heus *et al*, 1995).

Whilst a selection of everyday products are used within the home environment where such variations in the physical environment can have a lesser effect, there are still activities of daily living, leisure and work that require the use of everyday products outside or in less than optimum environments. Furthermore, developments in technology are enabling the use of more products whilst mobile and out of the home.

In summary, it would appear that the factors associated with the physical environment, in particular ambient illumination and temperature, could affect the two main product interaction capabilities (vision and dexterity) on a frequent basis. What we know is that both of these contextual factors affect the physiology of the eyes and the hands, therefore capability can vary dependent upon the environmental conditions.

However, to what extent does capability vary under everyday contexts? Is variation in ambient illumination and/or temperature enough to push a user from being included to excluded?

Experimental investigations

Two experiments were conducted with older adults (65+ years) to determine what effect variations in everyday lighting and temperature conditions have on vision and dexterity respectively. A minimum age criterion for the sample in both experiments was set at 65 years old. Hand function becomes significantly reduced at this age and the vast majority of people with sight problems are this age and older (Shiffman, 1992; www.rnib.org.uk). A dataset that details this reduction and variation in capability will allow for the design of mainstream products that are accessible to, and usable by, as many people as reasonably possible, without the need for special adaptation or specialized design (Clarkson et al, 2007).

The first experiment (n_1=38) measured the effect everyday lighting levels had on visual acuity (ability to perceive detail) of older adults (mean age=74 years, SD=6.1). Visual acuity was measured under four light levels at the distance of one meter. 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/cloudy day)
4) 40,000 lux (e.g., daylight)

Under each of these lighting conditions visual acuity was measured at four different contrast levels i.e. 90%, 50%, 25% and 10%. For full details of methodology and results please see Elton and Nicolle (2009).

The second experiment (n_2=14) measured the effect everyday cold temperatures had on the dexterous abilities of older adults (mean age=69.57, SD=3.756). Fine finger dexterity (ability to manipulate objects with the fingertip part of the hand), power grip (maximum grip strength a person can exert with their hand) and pinch grip (maximal force that can be exerted between the index finger and thumb pulps) were measured in the warm (19°C-24°C, an environment that keeps the body at an optimum point) and in the cold (a climatic chamber regulated at 5°C). The temperature for the cold environment was based on the average UK winter temperature and the temperature threshold used by the Met Office to issue a cold weather warning, which is 5°C. For full details on methodology, rationale and results please see Elton *et al* (2010).

Results

In experiment one (vision/ambient illumination) results showed that the mean readable letter size, across all contrast levels, generally decreases as the level of ambient illumination increases. Mean acuity scores, measured at a distance of one meter, are detailed in Table 2.

Table 2. 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

On average, participants could read letters 1.4mm smaller in daylight compared to street lighting. 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. When the lighting level changed from daylight to street lighting, there was a decrease of up to 44% in the number of participants able to correctly read particular rows of letters.

For experiment two (dexterity/cold), a reduction in mean fine finger dexterity was observed across a number of tests when in the cold environment. Results from the experiment are detailed in Table 3.

Table 3. Average dexterous performance in warm and cold environments

Dexterity Test	Warm (19°C – 24°C) Mean score and SD	Cold (5°C) Mean score and SD
Perdue Pegboard (no. of pins inserted)	Mean = 35.50 SD = 1.46	Mean = 33.14 SD = 1.02
Moberg Pickup Test (sec)	Mean = 13.79 SD = 2.21	Mean = 15.74 SD = 4.84
Mobile Phone (sec)	Mean = 13.35 SD = 4.28	Mean = 14.20 SD = 3.60

Mean performance on the Perdue Pegboard (picking up and placing as many pins as possible into holes on a pegboard in 30 seconds) was reduced by 7%, entering an 11 digit mobile phone number took on average 6% longer, and performance on the Moberg Pick-up test (picking up and placing 12 everyday items into a container as quickly as possible) took on average 14% longer in the cold. Results indicated that reductions in performance on the Perdue Pegboard and Moberg Pick-up test were significant ($p<0.05$) when participants were exposed to the cold (5°C).

Discussion

In reviewing and analysing the literature, it was possible to identify the key capabilities involved in the majority of product interactions (vision and dexterity) and the aspects of context of use that affect them. Factors associated with the physical environment, i.e. ambient lighting and temperature, were identified as aspects of context frequently experienced when interacting with products.

Whilst inclusive design capability data already exists for vision and dexterity, there is currently no data that takes into account the effects these aspects of context of use have on these capabilities.

Results from the two experiments have shown that contexts of use (i.e. ambient illumination and temperature) can have a significant effect on capability. For vision, the size of detail capable of being perceived/recognised can vary up to 1.9 mm in a typical day. Thus, detail on products that can be successfully perceived during the daytime may be illegible at night under street lighting, resulting in the user becoming excluded. In certain scenarios this could be up to 44% of the target population, as results from experiment one showed that the number of participants able to correctly read particular rows of letters decreased by this amount when the lighting conditions changed.

The results from experiment two suggest that fine finger dexterity is affected by everyday cold temperatures. On average, performance on such tasks was reduced between 6%-14%. This meant tasks either take substantially longer (e.g. entering a mobile phone number) or the same work rate is not possible (e.g. placing the same number of pins into a board) when in the cold at 5°C. In relation to product interaction it is likely that such tasks as using a mobile phone, pressing a sequence of buttons on a screen or keypad, using a stylus to interact with a touch screen, and picking up and placing small objects are likely to be affected.

Conclusion and future work

The aim of this research was to understand the extent to which everyday contexts of use can exclude people from using products in their daily lives, especially those who are older or disabled. This research has shown that everyday contextual factors such as ambient illumination and temperature levels can significantly reduce capability. Evidence presented in this paper suggests that failure to take account of the effects everyday contexts have on capability could result in the target population becoming unintentionally excluded, especially those already working to the limits of their ability. Thus, if design decisions are based on capability data only measured in a neutral environment, it could result in everyday products becoming unusable in everyday contexts of use. Further experimental work will be conducted to increase the reliability and validity of the dexterity cold temperature data. Following this, the data will be translated into a usable form for product designers.

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