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VISUALISING DESIGN EXCLUSION

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Abstract

'Design exclusion' arises when a product cannot be used effectively because of choices made during the design process. Understanding the causes of such design exclusion is essential if better products, which accommodate the widest range of user capabilities, are to be designed. This paper investigates the prevalence of multiple minor impairments among older users who are most vulnerable to design exclusion. Effective ways of representing these impairments are also discussed, with the aim of helping designers better understand user capabilities, and thus reduce design exclusion.

Keywords: databases, engineering diagrams, product data handling

1 Introduction

Studies show that by 2021, half the adult population in the UK will be over 50 [1] and that similar trends are observable elsewhere. Such ageing populations are known to exhibit an increasing divergence in physical capabilities [2], in general the population becomes less capable. At the same time, the products that we use everyday become ever more complex. Hence, when the demands made by such products exceed the capabilities of the user, then the user will find it difficult, or at worst impossible, to use the product, thus leading to exclusion. As populations age and capabilities fall, it becomes increasingly necessary for products to support a wider range of physical capabilities to avoid the risk of exclusion [3].

Legislation such as the UK 1995 Disability Discrimination Act [4], the US 1990 Americans with Disabilities Act [5] and Section 508 of the US 1998 Workforce Investment Act [6] also provide a case for designing for the widest possible population.

However, in spite of the need for more inclusive design practices, industry has been slow to adopt them. There are a number of reasons for this: a lack of awareness of the issue; a lack of motivation; and a lack of appropriate design methods. In order to understand this situation it is necessary to investigate the background behind the existing theories of designing for a wider population.

A number of design approaches exist that are targeted at specific population groups or impairment types. For example, Transgenerational Design [7] focuses on design for the elderly, while Rehabilitation Design [8] focuses on specific impairment types. They can also be targeted at specific cultures. For instance, Universal Design [9] dominates US and Japanese approaches to inclusive design, whereas Europe has tended to develop other methods, such as the User Pyramid Approach [10]. When combined, the existing approaches offer complete coverage of the population needs, where individually they do not.

Moreover, whilst all these methods have their merits, none attempt to define metrics for evaluating the effectiveness of the final product or to provide detailed information to assist the designer in reducing design exclusion. Consequently, a more integrated and practical method is required [11].

2 The Great Britain disability surveys

This section describes data, assembled by the UK government as a means of assessing future care-provision requirements in Great Britain, which may be adapted for product evaluation. These data include the Survey of Disability in Great Britain and the Disability Follow-up (DFS) to the 1996/97 Family Resources Survey (FRS).

The Survey of Disability in Great Britain [12] was carried out between 1985 and 1988. It aimed to provide up-to-date information about the number of disabled people in Britain with different levels of severity of functional impairment and their domestic circumstances. The purpose of the survey was to provide information to allow the planning of welfare benefits and services provision.

An innovative feature of the survey was the construction of an overall measure of severity of disability, based on a consensus of assessments of people acting as 'judges', including doctors, physiotherapists, occupational therapists, psychologists, UK Department of Health staff and representatives of disabled people. In essence, the severity of all thirteen types of disability is established and the three highest scores combined to give an overall score, from which people are allocated to one of ten overall severity categories.

The Disability Follow-up [13] to the 1996/97 Family Resources Survey [14] was designed primarily to update information collected by the earlier Survey of Disability in Great Britain and to provide data on entitlement to state benefits. The results showed that an estimated 8 582 200 adults in Great Britain – 20% of the adult population – had a disability according to the definition used (Figure 1).

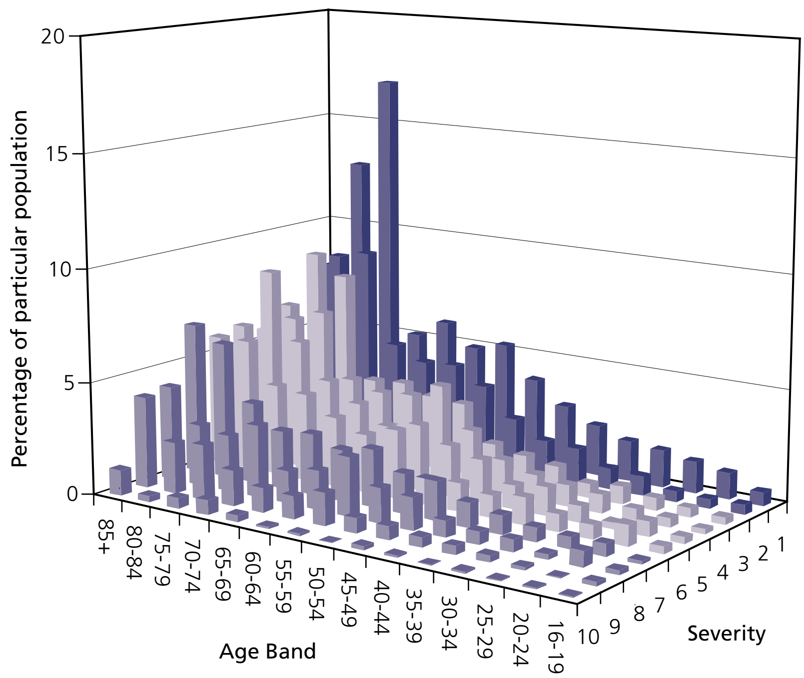

Figure 1. Distribution of disability for Great Britain

Of these 34% had mild levels of impairment (categories 1-2 – i.e. high capability), 45% had moderate impairment (categories 3-6 – i.e. medium capability) and 21% had severe impairment (categories 7-10 – i.e. low capability). It was also found that 48% of the disabled population were aged 65 or older and 29% were aged 75 years or more.

For the purposes of product assessment, 7 of the 13 separate capabilities used by the surveys are of particular relevance. These may be grouped into three overall categories:

- motion – *locomotion*, *reaching and stretching* and *dexterity*;
- sensory – *seeing* and *hearing*;
- cognitive – *communication* and *intellectual functioning*.

It should be noted that the scales were not defined with product assessment in mind. However, they can be successfully adapted to this task.

3 The prevalence of capability losses

A summary of the DFS data is presented in Figure 2 for the 16-49 years old and 75+ populations. Perhaps the most striking feature is the order of magnitude difference in the scales used for each figure. While the graphs have similar distributions, the percentage of those with a loss of capability in the 75+ age band is 10 times higher than for the 16-49 band.

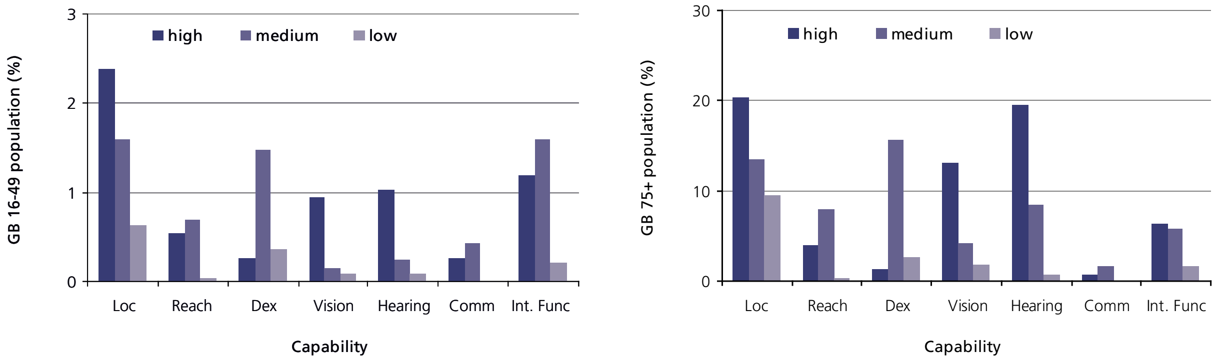

Figure 2. Capabilities for Great Britain 16-49 and 75+ populations

Further data is available for each individual capability loss. Examples are shown in Figure 3 for *dexterity* and *seeing*.

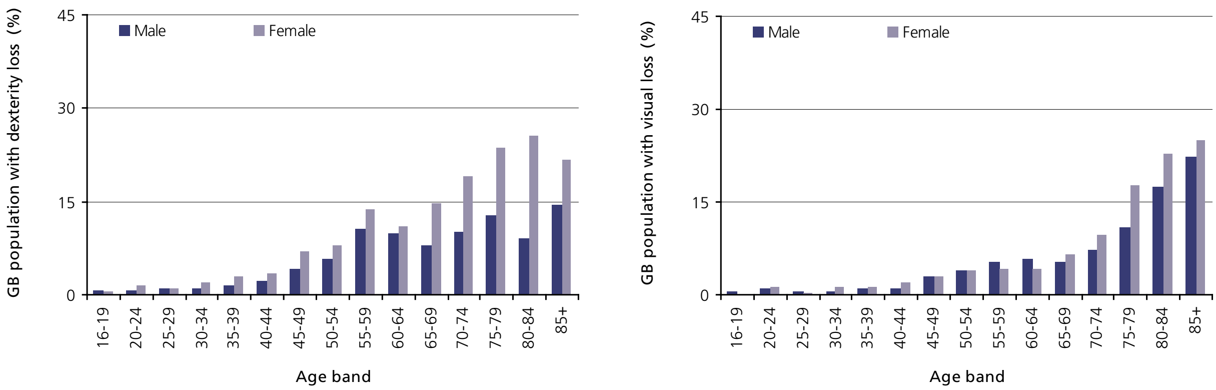

Figure 3. Dexterity and seeing capabilities for Great Britain 16+ population

Many people will, at some stage of their life, exhibit more than one capability loss. From a design perspective this is important since each loss has the potential to cause exclusion. Design improvement needs to address each capability loss if the full benefit of the improvements is to be realised.

The disability surveys provide valuable information for analysing multiple capability losses. For example, Table 1 summarises the data extracted from the Disability Follow-up Survey. It is evident that at least half of those with some loss of capability have more than one loss of capability.

Table 1. Multiple capability losses for GB

Loss of capability	Number of GB 16+ population	Percentage of GB 16+ population
Motion	6 710 000	14.3%
Sensory	3 979 000	8.5%
Cognitive	2 622 000	5.6%
Motion only	2 915 000	6.2%
Sensory only	771 000	1.6%
Cognitive only	431 000	0.9%
Motion and sensory only	1 819 000	3.9%
Sensory and cognitive only	213 000	0.5%
Cognitive and motion only	801 000	1.7%
Motion, sensory and cognitive	1 175 000	2.5%
Motion, sensory or cognitive	8 126 000	17.3%

4 Multiple capability losses

Clearly, some of those represented in the *dexterity* graph in Figure 3 are also represented in the *seeing* graph. It would be helpful if those with each capability loss could be represented on the same graph, highlighting those people with both losses. After much trial and error, experimenting with a variety of forms of histogram and charts, it was decided that a simple 'bubble' diagram would be the most effective way to show such data. Figure 4 shows such a diagram for *dexterity* and *seeing*.

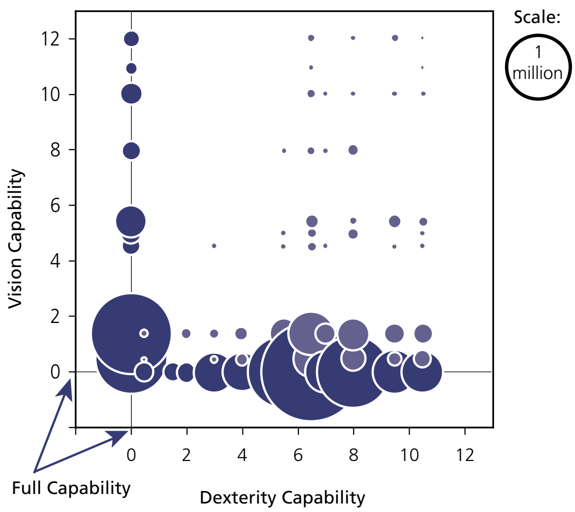

Figure 4. Multiple capability losses

The darker circles correspond to the percentage of people who exhibit either of the capability losses, but not both. Conversely, the lighter circles represent people showing losses in both capabilities. Figure 5 shows the same diagram accentuating areas of limited and significant coupling. These areas are crucial to identify if designers are to appreciate the independence, or otherwise, of users' capabilities. In the case of dexterity and vision the area of limited coupling suggests that these capabilities could be regarded as largely independent for the larger capability losses. However, small losses of vision capability are tightly coupled to losses of dexterity. This implies that design improvements to reduce dexterity demands must be accompanied by a reduction in vision demands (if not already reduced) if all users formally excluded due to dexterity are to be accommodated.

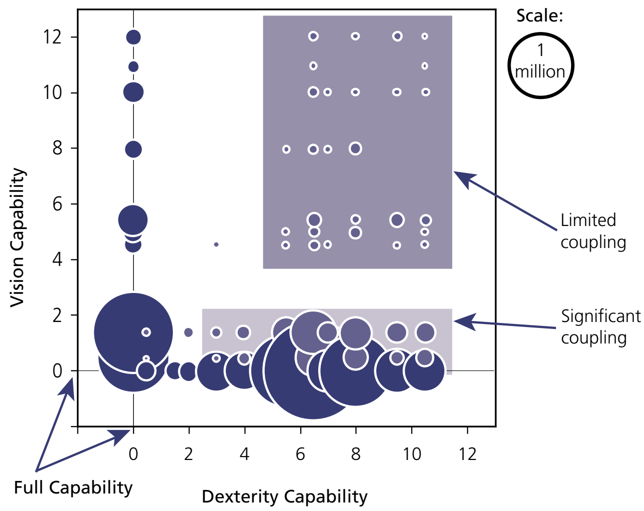

Figure 5. Multiple capability coupling

The 'bubble' diagrams provide a direct summary of capability distribution. They may be drawn at various levels, describing either *motion*, *sensory* and *cognitive* capabilities or any of the scales that make up these higher level descriptions. For example Figure 5 shows a set of graphs for these higher level capability losses.

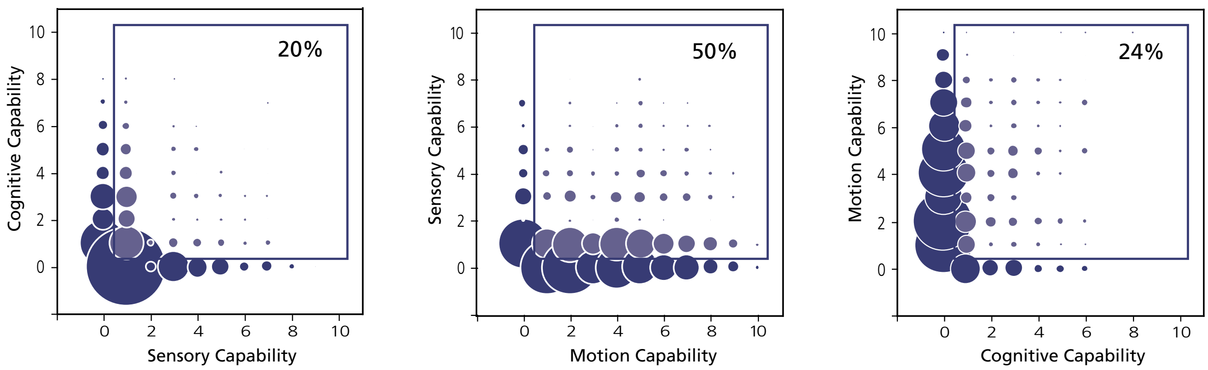

Figure 6. Multiple capability losses for GB 16+ population

The area of each circle represents a percentage of 16+ age band. The percentages of couplings between each pair of capability losses are shown on each plot. For example, it is evident that there is a high level of coupling (50% - represented by the circles inside the square) between motion and sensory capability losses. Of particular note is the fact that many people with some level of motion impairment also have minor sensory or cognitive impairments.

5 A Case study of design exclusion

Early kettles (A), such as the one shown in Figure 7, were made of metal and suspended over a hearth. They had a large handle, which doubled as the means of suspension, mounted above the body of the kettle. Such kettles required limited dexterity and were well balanced for carrying and pouring, but care had to be exercised when using them close to the open fire. The corded electric kettle (B) retained the shape and balance of the earlier models and removed the need for an open heat source, but had the disadvantage of the additional dexterity required to insert and remove the cord.

In contrast, the early plastic jug (corded) kettles (C), although lighter, introduced a new problem. The side-mounted handle changed the balance of the kettle, making it more difficult to use for those with limited upper-body strength. The more recent arrival of the traditional shaped cordless kettle (D) has partly resolved this issue although the overall weight of these metal kettles (plus the heating elements) remains a problem for users with limited strength.

A – early kettle | B – metal corded kettle | C – plastic jug corded kettle | D – traditional cordless kettle | E – stylish cordless kettle | F – no pour cordless kettle

Figure 7. A range of kettles

The increasingly diversified kettle design does not guarantee better inclusivity of the product. Kettles designed more to be fashionable and for social rather than practical acceptability (e.g. kettle E) may be prone to failing usability and accessibility testing. However, when designers are aware of the issue and address the problem explicitly, innovative solutions come as a result, such as the 'no-pour' concept kettle (F). The three cordless kettles (D, E and F) will be assessed in the following sections.

The first step of the assessment process is to state any assumptions regarding the environment in which the kettle is to be used and the sequence of actions encountered when using it. In this case, it will be assumed that the kettle will be positioned to suit the height and mobility of the user. The basic actions required would be: to pick up the kettle (or the jug of kettle F) from its base; carry it to the nearby water tap; fill the kettle with water; return it to its base; switch it on; and pour the boiling water into a cup.

The second step of the assessment requires the determination of the number of users excluded from using the products as a result of the mismatch between their capabilities and the functional demands made by the kettles. This is calculated by assessing the levels of each of the functional capabilities required to undertake the actions listed above.

Consider first the relatively heavy traditional cordless kettle (D). The handle makes it easy to carry, and the coloured switch button is big and obvious. It is possible to fill it with water through the broad spout without opening the lid, which is tight and hence may require two-handed operation.

When pouring water to a cup, the user needs to tilt the kettle to a steep angle with caution, as the broad spout is prone to spilling water. The inner water gauge is difficult to detect and the shiny chrome surface will easily be marked by water.

The 'fashionable' kettle (E) with its matte surface is more stain resistant. It is very well balanced when sitting on the base, but difficult to balance when being carried. The spout is narrow and pointed - good for pouring water into a cup, but not for filling water through. The user needs to open the stiff lid by using the very small knob.

The water gauge is hidden inside the kettle, hence the user needs to find it by looking into the dark interior through a small opening. Finally, the *black* on/off switch is positioned under the *black* handle and attached to the *black* base, which makes it hard to find. In addition, the filter demands high dexterity to remove and replace.

The novel kettle design (F) is a new solution that arose from the design team working with disabled users. The designers identified problems with the use of traditional kettles and identified the following priorities for an inclusive kettle:

- safety (heat of unit/boiling water);
- filling (spout size/location, water level, lid remove and replace);
- pouring (seeing cup, tipping, weight, secure grip, low strength);
- lifting (weight, accurate water level);
- base (stability, cable management);
- stigma (not for "the disabled").

The innovative solution is an aesthetically pleasing, light-weight, 'no-pour' kettle with a cool wall, audio alert, auto-retractable cable, and a water level indicator also marked in Braille. However, it is not yet on the market.

The assessment of the capability demands placed on the users by each of the kettles is shown in Table 2. The demands made by each kettle are assessed in terms of the user capabilities, as defined by the Disability Follow-up survey [13], required to use the product taking account of the complete cycle of use. The user capability demands are then translated into the number of people excluded from using the product by counting all those with lower capabilities.

Table 2. Comparing levels of exclusion

Capabilities	Kettle D (1.7 litre)		Kettle E (1.7 litre)		Kettle F (1 litre)	
	Minimum requirement	Total 16+ excluded	Minimum requirement	Total 16+ excluded	Minimum requirement	Total 16+ excluded
Locomotion	n/a	0	n/a	0	n/a	0
Reach and stretch	6.5	365 000	6.5	365 000	6.5	365 000
Dexterity	5.5	2 105 000	3.0	2 727 000	7.0	945 000
Vision	5.0	319 000	4.5	387 000	8.0	137 000
Hearing	n/a	0	n/a	0	n/a	0
Communication	n/a	0	n/a	0	n/a	0
Int. functioning	7.0	305 000	6.0	488 000	10.5	60 000

It is clear that the no-pour kettle (F) excludes fewer users that the other two designs and that the 'traditional' design (D) is better that the 'stylish' design (E). However, care must be exercised with these results. There may be double counting, where users have more than one capability loss. Table 3 shows the total number of users excluded from the GB 16+ population for kettles D, E and F. In all cases the total number of people excluded is less than the sum of those excluded by each individual capability loss.

Table 3. Total exclusion for the GB 16+ population

	Kettle D (1.7 litre)		Kettle E (1.7 litre)		Kettle F (1 litre)	
	(%)	(people)	(%)	(people)	(%)	(people)
Total excluded	10.6	2 506 000	13.7	3 234 000	5.2	1 229 000

Note the difference of over 0.7 million people in the exclusion figures for kettles D and E, two kettles that are readily available. In addition, kettle F has the potential to include at least 1.25 million new users, at least in theory.

6 Countering design exclusion

Assessing capability demands is only a part of a larger process required to counter design exclusion. There is a need for a range of tools and techniques to help designers and design managers with this task.

The inclusive design cube (Figure 8) was proposed to assist in the visualisation of the scale of exclusion and the resultant design task.

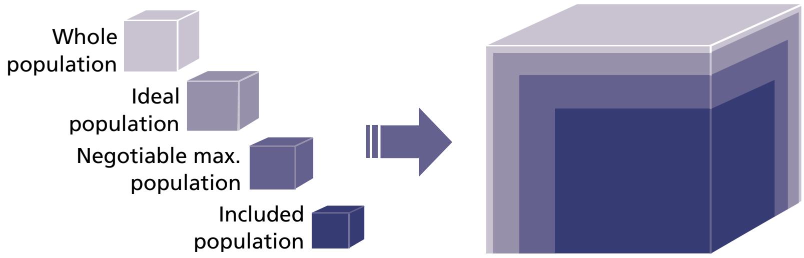

Figure 8. The inclusive design cube

The axes represent motion, sensory and cognitive capabilities. Hence, the cube conveys a sense of the overall level of exclusion and some indication as to its source. Exclusion is then best addressed by looking first at the sensory axis, followed by the cognitive axis and finally the motion axis.

The sensory axis addresses how the user perceives information from the product. This involves assessing the nature and adjustability of the output media used, their appropriateness for the required functionality, and the physical layout of the product and its interface.

The cognitive axis assesses the matching of the product behaviour to the user mental model. Once the output media (channels) are defined, the functionality (and content in the case of an information product) can be added to the product and evaluated. Cognitive walkthrough is a popular technique for mapping the product behaviour to that expected by the user.

The motion axis focuses on the user input to the product. This involves assessing the nature and adjustability of the input media, their appropriateness for the providing the necessary functionality, and the physical layout of the product.

Areas of design exclusion can also be superimposed on the bubble diagrams to assist the designer in identifying appropriate directions for product improvement. For example, there is significant coupling between vision and dexterity capability, which is pertinent to kettle design (Figure 9).

Polygons A and B combined together illustrate the exclusion of kettle E for vision and dexterity demands. Polygon B, on its own, illustrates the exclusion of kettle F for the same capability demands. Thus polygon A shows the difference between the exclusion of kettle E and that of kettle F, which corresponds to some 1 897 000 UK adults.

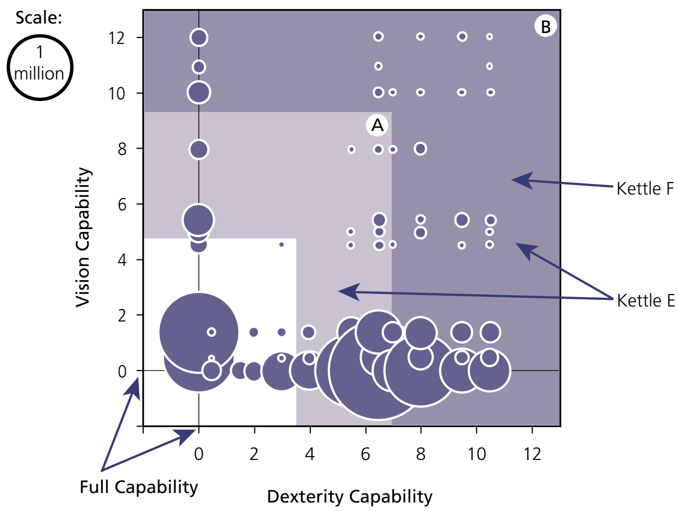

Figure 9. Multiple capability losses

It is obvious that if kettle E is to be improved to achieve the same level of inclusion as kettle F, both vision and dexterity demands need to be reduced simultaneously. The reduction of vision demand will only include those bubbles hugging the vision axis in Figure 9, but not those in the coupling region (off-axis). Such information is useful to designers, because when they improve products, it is important to know if the changes proposed will indeed include more users, or whether certain users will still be excluded for some other reason.

7 Conclusions

In exploring and visualising design exclusion, the *bubble* diagrams have a number of unique advantages:

- they can illustrate the design exclusion of an existing product/concept in a way that is clear and explicit;
- they can show regions of significant coupling and thus highlight the problem space for designers;
- they allow visualisation of potential improvements, thus helping design decision making.
- the patterns of combined capabilities can be applied to other sources of data for in-depth analysis to ensure that the best data set is always adopted for research in question.

However, while the *bubble* diagrams are effective at representing particular levels of exclusion for specific capability demands, there is a need to understand and clarify the mapping between product features and the resultant demands on the user. Further work will also include developing tools with potential users, with reference to other data sources and the users' interaction with products.

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