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Estimating Exclusion: A Tool to Help Designers

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Abstract

An exclusion audit assesses how inclusive a product or service is. This is useful for comparing designs and identifying points for improvement. In an exclusion audit, the designer or usability expert identifies the demands a product places on the user's capabilities and enters these into an exclusion calculator. This software then estimates the proportion of the adult British population who would be excluded from using the product because their capabilities do not meet these demands.

This paper describes research on improving the exclusion calculator based on a recent reanalysis of the calculator's underlying dataset. This enabled the capabilities to be broken down into more specific sub-categories or "demand types". An experiment investigated the use of these demand types in the context of an exclusion audit. It found that participants could determine the demand type of an action consistently, in the majority of cases. This approach was adopted in a redesign of the calculator, described in this paper.

Keywords

Inclusive Design, Design Tools, Exclusion

1. Introduction

In order to develop more inclusive products and services, it is important for designers to assess how inclusive existing products and new concepts are. This can help them to compare possible designs and identify how they could be improved.

Overview of the exclusion audit and exclusion calculator

An exclusion audit [10] is one way of doing this. It is based on the principle that an individual is excluded from using a product if their capabilities are less than the abilities demanded by the product, given the environmental context [7]. For example, a mobile telephone may have small buttons requiring a certain level of dexterity to operate. Someone with low dexterity capability might be unable to press the buttons accurately, particularly in cold weather, and thus be effectively excluded from using the phone.

The exclusion audit is supported by a piece of software called an exclusion calculator [2]. In this, the assessors input the levels of demand the product or service places on

some key user capabilities, including vision, thinking and dexterity. For example, they would enter the level of dexterity required to press the buttons on the mobile telephone, the level of vision needed to see the screen, and the other levels of capability required.

The calculator then compares these demands against a nationally representative database of people's capabilities. It determines whether each individual in the database would be able or unable to use the product based on their capabilities, and scales the results up to the population as a whole [11].

The database used for this purpose is the Office of National Statistics Disability Follow-up Survey (DFS) [4]. This survey was chosen as it is the best available single survey that covers the whole range of user capabilities [5]. However, research is currently underway to develop and conduct a national survey to gather capability data that is more suited to assessing product use [3]. In the meantime, the DFS data can provide a basis for exclusion calculations. Furthermore, it allows work to continue on developing the calculator as part of a research programme on how to improve exclusion calculations and better support inclusive design. The improved version of the calculator will use the data from the new survey when it becomes available.

Related work

There are many methods for assessing the inclusivity of products and services [c.f. 1]. Many involve users directly, by asking them about or observing their response to the products. This is extremely valuable in identifying the issues that real users have with products. However, the findings are based on a small proportion of the target users, so it can be difficult to understand their significance for the user population as a whole.

The exclusion audit is one of a group of methods, called analytical methods, that address this issue. In an analytical method, an expert (e.g. a designer or usability expert) analyses the product, taking into account a range of users. For example, in an exclusion audit, the expert explicitly considers the capabilities of people from across the whole user population and the impact these have on use of the product.

There are other analytic methods available, such as task analysis and heuristic evaluation. The exclusion audit differs from many of these by considering the whole range of diversity within the population, which is particularly important for inclusive design. It also directly relates the usability assessments to population figures, enabling the expert to prioritise problems according to how many people would be affected.

Another design approach that uses population data on capabilities is engineering anthropometrics [e.g. 8]. However, this is rarely accompanied by a systematic method of assessing a product and it separates out the various measurements, examining just one capability (or part of a capability) at a time. Anthropometric methods are therefore often unsuitable for predicting exclusion when several capabilities are used in combination to perform a task. For example, using a mobile telephone may require both vision and dexterity. The number of people who would be unable to use it cannot be determined from separate sources of vision and dexterity data, as these sources would not say how many people would have problems with both aspects [6].

The exclusion audit should be used in conjunction with user trials and an expert appraisal of the product. This combination benefits from input from real users, as well as using data from the whole population and advice from experts. In particular, the

exclusion audit provides a population perspective, and helps to prioritise issues based on their significance within the population of interest [7].

2. Development of the exclusion calculator

The first version of the calculator

As mentioned above, the exclusion calculator is based on data from the Disability Follow-up Survey (DFS) [4]. Participants in this survey were asked up to 300 questions about their ability to perform a range of everyday tasks, such as reading newspaper print and picking up a safety pin. Their answers were then grouped into 13 ability categories, 7 of which are most relevant for product design: 'seeing', 'hearing', 'intellectual function', 'communication', 'locomotion', 'reach & stretch', and 'dexterity'.

The aim of the survey was to help plan welfare support. Therefore, participants' capabilities were given "severity scores" indicating how much they would impair their quality of life. For example, a participant received a high severity score for vision if the vision activities they could not perform were likely to seriously impact their quality of life.

The first version of the exclusion calculator and audit [6, 10] used these severity scores as indicators of participants' capabilities. For example, a participant's vision capability was represented by their vision severity score from the survey. A high severity score corresponded to a low capability.

Reanalysis of the survey data

These severity scores give an approximation of the participants' capabilities. However, they are not a very accurate indicator of capability as relates to product use as they are really meant for determining the impact of capability on quality of life [11]. More accurate information on what the participants could and could not do is available in the underlying survey data. This data is publically available, but was not used originally because it did not contain complete sets of answers for all the participants. This is because most of the participants were not asked all the questions in the survey.

The dataset was therefore examined in more detail and it was determined that complete sets of answers could be reconstructed by following through the control logic of the original survey [12]. In most cases, when the survey omitted to ask a participant a question, this was because the survey designers thought the answer was obvious based on the participant's previous responses. For example, if a participant had previously said that they could not walk at all, the control logic of the survey meant they were not asked the question "can you walk one step?" because the answer was obviously "no".

By reconstructing all this data, a full database could be produced with answers to all the relevant questions for all 7168 participants. These answers could then be organised to produce a different set of scales that are more relevant to product assessment than the severity scales. In particular, these scales can break down the ability scales used in the first version of the exclusion calculator into more specific sub-scales. For example, the underlying survey data contained information on whether participants could perform a variety of fine finger manipulation and grasping tasks. Therefore, scales for fine finger manipulation and grasping could be constructed. These formed sub-scales of the

dexterity scale. In this paper, sub-scales are also called “demand types” because they describe more specifically the type of a demand placed by a product.

It was possible to produce sub-scales of this type for five of the seven ability scales. However, the underlying data for ‘intellectual function’ and ‘communication’ was unsuitable for constructing ordered demand scales because the data for these abilities did not contain clear sets of tasks of increasing difficulty [12]. Instead, the reanalysis enabled the identification of the participants who could not do particular ‘thinking’ (‘intellectual function’ and ‘communication’) tasks. As a result, instead of rating the level of ‘thinking’ ability required to use a product, assessors were asked to identify which of the set of standard ‘thinking’ tasks were involved in using that product. This included tasks such as “Think clearly, without muddling thoughts”, “Tell the time of day, without any confusion” and “Read a short newspaper article”.

Experiment

An experiment was conducted to investigate the potential of dividing the capabilities into sub-categories or “demand types” as described above. The ‘thinking’ capability was not examined because its data was structured differently. In the experiment, participants were given various vision and dexterity tasks and were asked to determine what type of demand they placed on the user. More details on the experiment are given in Section 3.

No exclusion calculations were actually performed in the experiment, so the choice of demand types was based on what could hypothetically be achieved with the dataset rather than what calculations could be performed with the calculator at that time.

The results from the experiment indicated that participants were happy doing the categorisation and that they tended to agree on the demand types chosen (see Section 3 for more details). However, the assessment of dexterity did cause some confusion and misunderstanding. This assessment involved assessing the actions of each hand separately and saying whether the left and right hands’ actions could be interchanged, as well as choosing between two dexterity demand types.

New version of the calculator

The new set of capabilities and demand types was implemented in the 2009 version of the exclusion calculator. However, the implemented version of dexterity was simpler than that used in the experiment. The implementation assumes that both hands do the same thing, at the same level of demand. This was because allowing the left and right hands to do different things, and allowing these left and right hands’ actions to be interchanged, creates significant complexity for calculating the exclusion figures. The experiment also found that it caused the assessors confusion. The 2009 version of the calculator is described in detail in Section 4.

Further work

Further work involves developing the dexterity calculations so that the calculator can cope with tasks that involve the left and right hand doing different things. The interface for this also needs to be developed so that it does not confuse the assessors.








3. Experiment

The experiment examined the division of capabilities into demand types. In particular, it investigated whether participants are able to consistently determine the demand type of a given task, within the context of an exclusion audit. Forty people took part in the experiment, 20 men and 20 women, aged between 20 and 60 (mean 34.5).

This study was part of a larger experiment comparing different methods for rating product demands. Due to lack of space and the focus of this paper, this is not reported here.

Experiment materials

The participants were asked to determine the demand types involved in using two products. For each product, they were asked to examine the tasks involved in achieving a specific goal: recharging batteries using the battery charger, and calling the speaking clock using the telephone.

Tasks	Pick up receiver	Dial speaking clock
 Vision	See handset <input type="text"/> <input type="text"/>	Read number of speaking clock <input type="text"/>
 Hearing	Hear dial tone	
 Dexterity	One hand: Grasp and lift the handset <input type="text"/> <input type="text"/> ----- Other hand: Nothing <input type="text"/> ----- Left  ↔  Right Interchangeable? <input type="button" value="Yes"/> <input type="button" value="No"/>	One hand: Grasp and lift the handset <input type="text"/> <input type="text"/> ----- Other hand: Nothing <input type="text"/> ----- Left  ↔  Right Interchangeable? <input type="button" value="Yes"/> <input type="button" value="No"/>

For each product, they were given a worksheet (see Figure 1). The tasks involved in the goal are listed along the top, and the capabilities down the side. The column for a task indicates which capabilities are involved in that task. E.g., the task “Pick up receiver” involves seeing the handset (Vision), hearing the dial tone (Hearing), and grasping and lifting the handset (Dexterity), among other actions.

The figure shows a close-up of the Dexterity assessment. Participants were asked to examine what the left and right hands had to do separately, and whether the hands could be interchanged.

Figure 1: Part of the worksheet used in the experiment.

Participants were also given booklets listing the possible demand types for each capability, and describing the method to be used for rating the demands.

Experiment procedure

After obtaining participants' consent, the experimenter showed them a DVD that explained the exclusion audit method and described an example assessment. The participants were then provided with the materials for the example in the DVD so that they could practice if desired.

Participants were then asked to assess the two products. Half of them assessed the charger first, and half assessed the telephone first. For each assessment, they were given a worksheet, as described above. They were asked to determine the demand types and rate the demand levels involved in the vision and dexterity actions. They examined only vision and dexterity to keep the length of the experiment down and because these capabilities are the most relevant for product interaction.

After assessing both products, participants completed a short questionnaire about themselves and what they thought of the method.

Preliminary considerations for analysis

As mentioned above, this study was part of a larger experiment comparing different methods for rating product demands. Half of the participants used one method and half used another. However, Chi-squared tests indicated that there were no significant relationships between the method used for rating demands and the demand types selected. Hence, the data from all the participants could be combined for analysing the demand types selected.

In addition, there were two sets of actions where some of the actions were simply to "keep doing" something. For example, the first dexterity action for the telephone was "Grasp and lift the handset" while the second, third and fourth were "Keep holding handset". In almost all cases, the participants' choice of demand type for the "keep doing" actions was the same as their choice for the initial action.

This implies that the "keep doing" assessments were not really distinct assessments, but merely repetitions of the initial assessment. Leaving them in the dataset would give undue weight to the findings from these particular assessments and thus skew the results. Therefore, the "keep doing" actions were removed from the results for the remainder of the analysis. The initial actions in each set (e.g. "grasp and lift handset") were kept in. This left 19 actions: seven Vision and five Dexterity actions for the assessment of the charger, and four Vision and three Dexterity actions for the phone.

Results

For each action, participants were asked to choose one of three options for the demand type, as shown in Table 1.

Table 1. Possible options for demand types in the experiment

	Vision	Dexterity
Option 1	Reading text at various sizes	Picking up and carrying objects
Option 2	Recognising a friend at various distances	Performing fine-finger manipulation
Option 3	Both	Both

In order to determine how the participants' judgments compared to chance, we compared this situation to a hypothetical random situation, where each of the 40 participants randomly selected one of these three options. In this hypothetical situation, a cumulative binomial calculation indicates that the probability of 21 or more participants agreeing on the option is less than 5%. So a judgment was considered to be consistent if 21 or more participants agreed on the option.

Based on this criteria, 17 of the 19 actions were categorised consistently. The remaining two were "feel charger is plugged in correctly" and "pick up one battery".

Discussion

The results should be viewed as indicative rather than definitive because participants only carried out a small number of relatively simple assessments. There may be other kinds of demand types or products that they would have found more or less difficult.

Nonetheless, the study provides a promising indication that assessors should be able to specify the capabilities involved in an action more specifically, before going on to assess the levels of ability needed to do that action.

4. Redesign of the exclusion calculator

The exclusion calculator was redesigned to use the new set of demand types. This section describes the interface of the new version of the calculator and explains how it can be used to help perform an exclusion audit. The calculator itself is freely available from the Inclusive Design Toolkit website [2].

The first part of an exclusion audit is to identify the product and goal that will be assessed, as well as any assumptions about the context of use. For example, an assessor may decide to examine the goal of making a telephone call on a landline telephone. Assumptions may include good lighting and a quiet environment.

The assessor then breaks down this goal into a sequence of tasks. For example, making a telephone call could be divided into: pick up the receiver, dial the number, speak to the recipient, and replace the receiver.

Each task is then assessed separately, by entering the level of demand that task places on various user capabilities: Vision, Hearing, Thinking, Dexterity, Reach & Stretch and Locomotion.

Once the assessor has selected a capability, he or she is presented with the possible demand types for that capability and is asked to indicate which one(s) are involved in the task. As in the experiment, the demand types for Vision are "Reading text at various sizes" and "Recognising a friend at various distances" (see Table 1). The demand types for Dexterity are shown in Figure 2 on the next page.

Rather than asking the assessor to examine the left and right hand separately (as in the experiment), the calculator presents separate sub-categories for doing things with one hand or with both hands at the same time (see Figure 2). For example, picking up the receiver has the demand type "picking up and carrying objects with either the left or right hand" as only one hand is needed. This was done to simplify the exclusion calculation and reduce confusion for the assessors (see Section 2).

For each demand type, the calculator then asks the assessor to judge whether the task being assessed is harder, easier or about the same as a set of standardised tasks of that type. For example, for “Picking up and carrying objects”, the task is compared to picking up a mug, a pint of milk and a bag of potatoes (Figure 3). In the example, an assessor might rate picking up a telephone receiver as of comparable difficulty to picking up a mug, as in Figure 3.

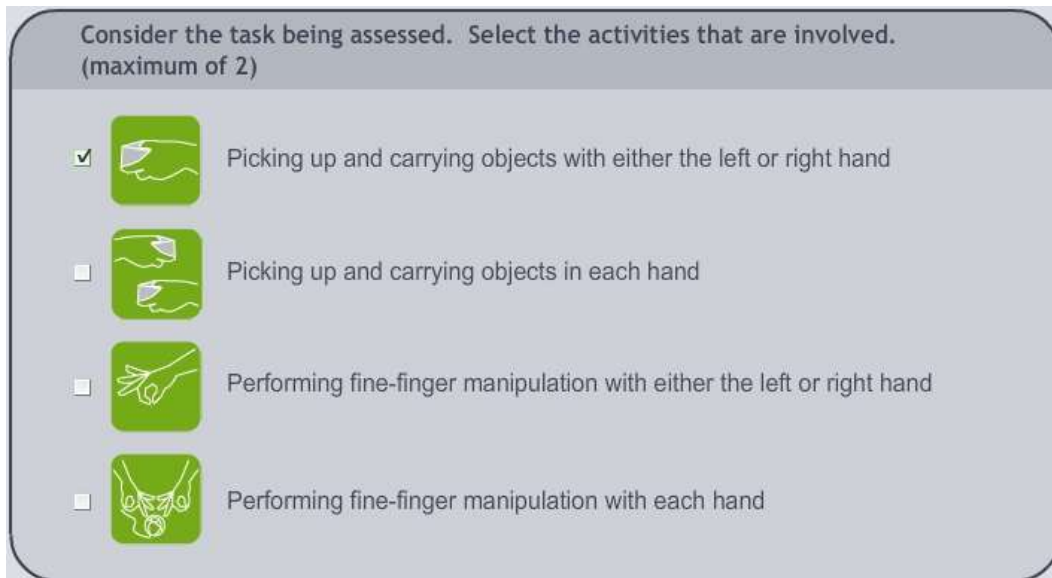


Figure 2. Close-up of the calculator screen for selecting the types of activities involved in a dexterity task

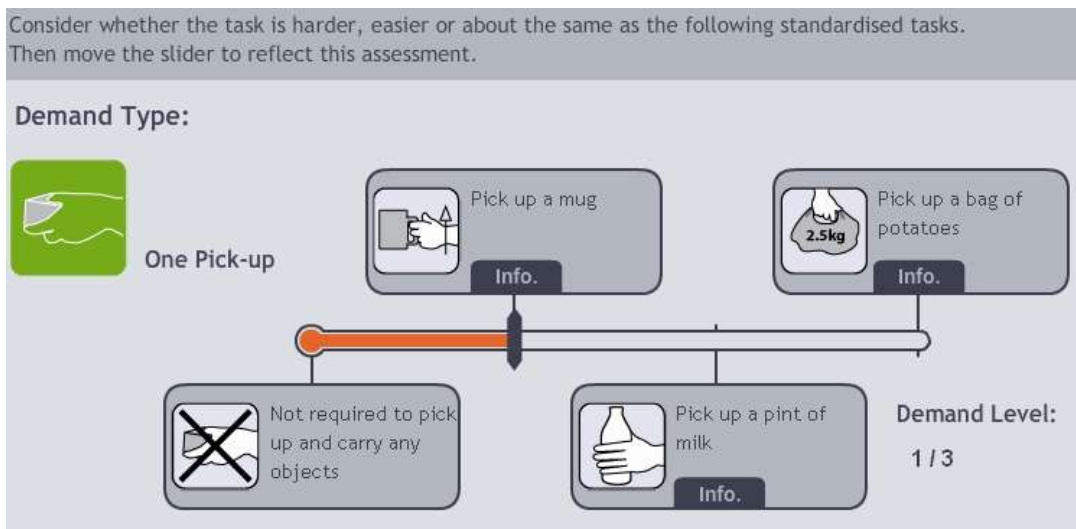


Figure 3. Close-up of the calculator screen for setting the level of demand for a dexterity task of type “Picking up and carrying objects with either the left or right hand”

A similar assessment can be performed for the other capabilities, except for Thinking. The thinking demands are assessed differently as described in Section 2. Rather than rating the level of thinking demand on scales, the assessor chooses from a list of standardised thinking tasks, such as “Think clearly, without muddling thoughts”, “Tell the

time of day, without any confusion” and “Read a short newspaper article”. The assessor selects the tasks that best match what the user needs to do in order to complete the task. For example, entering a phone number involves “thinking clearly, without muddling thoughts” and “doing something without forgetting what the task was in the middle of it”.

Once the levels have all been set, the assessor clicks “Calculate exclusion” to estimate the numbers and proportion of the British population excluded by that set of demands. The results are displayed in graphs as shown in Figure 4. A table of results is also available. The pie chart on the left shows the number of British adults excluded from the task overall and bar graph in the middle indicates the number excluded on the basis of each capability individually. The graph on the right shows how much the exclusion would be reduced if the demand on one capability was eliminated. The first bar shows the reduction if the vision demand was eliminated, the second shows the reduction if the hearing demand was eliminated, and so on.

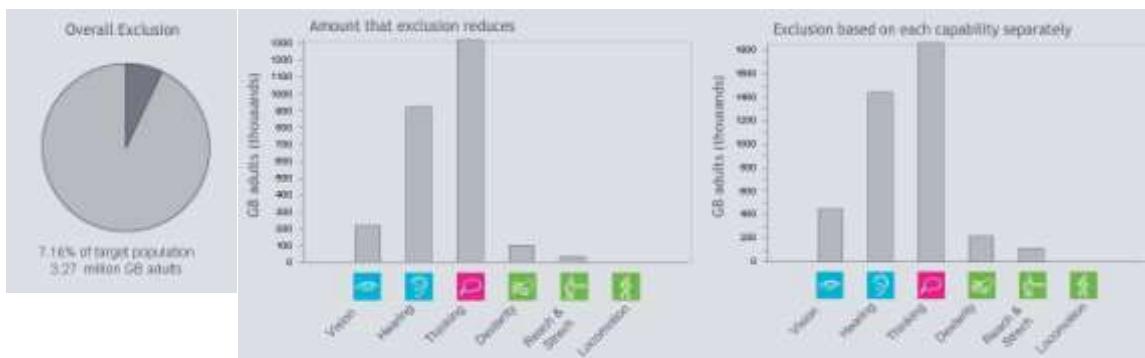


Figure 4. Results of the exclusion calculation

For example, if the dexterity demand of picking up the receiver was removed but the other demands were kept as they were, then about 1,300,000 further adults would be included. This is less than the number (about 1,800,000) excluded on the basis of dexterity, as some of those excluded by dexterity are also excluded by other demands. This information can help to identify where there is the most scope for improving the inclusivity of a product. It can also be used to examine how the inclusivity would be affected by potential design changes.

The exclusion calculator estimates the exclusion caused by a single task, such as entering a phone number. The exclusion involved in an entire task sequence, such as making a phone call, can also be calculated. This can usually be done by using the same exclusion calculator and setting the demand for each capability to the maximum demand for that capability over the whole set of tasks, as described in [9].

5. Conclusions and Further Work

The exclusion calculator assesses how inclusive a product or service is, by estimating the proportion of the adult British population who would be excluded from its use. A reanalysis of the underlying data allowed the software to be redesigned so that assessors first determine the types of demands involved in an action more specifically.

This simplifies the following step in the audit process where assessors rate the level of demand that action places on a capability.

The experiment described in this paper showed that participants could determine the demand type of an action consistently, for almost all the actions examined in the experiment. This indicates that this is a promising path for the development of the calculator.

Further work will develop the dexterity calculations so that the calculator can cope with tasks that involve the left and right hand doing different things. In addition, research is currently underway to develop and conduct a national survey to gather capability data that is more suited to assessing product use. The calculator and audit method will be further developed to use the data from this survey when it becomes available.

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