

Evaluating inclusivity using quantitative personas

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Exclusion assessment is a powerful method for assessing inclusivity in a quantitative way. However, its focus on capability data makes it difficult to consider the effect of other factors such as different ways of using a product. We propose addressing this by combining exclusion assessment with quantitative personas. Each persona represents a group of people with similar capabilities, and is enhanced with other personal information. The capabilities of each persona are compared against the product demands to assess whether they (and thus the group they represent) could do a task. The additional persona information helps to determine how they approach and conduct the task. By examining personas that cover the whole of the target population, it is possible to estimate the proportion of that population who could complete the task. We present a proof-of-concept study using personas created from Disability Follow-up Survey data. These were used to assess the task of carrying a tray of food across a cafe, taking into account how using mobility aids restricts hand use.

Inclusive design; exclusion assessment; persona; assistive technology

1. Introduction

The British Standards Institute (2005) defines inclusive design as “the design of mainstream products and/or services that are accessible to, and usable by, people with the widest range of abilities within the widest range of situations without the need for special adaptation or design” (p. 4). To achieve this, it is important to understand the range of capabilities, needs and situations in the population as a whole.

It is also useful to assess how a product or service measures up to this definition, determining how many and what kinds of people it is usable by (and conversely, how many people are unable to use it). This can help to identify the need for further work and to prioritise issues. It can also be a powerful tool in convincing designers and managers that they need to make improvements to products (Goodman-Deane, Waller, Bradley, Bradley and Clarkson, 2018).



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Exclusion assessment aims to achieve this. This method uses population data on users' capabilities to estimate how many of them would be unable to complete the series of tasks needed to use a product or service effectively. However, the focus on capability data can make it difficult to consider the effect of other factors affecting product use, such as different user goals, needs, ways of using a product and use scenarios. All of these vary from person to person based on more than their capabilities.

In this paper, we propose a method of combining exclusion audits with personas to facilitate the consideration of factors like these.

1.1. Exclusion assessment

Exclusion assessment is based on the idea that product interactions place demands on users' capabilities. Users may be excluded from using a product if any of its demands are higher than their capabilities. For example, a product with very small text requires a high level of vision capability. People with lower vision capability will be excluded from its use.

The method uses data on people's capabilities on a population level. The standard method uses data from the 1996/97 Disability Follow-up Survey, conducted by the Office of National Statistics (Grundy & Great Britain Department of Social Security, 1999). Although the data is now rather old, it is still the best source of coherent population-level data covering a range of capabilities and different levels of capability loss (Waller, Langdon & Clarkson, 2010). Using this dataset allows the method to take into account a range of capabilities and to account correctly for people with more than one type of capability loss.

The exclusion assessment method (Waller, Langdon & Clarkson, 2010; Cambridge Engineering Design Centre, 2017b) involves first breaking down the use of the product or service into a series of tasks, using task analysis. For each task, the assessors examine each capability in turn, determining what level of that capability is needed to complete the task. This is rated on a scale for that capability, which is based on the measurement scales in the Disability Follow-up Survey. These demand ratings are then compared with the capability of the people in the survey sample to determine how many of them would not be able to complete the task. As the survey is population-representative, this can be used to calculate how many people in the British population as a whole (in 1997) would not be able to complete the task. By doing this for all the tasks in the task sequence, it is possible to estimate how many people would be unable to use the product or service. The Exclusion calculator software (Cambridge Engineering Design Centre, 2017) helps to facilitate this process and performs the underlying calculations.

Exclusion assessment has been used successfully in both research and commercial contexts, along with other methods, such as user trials (e.g. Clarkson, Cardoso & Hosking, 2007). They can be useful in identifying usability issues and potential improvements (Goodman-Deane, Ward, Hosking & Clarkson, 2014).

However, exclusion assessment is typically only used for one task analysis at a time. It *can* be used when there is more than one way of using a product to achieve a single goal (Waller, Bradley, Langdon & Clarkson, 2013) but this gets increasingly complicated with increasing numbers of alternatives. It is also difficult to take into account other user information (not about capabilities) that may also affect how people use a product.

In this paper, we propose a way of combining exclusion assessment with quantitative personas to overcome some of these issues.

1.2. Personas

Cooper (1999) defined the first model of the personas tool. He described personas as fictional profiles of users that represent the patterns found in qualitative research. In the years since, personas have been developed and used in different ways. They have been shown to be effective in

focusing the design process on user needs and goals and in improving communication among the design team (Miaskiewicz & Kozar, 2011; Grudin & Pruitt, 2002). Personas allow the incorporation of a wide variety of different kinds of information about users, including capability data and information about lifestyle and social networks. However, there is little consensus over exactly what kinds of information should be included (González-de-Heredia, Justel, Iriarte & Beitia, 2017).

Personas have the potential to be particularly effective in inclusive design because of their power to help designers to think about users who may be very different to themselves. However, few persona sets consider the capabilities and/or the aging process of the personas. These are discussed below.

The Designing with People website (Helen Hamlyn Centre for Design, undated) provides ten profiles that represent people with disabilities. These profiles include information such as: name, age, medical condition, assistive aids, things that they can and cannot do, a typical day, the five most “important” things in their life, and a message they want to give to designers. They differ from typical personas in that they describe real individuals. They were chosen “to represent a spectrum of capability across the UK population”. The stated goal of this project was “to give the designer a more holistic portrait of the individual than can be supplied by reading capability data alone”. As such, this shows the potential of personas to include a wider range of information, but the profiles are not suitable for quantitative evaluation because the set of personas does not attempt to cover the entire population. In addition, there is no information given on how many people each profile represents.

Another set of profiles is provided by TACSI, The Australian Centre for Social Innovation (Burkett & Jones, 2016). As with the Designing With People set, these are descriptions of real users rather than fictional. They were based on interviews with “a diversity of baby boomers” seeking to understand “how they see this idea of ‘ageing well’” (p. 1). Burkett and Jones (2016) describe ageing as a systemic event not a personal event. As a result, the profiles include information on aspects such as: family, housing, income, social network, vulnerability factors, major life events and resilience factors. The descriptions are qualitative and aim to give the designer a holistic view of the person’s background and situation. These personas do not include detailed information on capabilities and so are not suitable for assessing usability.

In contrast, the descriptions proposed by Reeder, Zaslavsky, Wilamowska, Demirir and Thompson (2011) are personas in the more usual sense of the term. They are fictional descriptions with a quantitative basis. They were produced using cluster analysis of data from a small study of people aged 85 and over. The personas include information on age, education, health conditions, experience with computers and social support. They also contain ratings of general health, functional status and cognition. However, the rating scales used are not specific enough to facilitate product assessment. For example, the cognitive status of the personas is described as “minor cognitive changes” and “moderate cognitive changes”. This set of personas was focused only on the “oldest old” segment of the population and thus only included two personas.

Wöckl et al. (2016) created a larger set of thirty personas to represent the diversity among older people in Europe. These personas were created from a survey data of 12,500 older people in different European countries using partitional clustering. They include a wide range of information including general health, limitations in Activities of Daily Living, economic situation, social activities, psychological well-being and a range of capabilities. The capabilities include hearing, eyesight, cognitive function and memory. However, like the personas in Reeder et al. (2011), the scales used to describe capabilities are not specific enough for product assessment. For example, eyesight is described as “good, less than good, glasses, cataract”. In addition, most of these capabilities were not included in the initial cluster analysis which means that it is unclear how well they represent the cluster as a whole.

The most similar system to that proposed in this paper is HADRIAN (Marshall et al., 2010), which uses descriptions of 100 real people. Unlike the previous examples, these profiles include detailed data on capabilities, as well as preferences and experience with a range of daily activities. Indeed,

the aim of HADRIAN is to assess exclusion and identify problems and solutions. When assessing a task, each of the individuals in the database is run through the task in turn to determine whether or not they would be excluded by it. However, the set of people is "clearly not representative of the more general population" (Marshall et al., 2010, p. 258). Indeed, the authors explain that there was a "deliberate decision to skew the data towards the older and disabled" (p. 258). This makes it difficult to determine how many people these problems would affect in the population as a whole. More recent work on HADRIAN has investigated correlating the capabilities of the individuals in the database with data on the population as a whole from the Disability Follow-up Survey (Marshall et al, 2016). This provides some useful insight but currently only considers one capability type at a time

2. Proposal

We propose using personas to evaluate how many people will be able to use a product or service. To do this, the personas need to have certain characteristics, each of which is discussed in more detail below:

- **Appropriate information content:** The personas need to include the right type of information to determine whether each persona would be able to use the product;
- **Quantitative basis:** We need to know approximately how many people are represented by each persona;
- **Representativeness:** Each persona needs to represent a group of people in the population with sufficient accuracy for the assessment.

Once suitable personas have been created, they can be used to evaluate a task by stepping through the task for each persona in turn. This is described further in Section 2.4.

2.1 Appropriate information content

The personas need to include the right type of information to determine whether each persona would be able to use the product. Typically this means determining whether they could carry out particular task steps with the product. The information required may be different from the kind of information that is useful for building empathy and impact. For example, giving each persona a name is vitally important for persuading designers to engage them. However, it is not useful for determining if that persona can use a product.

To determine if a persona can use a product, we use the model in an exclusion audit (see Section 1.1), where a person is excluded from using a product if any of the product's demands are higher than their capabilities. Therefore, assessing if a persona can use a product requires information on the persona's capabilities. Exactly which capabilities are relevant will depend on the type of product being assessed. Which capabilities can be used will also be limited by the datasets available.

An advantage of using personas to do the assessment is that multiple kinds of information can be included in them. As well as user capabilities, there are other factors that also influence product use, such as the social context and prior experience. It may be useful to include some of these in the personas.

2.2 Quantitative basis

In order to evaluate how many people will be able to use a product or service, it is necessary to know approximately how many people in a selected user population are represented by each persona. To do this, the personas must be based on quantitative data about the target population.

Once a dataset is chosen, a statistical method such as factor analysis or cluster analysis can be applied to identify groups in that dataset that can form the basis of personas. An example using cluster analysis is given in Section 3.3.

2.3 Representativeness

Each persona needs to represent a group of people in the population with sufficient accuracy for the assessment. It needs to be close enough to all the members of the group that it is possible to say with some certainty that if the persona can use the product, then the members of the group will be able to as well.

There is a trade-off between the number of the personas and their accuracy. The smaller the groups, the more similar their members are to each other, and the more representative their personas can be. However, smaller groups also mean more groups. If the number of groups and personas is too large, then doing an assessment using them becomes unmanageable.

It is important to note that the ideal number of personas for doing an assessment is very different from the ideal number to use throughout the design process. For example, Cooper (1999) recommended creating between three and twelve personas, and Pruitt and Grudin (2002) suggested between three and six. When using personas throughout the design process, the set needs to be small enough for the design team to keep the whole set in mind. However, this is not necessary for an assessment where a bigger concern is how representative the set of personas is.

When performing an assessment, there is no need to keep the whole set of personas in mind. A designer can work through the assessment for each persona at a time. Therefore, a much larger set is feasible. However, it is still possible for the set to become so large that the method becomes unwieldy and frustrating. We estimate that more than 50 personas would be difficult.

2.4 Using the personas for evaluation

Once suitable personas have been created, they can be used to evaluate a task. This can be done by stepping through the task for each persona in turn. For each, the evaluation looks at the ways that persona would be likely to attempt the task. The persona's capabilities are then compared with the demands of the task steps to determine whether they would be able to complete them. Other information can also be taken into consideration such as the use of mobility aids. This process is described in more detail using an example in Section 3.5.

If a persona cannot complete the task, then it can be assumed that the group he or she represents cannot complete it either. By examining a range of personas that cover the whole of the target population, it is possible to gain an estimate of the proportion of that population who could not complete the task, and thus an estimate of population-level exclusion.

This information can then be used by a design team to identify the particular tasks involved in using a product or service that cause the most exclusion. It can also help to identify why those tasks are particularly problematic, and thus help to develop ways to improve the product or service and reduce exclusion. An example of how exclusion calculations can be used in this manner is given in Goodman-Deane et al (2014).

3. Proof-of-concept

This section presents a proof-of-concept study, based on the analysis in Demin (2009). It demonstrates how a set of quantitative personas for evaluation could be created, using cluster analysis on the data from the Disability Follow-up Survey. Some of the personas are then used to assess a task in Section 3.5. In a full study, the task would be analysed for all the personas in the set. However, just a few examples are shown here as a proof-of-concept.

3.1. Information content

The personas were based on data about user capabilities so that they could be used for assessing product use. The study used a subset of the capabilities typically used in an exclusion audit: vision, hearing, dexterity, reach & stretch and locomotion. It omitted the scales for thinking and

communication because they were less relevant to the particular products being assessed and because of a lack of transparency in these scales.

Note that this analysis uses earlier versions of the scales than are currently used in the exclusion calculator software (Cambridge Engineering Design Centre, 2017). Each capability was described using more than one subscale. For example, locomotion included walking, managing stairs, bending and balancing. There were sixteen separate subscales in total, each scored 1 (low ability), 2, 3 or 4 (full ability).

Once the personas were constructed, additional information was added to round out the personas as described in Section 3.4.

3.2. Data set

The personas were constructed using data from the 1996/97 Disability Follow-up Survey, for compatibility with the exclusion assessment method (Waller, Langdon & Clarkson, 2010). The method and survey are described in more detail in Section 1.1.

The full dataset contained 7,168 people. The study in this paper was conducted as part of an assessment of assistive equipment. Therefore, sift criteria were applied to the dataset to identify just those individuals who were on the borderline of being eligible for the provision of assistive equipment. To be included, participants had to have a capability loss in the range in Table 1 for at least one capability. This indicated a level of capability loss that might make assistive technology helpful. They were excluded if they had a higher rating for any capability, indicating that their capability loss was sufficiently severe that they would automatically receive help. The particular boundaries were chosen based on the requirements for different kinds of disability assistance.

Table 1 Summary of sift criteria. The severity of capability loss had to sit between the lower and upper thresholds for at least one capability.

Capability	Lower threshold (inclusive)	Upper threshold (inclusive)
Vision	4.5	5.5
Hearing	2	5.5
Dexterity	3	7
Reach and Stretch	3.5	5.5
Locomotion	3	5.5

Application of these sift criteria identified 2,225 people within the dataset who were borderline for assistive equipment provision.

3.3. Clustering

K means cluster analysis was used to identify and group individuals in the dataset based on their type and level of capability loss. This method was chosen due to its simplicity and speed for running on a large dataset.

When a set number of clusters is entered, this method creates that number of clusters from the data. The data was initially explored by inputting various numbers of clusters between 10 and 600. In each case, the Euclidean distance of points from their cluster centres was calculated by the equation:

$$\sqrt{\sum_{capabilities} (capability - capability_{clustercentre})^2}$$

At 35 clusters, the average distance between each point and its cluster centre was approximately equal to one point on the capability rating scales. This gives reasonable accuracy for exclusion analysis, while being a small enough number of personas to manage. So 35 clusters were chosen.

3.4. Describing personas

For each cluster, a representative was chosen that was close to the cluster centre. The representative was described using the capability scores from the DFS data as shown in Table 2.

The number of people in the British population represented by a cluster was calculated as follows:

- Each of the 7,168 people in the Disability Follow-up Survey had a multiplier associated with them. This multiplier indicated how many people that person represented in the British population as a whole. This multiplier was calculated by the organisation that completed the original survey.
- The multipliers for all the people in a cluster were added up to give a number for the cluster as a whole. This number indicates the number of people in the British population who were represented by that cluster.

Table 2 Example of the capability scores for a persona. The scores are only shown for capabilities that are less than "full ability" (i.e. less than 4 on the scale).

Cluster Number: 3		
Number of survey participants in this cluster: 4		
Number of people in the British population represented by this cluster (1997 statistics): 5,060		
Capability	Capability score	Description of capability level
Walking	3	Can walk 200 yards without stopping but not 400 yards
Fine-finger manipulation (both hands)	3	Can pick up a safety pin with each hand but cannot tie a bow in laces without difficulty
Strength (both hands)	3	Can pick up and carry a pint of milk in each hand but not a bag of potatoes
Hearing sound	3	Can hear a telephone ring but cannot follow TV at a volume that others find acceptable
Hearing speech	2	Can hear someone talking in a loud voice in a quiet room but cannot use an ordinary telephone

Other information was then added to the information in Table 2 to turn it into a persona: name, age, photo, some personal and social information, and information on medical conditions and assistive equipment used. The information was based on the assessors' knowledge of the likely situations of participants with these kinds of capabilities. Examples of these personas are shown in Figure 1.

It is important to note that this additional information was not used in the initial cluster analysis. As a result, only the capability information in the personas is statistically representative of the clusters. The other information can help to inform the assessment and design of a product, but is not necessarily accurate for all members of the cluster. It may be possible to include further information into the cluster analysis so that this information is also statistically representative. However, this example uses just the capability data as a proof-of-concept.

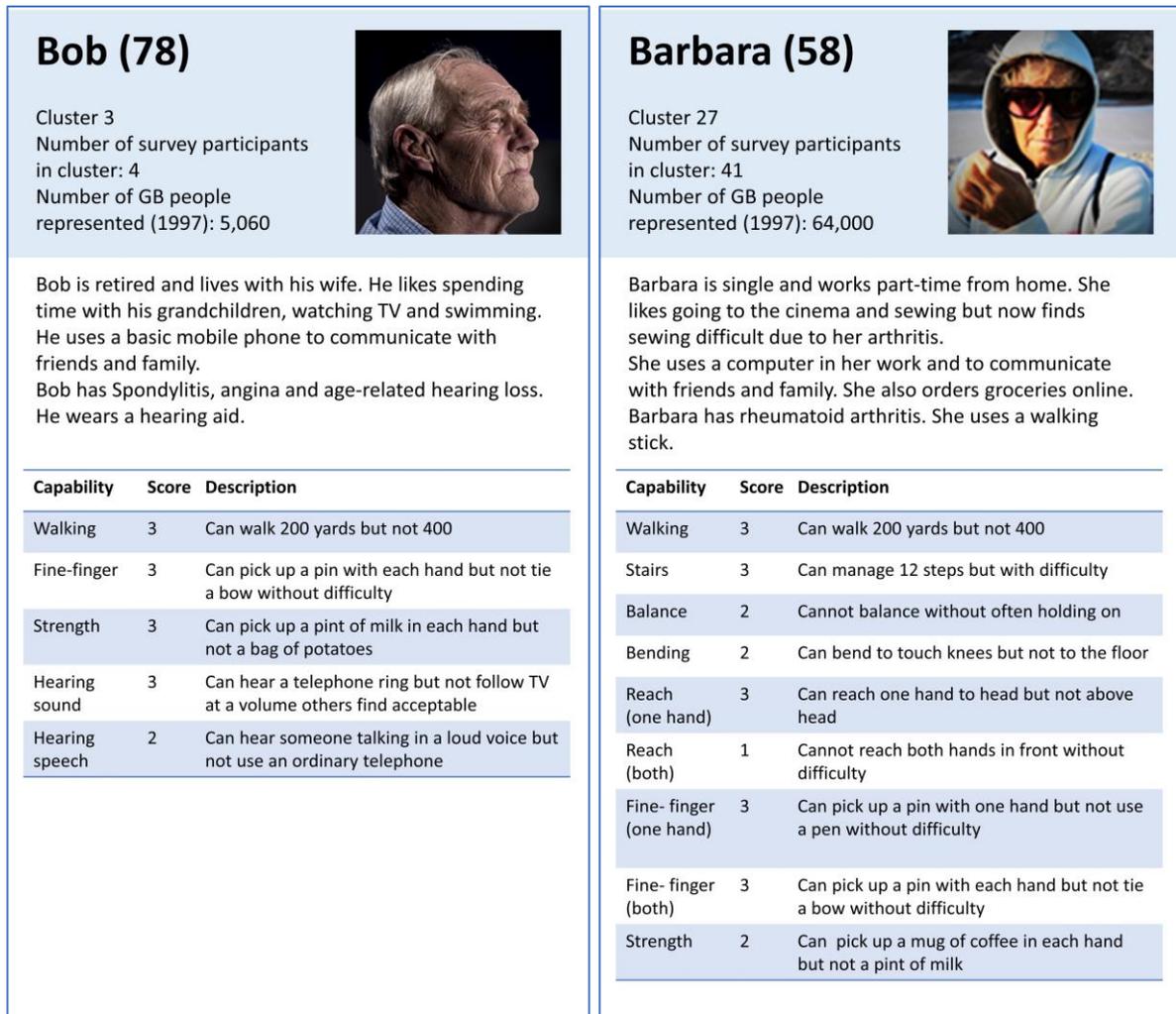


Figure 1 Persona examples

3.5. Using the personas for evaluation

As an example, we examined whether the personas can complete a simple task: carrying a tray of food across a café. To do this properly, it is important to consider the use of mobility aids that may restrict the availability of the hands. This is difficult to do in a standard exclusion analysis Waller et al, 2010) because the demand on each capability is assessed separately.

In the task, the environment is a large café. There are several other customers but the café is not crowded. The tray is initially on a serving counter, and is to be carried to a table 15m away. The user must navigate round other tables. There is enough space to be able to use mobility aids including a wheelchair. The tray is too large to be carried with a single hand, is well balanced and weighs about the same as a pint of milk.

Table 3 gives the task analysis for this task. A fuller task analysis would include pulling a chair out and sitting down, but this example focuses on the core tasks for the purposes of the proof-of-concept.

The basic demands involved in each task step were assessed to the nearest 0.5 using the exclusion assessment method (see Section 1.1). The results are shown in Table 3. These were then compared to the personas in Figure 1. Both Bob and Barbara (personas 3 and 27) have higher levels of capability for each scale than the corresponding demands. Therefore, according to a standard exclusion audit, they should both be able to do the task and so be *included*.

Table 3 Task analysis for carrying a tray of food to a table 15m away. Only non-zero demands are shown.

Task step	Task description	Non-zero demands (1=someone of low capability would be unable to do this task, 4= someone of full capability would be unable to do this task)				
		Vision (recognition)	Walking	Balance	Reach (one hand)	Strength (two hands – each hand takes half the weight)
1	Pick up tray	0.5	0	1	1	1
2	Hold tray and move to table	1.5	0.5	0	0	1
3	Place tray on table	0.5	0	1	1	1
Overall		1.5	0.5	1.5	1	1

However, Barbara needs to use a walking stick to walk across the room. This takes up one of her hands, leaving only one available to hold the tray of food, but the tray is too large to hold in a single hand. As a result, she cannot complete the task and so is *excluded*.

Barbara represents cluster 27. If she is assessed as excluded from the task, then so are the 64,000 people in the population that she represents (see Figure 1). If this analysis is repeated for all 35 personas, then it is possible to add up all the people represented by all the excluded personas to get an estimate of the number of people in the population as a whole who would be excluded from completing the task.

The exclusion figure is higher than that obtained from an exclusion assessment because it takes into account the impact of using a mobility aid on carrying out the task.

In a full analysis, exclusion would be estimated for multiple tasks involved in using the café. These could be compared and, if the exclusion associated with carrying a tray was particularly high, then effort could be put into addressing it. The analysis above reveals that part of the cause of the exclusion is the difficulty of carrying a tray while using a mobility aid at the same time. Ways of reducing the exclusion might include providing a tray that can be carried in one hand, providing a trolley on which the tray can be placed or providing a table service.

4. Discussion

4.1 Data used in the cluster analysis

The proof-of-concept used data from the 1996/97 Disability Follow-up Survey because it is the dataset used in the general exclusion assessment method. In addition, it is one of the few population-level datasets providing detailed data on a wide range of different types of user capabilities. However, this dataset is now rather out-of-date. It may be possible to update the data from this survey by adjusting for changes in population demographics over the last 20 years. Alternatively, the method described in this paper could be used with other datasets that provide suitable information about the user characteristics of interest on a population level.

Note also that the proof-of-concept only used capability data in the cluster analysis. The information on mobility aids was added based from the assessors' knowledge of participants' likely situations. Making assessments based on the use of mobility aids is therefore a bit of an extrapolation – probably a reasonable extrapolation but not statistically representative. As a result, it is not entirely accurate to use the multipliers for each cluster to determine the total number affected in the population. If we want to use the multipliers, we should really include mobility aid information in the initial analysis. This similarly applies to any other additional information used in the assessment.

4.2 Clustering methods

The proof-of-concept used cluster analysis to identify groups for the personas, but other methods are also possible. Brickey, Walczak and Burgess (2012) identified several persona grouping

techniques. Many of these are manual methods and so are not suitable for quantitative analysis of large survey samples. However, there are several promising semi-automated techniques, including factor analysis and principle component analysis, as well as cluster analysis. In addition, Persad et al. applied Topological Data Analysis to capability survey data, identifying 14 clusters describing the capability distribution in the sample (Persad, Goodman-Deane, Langdon and Clarkson, 2018).

4.3 Number of personas

The proof-of-concept study examined a subset of the total population and identified 35 personas. Even more personas would be needed to cover the whole population with the same degree of accuracy. However, such large numbers of personas may become difficult to use. Even going through the use of a product for each of the 35 personas in the proof-of-concept is tedious and time-consuming, and it may be unlikely that a designer would do this in practice.

Further work is needed to determine whether it is possible to do a reasonably accurate assessment with a smaller number of less representative personas.

Alternatively, the full set of personas could be produced, but a full audit only conducted for a few of them. Perhaps the assessor could perform a standard exclusion audit and then look through the set of personas, highlighting any for whom there are likely to be additional issues. Further assessment is only done for these personas, not for the whole set. Even for these, the full assessment may not be necessary in every case. There are likely to be some personas for whom it is obvious that they could not complete the task, or perhaps would not even attempt the task. These could just be marked as "excluded" without having to look through all their capabilities or steps in the task analysis.

It may be possible to identify subsets of personas in advance that should be considered for particular kinds of products or tasks, so that the assessor does not have to do this step him/herself. This smaller set of personas could also be used in the ways more typical of personas in general – for awareness raising, empathy building and maintaining a user-centred focus throughout a project. It could also be useful for helping designers to visualise the diversity of the target user group.

4.3 Ways of using this kind of personas

The example in Section 3 showed how these personas could be used to examine a situation where one capability affects another. In contrast, standard exclusion assessments assume that capabilities are fixed. For example, if someone can use both hands, the assessments assume that they can use them in all situations. However, this is not always true. In particular, use of a mobility aid means that someone can only use one hand when walking.

This applies to other capabilities as well. For example, someone with poor balance capability may be able to use both hands without difficulty when seated. However, if the task requires standing, especially on an unstable surface (e.g. a moving bus), they need to use one or even both hands to hold on.

Similarly, someone with reduced vision capability may have reduced concentration capability if the task requires a high level of vision. They may need to spend some of their concentration trying to read text that is on the edge of their ability.

These types of personas may also be useful in situations where different users are likely to do tasks in the different ways, e.g. using coping strategies to overcome some capability loss. While exclusion audits can examine situations with multiple task analyses (e.g. Waller et al., 2013), this gets increasingly complicated with increasing numbers of variations in ways of doing the task.

This is particularly relevant to digital products, where there are often multiple ways of achieving a goal. In fact, when it comes to digital products, it is often less a case of whether people can or cannot do individual specific tasks, but how they go about trying to achieve the goal in the first place – what set of tasks they choose to perform. It is hard to determine this based on a list of their

capabilities, but the additional information in a persona can allow an assessor to make reasonable assumptions about what they would do.

Another issue when examining digital exclusion is that a sizeable segment of the population would rather not do certain tasks, such as use a new piece of technology or a computer. For example, faced with the choice between using a digital camera or failing to get a photograph of a special occasion, they may choose the latter. They may technically have the capabilities to do the task, but are essentially excluded due to a variety of reasons, such as a lack of self-efficacy. For example, the OECD (2016) found that 9.6% of working age adults opted not to use a computer in an assessment situation, even though they reported some prior experience with computers.

5. Conclusions

In this paper, we have proposed combining quantitative personas with exclusion assessment. This would facilitate the consideration of other factors (in addition to capabilities) when considering how many and who can use a product or service. We have discussed what kinds of personas would be necessary to do this in practice. A proof-of-concept example demonstrates that it is possible to create this type of personas and to use them in an assessment.

To our knowledge, this is the first time that a set of quantitative personas has been created with the level of accuracy about user capabilities necessary for product assessment. The proof-of-concept also shows how users' use of mobility aids can be taken into account when estimating exclusion. This is not possible in a standard exclusion assessment.

The paper highlights issues that need to be explored and different ways that quantitative personas could be used to improve exclusion assessments. These are all areas for further work and research. For example, further work could explore the use of different datasets and clustering methods, and different ways in which these personas could be used.

In particular, the personas in this paper are a proof-of-concept. As such, they were based on a subset of the full survey sample, focusing on those people who were borderline for assistive technology provision. The analysis was also based on an old version of the capability scales. The scales have since been revised to be simpler and easier to manage (Waller et al., 2013). In particular, the scales for hand function now allow an assessor to examine what people can do with their dominant and non-dominant hands or with their left and right hands, which is helpful when looking at some types of product use. The thinking scales have also been improved. Further work could develop personas for the full dataset, using the new scales. It could also include additional non-capability information in the clustering. It would be useful to produce a full set of personas and compare the exclusion results using this set with those from the exclusion calculator (Cambridge Engineering Design Centre, 2017).

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