Quantifying Exclusion for Digital Products and Interfaces

J. Goodman-Deane(✉), M. Bradley, S. Waller, and P. J. Clarkson

Cambridge Engineering Design Centre, University of Cambridge, Cambridge, UK
{jag76,mdb54,sdw32,pjc10}@cam.ac.uk

Abstract. It is useful to be able to estimate the numbers of people who are likely to be unable to complete task steps in a user journey and thus are excluded from using a product or service. This helps to identify and prioritise design issues and can lead to improvements in design. Existing approaches to quantifying exclusion have proven valuable for non-digital products and services. However, they do not explicitly take into account additional factors that impact digital interface use, such as technology experience and willingness to explore an interface. Digital inclusion is increasingly important as many services now incorporate digital interaction patterns. Thus it would be valuable to extend exclusion analysis into the field of digital interfaces. To this end, this paper proposes a new model of digital exclusion. The model is supported by the identification of key user characteristics that affect digital exclusion. We also outline three different approaches for using this model in practice to estimate the inclusivity of a digital interface.

1 Introduction

Digital inclusion is increasingly important as many services move online or incorporate digital interaction patterns. These include essential services, such as government information, banking and shopping. People who are unable to access and use digital technologies are increasingly likely to be excluded from many aspects of participation in society. Furthermore, they miss out on opportunities that could make life easier for them or enable them to stay independent for longer. This is a particular issue for older people, with adults over 65 having significantly lower rates of technology use (Office of National Statistics 2018). They are therefore likely to have less familiarity with digital interaction patterns.

There has been substantial interest in quantifying the numbers of people who are digitally excluded (e.g., OECD 2001; Cruz-Jesus et al. 2012). However, much of this work takes a broad standpoint, assuming that each person is either included or excluded. This is useful for policy making but less useful for improving individual services and interfaces. In reality, exclusion varies depending on the particular digital technology. Someone may be able and willing to use one piece of technology (e.g., a familiar e-mail client on a computer) but be completely confused by another (e.g., a navigation app on a smartphone). Another person may have access to the internet in their home but not on the move.

We propose addressing this by examining digital exclusion on the level of individual interfaces in specific target use settings. This could help designers to identify and

P. Langdon et al. (Eds.): CWUAAT 2020, *Designing for Inclusion*, pp. 140–149, 2020.
https://doi.org/10.1007/978-3-030-43865-4_15

prioritise exclusionary usability issues with their interfaces, help companies to choose between different possibilities, and assist in identifying gaps in provision from a broader perspective.

This is an approach that has been used successfully with non-digital products (Goodman-Deane et al. 2018a), as described in the following section. However, extending the approach to digital interfaces requires some modifications. In this paper, we describe how the underlying model of demand and exclusion can be adapted for digital interfaces, identify key user characteristics that affect digital exclusion, and outline three different approaches for using the model in practice to estimate the inclusivity of a digital interface.

2 Background

The exclusion estimation approach is based on the model of product interaction shown in Fig. 1 (Persad et al. 2007). Product interaction places demands on users' capabilities. Users will be excluded from using a product if any of its demands are higher than their capabilities.

Estimating exclusion uses this model by breaking down the use of a product into a series of tasks. The assessor evaluates each individual task against the points on various

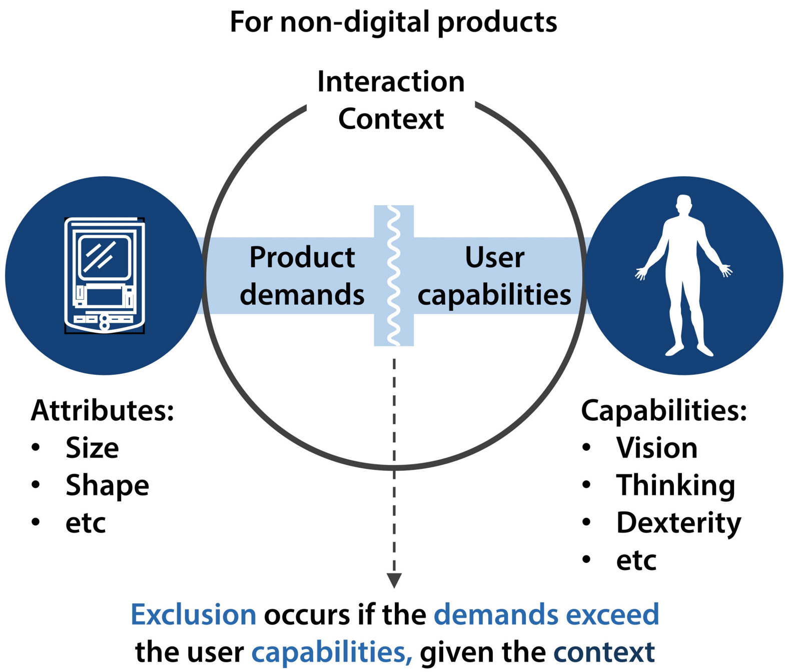

Fig. 1. Model of demand and exclusion for non-digital products (redrawn from Persad et al. 2007). Users will be excluded from using a product if any of its demands are higher than their capabilities

capability demand scales, such as vision and lifting strength (Fig. 2) (Waller et al. 2010). For example, a kettle that needs to be filled manually (and thus carried while full) requires a high amount of lifting strength. These demands are then compared with data on the spread of users' capabilities in the UK population, using Exclusion Calculator software (Cambridge Engineering Design Centre 2017). This estimates how many people would be unable to do that task in practice, e.g. how many people lack the strength capability to lift the full kettle.

It is important to note that operating most products requires a combination of several different capabilities, such as vision, dexterity and cognition. Thus, to estimate exclusion accurately, survey data is needed that covers multiple capabilities for each individual. To address this, the exclusion calculator uses data from the UK Disability Follow-up Survey (Grundy 1999) that covers motor, sensory and some cognitive capabilities.

It is recommended that exclusion calculations are complemented by other methods including user observation, user trials and expert appraisals to provide a more complete picture of the user interaction.

This approach has been insightful when used in collaboration with companies on non-digital products. The results from user trials are particularly effective in highlighting real issues, and the exclusion calculations help to indicate the prevalence of these issues in the wider population. This has helped to convince designers and managers of the need for more inclusive design, to break them out of a mindset of designing for people with similar capabilities to themselves or making guesses as to where users may struggle, and to educate them on what product attributes are likely to cause exclusion. It has

Fig. 2. One of the scales in the current exclusion calculator (Cambridge Engineering Design Centre 2017). Assessors compare the demand of the task against the points on the scale

identified areas that need to be improved, encouraged clients to make changes and enabled comparison of product alternatives (Goodman-Deane et al. 2018a).

3 A Model of Exclusion for Digital Interfaces

The model of exclusion shown in Fig. 1 is based on the theory that exclusion occurs if the demands of a product exceed the user's capabilities, given the context. This holds true for digital interfaces as well. For example, an interface may require the user to remember what they typed in on a previous screen. This places a sizeable demand on the user's memory capabilities.

However, this does not cover the whole picture. Successful use of a digital interface may depend on other aspects as well as the user's capabilities (see, e.g., Murad et al. 2012). For example, the interface may assume a user has knowledge of certain digital interaction patterns, a compatible learning style or attitude towards technology. It may be difficult for users to use the interface effectively if they do not have these characteristics. Many of these characteristics are not intrinsic human capabilities, and some cannot easily be conflated onto ordinal scales. As a result, it may not be possible to determine precisely whether a digital interaction demand exceeds a user's level of the characteristic.

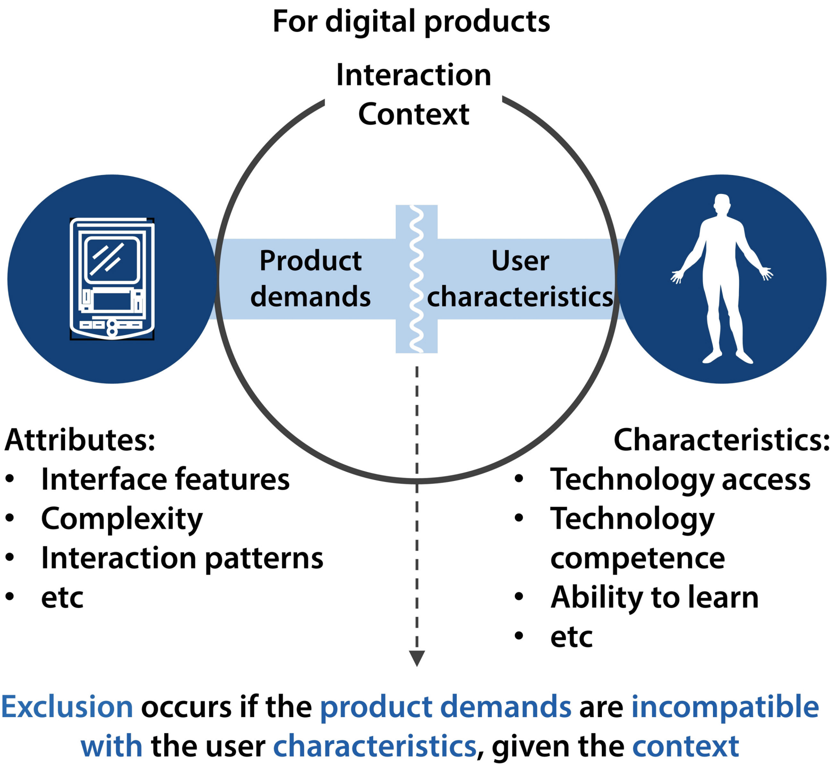

Fig. 3. Adaptation of the model of demand and exclusion from Fig. 1 for digital products

To address this, we propose modifying the model of exclusion as shown in Fig. 3. The user is now considered in terms of characteristics rather than capabilities, and exclusion now occurs if the product demands are incompatible with the user characteristics, given the context. A demand is considered to be incompatible with a user's characteristics if it requires something of the user (and their characteristics) that is not available in that context.

For some interface attributes, this is similar to the previous model. For example, a piece of text on a screen can cause exclusion because it is incompatible with the user's vision capability. It requires a level of vision from the user that they do not possess. This is the same as the vision demand exceeding the vision capability in the previous model.

However, for other attributes, it goes further. A service could be incompatible with a user's learning style and willingness to explore. The user may be unable to use the interface effectively in practice because they do not engage in the expected exploratory behaviours. In another example, it could be incompatible with a user's technology access because it demands a technology set-up that the user is not able to achieve given the technology available to them and their expertise in manipulating that technology.

4 User Characteristics Affecting Digital Exclusion

The new model (Fig. 3) considers each user in terms of their *user characteristics*. However, the term *characteristics* is extremely broad. It is possible to identify an enormous set of characteristics of users, many of which have little or no bearing on their use of technology, e.g., their hair colour or favourite food. It is important to narrow down the set and identify the key types of characteristics that affect the ability to use a digital interface. We conducted a literature review on this topic and identified several key areas, as shown in Fig. 4. Unfortunately, there is no room in this paper to describe the full range of papers referred to during this.

In summary, the key user characteristics are:

- **Cognitive capabilities:** Capabilities such as memory, executive function and attention play an important part in the use of digital interfaces, which are typically more complex than non-digital ones.
- **Neurodiversity:** Neurodiversity is a broad term, covering many neurological differences, including autism, ADHD and dyslexia. Many of these affect the ways in which people approach and interact with interfaces. Some interface attributes can be particularly difficult for people with certain characteristics. For example, text in particular fonts or colours can be problematic for some people with dyslexia.
- **Technology access:** Many interfaces require access to additional equipment and/or infrastructure to work properly. For example, a mobile data connection or a device with a certain specification may be required. It is important to note that technology access varies by situation as well as by person.
- **Technology competence:** Competence varies between interfaces, but there are key underlying skills that can be transferred to a new interface. Competence itself can be hard to measure quickly. However, it is heavily influenced by technology prior experience and it may be possible to estimate it in some cases using prior experience

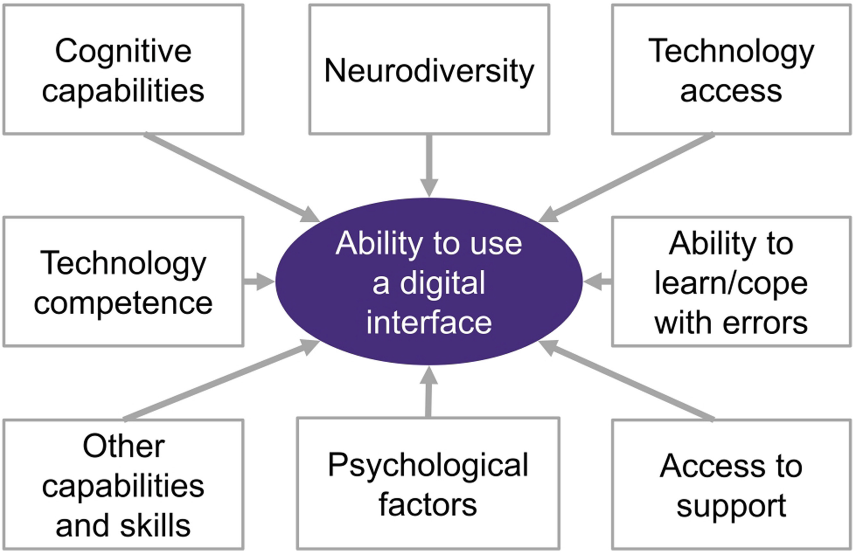

Fig. 4. Key user characteristics that affect a person's ability to use a digital interface. This was based on a literature review, with particular reference to Barnard et al. (2013) and Wagner et al. (2010)

(Blackler et al. 2010). It is also closely related to constructs such as intuitive use of technology (Blackler et al. 2010).

- **Ability to learn and cope with errors:** Digital interfaces often require users to learn new things. Even an interface that is similar to a familiar one will likely have some new aspects to learn, such as new sequences of button presses to achieve goals. Learning style can also be an issue. For example, many digital interfaces assume a level of willingness to explore or tinker with an interface and certain information processing styles, which vary across the population, e.g., by age and gender (Burnett et al. 2016). The ability to cope with and recover from errors is also critical in using digital interfaces. A well-designed interface with clear options for undoing actions can place less demand on this ability.
- **Other capabilities and skills:** These include sensory and motor capabilities, literacy and language.
- **Psychological factors:** Factors such as motivation, attitude to risk and technology self-efficacy (a person's beliefs about their ability to learn and use technology) can play a big part. For example, a complex-looking piece of technology may deter someone with low self-efficacy from trying it out, even if that person actually possesses the levels of capability required to operate it.
- **Access to support:** A person may be able to use an interface on a daily basis but will need help to set it up and if something goes wrong. If there is no one to provide support in these situations, they will be excluded from using the technology in practice. It is debatable if this is really a user characteristic or part of the interaction context. However, in either case, it affects digital exclusion.

5 Challenges

The method for estimating non-digital exclusion was outlined in Sect. 2. However, it may be difficult to use this in a digital setting for various reasons.

Firstly, there are a large number and variety of user characteristics that affect digital exclusion. In addition, some of these characteristics are hard to measure, and vary depending on the situation. For example, a person's level of confidence or self-efficacy may change depending on the particular interface they are facing. One possible way of addressing this is to consider subsets of characteristics that override or predict others. For example, if someone does not have the requisite technology access then they are probably excluded, regardless of their other characteristics. Furthermore, technology competence has been shown to be a strong predictor of performance on its own (e.g., Sengpiel and Dittberner 2008).

Other challenges arise when trying to match interface elements with user characteristics. It is possible to do this (at least roughly) with many aspects of a non-digital product. For example, an expert assessor may be able to give a rough estimate of the level of vision needed to read a piece of text (in a given context, e.g., without a screen reader or other assistive technology present). Doing this is also possible for some of the characteristics that affect digital exclusion, such as technology access. However, this is much more challenging when considering cognitive and expertise demands. For example, it is very difficult to determine the level of memory required to use an interface or a menu structure, or the level of expertise or prior knowledge needed to operate an unfamiliar app.

In addition, some of the characteristics that affect exclusion are not ordinal. Examples include learning style and aspects of neurodiversity. Such characteristics cannot be placed in a scale from low to high. As a result, it may not be possible to determine a particular "level" of the characteristic that is required to use an interface successfully.

Another issue is that different people use interfaces in different ways to achieve the same goals. One example of this is the use of assistive technology, such as a screen reader. Another example is the use of a wizard interface to achieve a goal that might be done more directly by someone with more experience. As a result, it may be necessary to examine multiple pathways in a task analysis and perhaps determine which one(s) are mostly likely for different people and situations.

6 Possible Approaches for Estimating Digital Exclusion

User trials are a key way to identify usability problems. However, it can be difficult to obtain a population-level view of exclusion with user trials without involving a large variety (and hence large number) of people. Therefore, in this section, we first focus on expert appraisal methods that utilize data about the spread of characteristics across the population as a whole. Section 6.3 then discusses how such data could be combined with user trials.

6.1 Compare Characteristics for Each Individual in a Dataset

The non-digital exclusion estimation method (described in Sect. 2) examines each person in a dataset in turn. For each individual, it compares their capabilities with the demands of the task to determine if they can do the task successfully.

Despite the challenges described in Sect. 5, it may be possible to use a similar method for digital interfaces, though it may be necessary to focus on just a few of the characteristics that impact digital exclusion. One possibility is the approach proposed by Bradley et al. (2018). In this approach, the assessors first perform a task analysis. For each task, they examine whether it requires the use of a digital interaction pattern. If it does, they determine whether the action required by the user is explicitly obvious for someone with no prior digital experience, e.g., if it maps "directly to an interaction pattern in the analogue world" (Bradley et al. 2018). If not, then the step is marked as exclusionary for everyone in the dataset with no prior experience of that particular interaction pattern (Bradley et al. 2015).

This method has the advantage that thousands of individuals in a dataset can be processed easily by a computer, comparing their known characteristics with the requirements of the tasks. However, it requires that a single task analysis be constructed that applies to all users, even though in practice different users approach an interface differently. It is possible to calculate exclusion for tasks that can be achieved in multiple different ways (Waller et al. 2013). However, the complexity of the task analysis, and the computation and interpretation of results increases dramatically as the number of different ways increases.

6.2 Quantitative Personas

A second possibility is to use quantitative personas as proposed in Goodman-Deane et al. (2018b). This method leverages personas that have been created from survey data using cluster analysis. Each persona is a fictional description of a user that represents a cluster or group of people in the population. They include information on the whole range of characteristics that impact digital exclusion. The assessor examines each persona in turn to determine if they would be able to complete the task with the digital interface. If they can, then it is assumed that the group they represent can do it too (and vice-versa).

This method allows an expert assessor to consider separately how each persona would approach a task. It also provides greater flexibility in considering how different user characteristics interact in particular situations. However, there is a trade-off between the number of personas that can feasibly be considered, and the validity of the assumption that "if a persona is excluded, then everyone in the cluster they represent would be excluded" (Goodman-Deane et al. 2018b).

6.3 Combining User Trials with a Dataset

Another approach, currently being developed by the authors, integrates user trials with survey data. In this approach, participants in user trials are given simplified versions of the survey questionnaire. The results enable the researchers to identify how many people in the survey (and thus in the wider population) are similar to each participant in terms of the characteristics that affect digital exclusion. The results from the user trials can therefore be quantified in population terms by assuming that if the participant in the user trial was excluded, then each person in the survey who is ‘similar’ to that participant will be excluded. Furthermore, the survey data can be examined to identify segments of the population who are not similar to any of the participants who have been recruited so far. This can be used to identify the extent to which the current user trial participants cover the diversity found in the wider population, and therefore to plan further recruitment.

This method is more expensive than the expert appraisal methods described earlier, but combines the advantages of both user trials and population figures.

7 Conclusions and Further Work

In this paper, we have presented a model of how digital exclusion arises due to mismatches between a product’s demands and a user’s characteristics. This is an adaptation of an earlier model that examined exclusion in non-digital products and services. We have also identified a wide variety of user characteristics that affect a user’s ability to use a digital interface and thus whether they are digitally excluded.

This model can be used to estimate how many people in a population would be unable to achieve particular tasks with a digital interface (and would thus be digitally excluded). We have described some of the challenges in doing this and suggested some promising approaches to deal with these.

All of these methods rely on having good-quality survey data about how the user characteristics vary across the target population. Therefore, we have recently conducted a survey of 338 people aged 16+ across England and Wales. The survey covered technology access, experience and expertise, attitudes towards technology, sensory, physical and cognitive capabilities, and demographics. Initial results can be found in Goodman-Deane et al. (2020). We are currently analysing the results of this survey to be used with the various approaches outlined in Sect. 6. This will help to determine which approaches are most promising in practice. Further work will examine whether exclusion estimates based on this data correspond to actual performance on usability tests.

Acknowledgements. This work, funded by the Department for Transport (DfT), was delivered through RSSB’s TOC’16 project: Towards the Inclusive Railway. Collaborative partners were Siemens Mobility, Keolis Amey Docklands and Astutim.

References

Barnard Y, Bradley M, Hodgson F, Lloyd A (2013) Learning to use new technologies by older adults: perceived difficulties, experimentation behaviour and usability. Comput Hum Behav 29(4):1715–1724

Blackler A, Popovic V, Mahar D (2010) Investigating users’ intuitive interaction with complex artefacts. Appl Ergon 41:71–92

Bradley M, Kristensson PO, Langdon P, Clarkson PJ (2018) Interaction patterns: the key to unlocking digital exclusion assessment? In: Proceedings of AHFE 2018, Orlando, FL, US, 21–25 July 2018

Bradley M, Langdon P, Clarkson PJ (2015) Assessing the inclusivity of digital interfaces – a proposed method. In: Universal access in human-computer interaction. Access to today's technologies, Proceedings of UAHCI 2015, Los Angeles, CA, US, 2–7 August 2015

Burnett M, Stumpf S, Macbeth J, Makri S, Beckwith L et al (2016) GenderMag: a method for evaluating software's gender inclusiveness. Interact Comput 28(6):760–787

Cambridge Engineering Design Centre (2017) Exclusion calculator. http://www.calc.inclusivedesigntoolkit.com. Accessed 9 Sept 2019

Cruz-Jesus F, Oliveira T, Bacao F (2012) Digital divide across the European Union. Inf Manag 49:278–291

Goodman-Deane J, Bradley M, Clarkson PJ (2020) Digital technology competence and experience in the UK population: who can do what. In: Proceedings of ergonomics and human factors 2020, Stratford-upon-Avon, UK, 27–29 April 2020

Goodman-Deane J, Waller S, Bradley M, Bradley O, Clarkson PJ (2018a) Using inclusive design to drive user experience improvements through to implementation. In: Langdon PM et al (eds) Breaking down barriers: usability, accessibility and inclusive design. Springer, Switzerland

Goodman-Deane J, Waller S, Demin D, González-de-Heredia A, Bradley M et al (2018b) Evaluating inclusivity using quantitative personas. In: Proceedings of DRS 2018, University of Limerick, Limerick, Ireland, 25–28 June 2018

Grundy E (1999) Great Britain Department of Social Security Disability in Great Britain: Results from the 1996/97 disability follow-up to the family resources survey. DSS Report 94. Corporate Document Services, London, UK

Murad S, Bradley M, Kodagoda N, Barnard Y, Lloyd A (2012) Using task analysis to explore older novice participants' experiences with a handheld touchscreen device. In: Anderson M (ed) Contemporary ergonomics and human factors 2012. CRC Press, Boca Raton

OECD (2001) Understanding the digital device. OECD Publications, Paris

Office of National Statistics (2018) Internet access – Households and individuals, Great Britain. www.ons.gov.uk/peoplepopulationandcommunity/householdcharacteristics/homeinternetandsocialmediausage/bulletins/internetaccesshouseholdsandindividuals/2018. Accessed 9 Sept 2019

Persad U, Langdon P, Clarkson PJ (2007) Characterising user capabilities to support inclusive design evaluation. Univ Access Inf Soc 6(2):119–135

Sengpiel M, Dittberner D (2008) The computer literacy scale (CLS) for older adults – development and validation. In: Proceedings of Mensch und Computer 2008, Luebeck, Germany, 7–10 September 2008

Wagner N, Hassanein K, Head M (2010) Computer use by older adults: a multi-disciplinary review. Comput Hum Behav 26:870–882

Waller SD, Bradley MD, Langdon PM, Clarkson PJ (2013) Visualising the number of people who cannot perform tasks related to product interactions. Univ Access Inf Soc 12(3):263–278

Waller SD, Langdon PM, Clarkson PJ (2010) Using disability data to estimate design exclusion. Univ Access Inf Soc 9(3):195–207