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Relating age, digital interface competence, and exclusion

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Abstract

Background: Understanding users' digital interface capability is crucial for designing interfaces that they can use effectively. This is particularly relevant when designing for user populations that may include older people, where important digital technologies often have limited uptake. Previous surveys have examined levels of technology access and use across the population, but this is only part of the picture.
Objective: This study aims to increase the understanding of how digital interface capability varies across the population. This can help designers to develop more inclusive interfaces, and inform policy makers and other stakeholders in their decisions.
Method: A survey was conducted in 2019 with 338 adults across England and Wales. It examined a range of user characteristics including digital technology access, technology experience and attitudes towards technology. Simplified paper prototype testing was used to assess actual performance on common basic interface patterns, such as accessing a drop-down menu and returning to the previous screen via a back arrow.
Results: The survey found that technology access, use, attitudes and competence all decline with age. These characteristics all have low levels in older age groups, particularly among those aged 75 and over. In particular, 44% of those aged 75+ got none of the eight basic interface tests correct.
Conclusion: It is important not to assume that end users are familiar with digital interfaces and specifically interface patterns, including those in common use today. This is particularly important when designing for target groups that include older people. Particular care should be taken with patterns that are different on smartphones than on laptops, such as bringing up an onscreen keyboard. It is also important to take into account that many older people have low levels of willingness to explore an unfamiliar interface and may need clearer guidance on how to navigate an interface.

Keywords: inclusive design, digital inclusion, digital competence, digital skills, interface patterns

Introduction

Digital technology use is increasingly important for engaging in daily life and participating in society. Many services are now primarily accessed online or involve using digital interfaces. This includes many government information, banking, shopping and healthcare services. Furthermore, technology offers great potential for enhancing social engagement and quality of life (Rogers et al, 2020).

However, this potential will only be achieved if people can actually use a technology effectively. Indeed, an inability to use digital public services can lead to economic, psychological and social harm (Schou and Pors, 2018). This is particularly relevant when designing for older populations, which have lower levels of technology use and competence (Office for National Statistics, 2020; Hargittai et al, 2019). There is also the risk of technology use itself causing harm, e.g. through cyberbullying or online theft (Blank and Lutz, 2018). Nevertheless, technology still has enormous potential to benefit people, including older people (Blank and Lutz, 2018), especially if it is designed inclusively to match the needs and abilities of the users.

The term "digital exclusion" is often used to refer to "the situation where people cannot participate in society due to either lack of access or inability to use digital technologies" (Park and Humphry, 2019). Indeed, the ability to use a technology goes beyond issues of access to include experience, attitudes, skills and capabilities (van Dijk, 2005; Goodman-Deane et al, 2020b). However, as Fourman et al (2015) say, "motivation and skills are hard to measure, so quantitative studies often focus on the access divide". Therefore, the term "digital interface exclusion" is used in this paper to emphasize that someone is excluded from using a technology even if they have access to it, if they are unable to use its interface effectively.

It is thus extremely important to design interfaces that are easy to use for a wide range of people with different technology experiences, attitudes

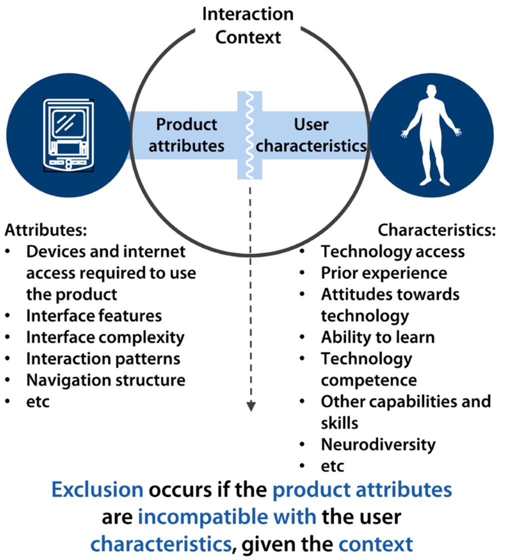


Figure 1. Model of digital interface exclusion (adapted from Goodman-Deane et al, 2020b)

and capabilities. To do this, it is necessary to understand how these characteristics vary across the population and how they impact interface use. This paper aims to increase this understanding in order to equip designers to develop more inclusive services, particularly when their target user group includes older people. Services may be more inclusive because they have more usable interfaces or because they provide alternative methods of non-digital access or interaction, such as phoning a helpline or talking to a service assistant. The study described in this paper increases this understanding of users by examining a range of characteristics, including technology access, experience, attitudes and competence. This helps to provide a more holistic view of people's ability to interact with digital interfaces. The paper also provides an improved understanding of people's competency at the basic skills involved in using digital interfaces, by directly assessing these skills rather than relying on proxy measures or self-report. Initial top-level results from the survey were previously published in (Goodman-Deane et al, 2020a).

Factors affecting digital interface exclusion

Digital interface exclusion arises due to a mismatch between the product's attributes and the user's characteristics, within the context of use (*Figure 1*). These user characteristics extend beyond basic user capabilities to include technology access, technology experience, intentions, attitudes, learning and competence on component tasks (Wagner et al, 2010; Goodman-Deane et al, 2020b).

This is related to work on Technology Acceptance Models (e.g. Barnard et al, 2013), originally proposed by Davis (1989), which identify factors affecting technology adoption. However, digital interface exclusion differs from technology adoption in its focus on how technologies and their interfaces are used in practice. For example, a user may adopt a technology but not be able to use all of its features effectively. They may therefore be excluded from parts of the service that it offers. Although similar types of factors are involved, they are not identical and may play a different role. It is important to consider this range of factors in order to understand digital interface exclusion and how it varies between users. The study described in this paper aims to support this by providing data on this whole range of factors.

Ageing and digital competence

Digital competence refers to a person's capability to use digital interfaces. Previous work has shown that many of the factors affecting digital competence vary with age. In particular, population based surveys have found that technology use decreases with age (see, for example, Office for National Statistics, 2020). Other work has shown lower levels of digital competence in the older population (e.g. Hargittai et al, 2019).

This is partly a result of changes in physical, sensory and cognitive capabilities, including fluid intelligence and the ability to learn new skills (Hawthorn, 2000). Differences in prior technology experience and knowledge may also contribute (O'Brien et al, 2012). Motivation and attitudes also play a part, and older people are also more susceptible to "digital disengagement", where people stop or reduce their technology use after being more regular users (Olphert and Damodaran, 2013).

The experience of ageing has changed in recent years, with improvements in healthcare and assistive technology and greater integration of technology into daily life. In particular, many older people now have at least some prior experience with computers. However, there are still many challenges for older adults in engaging with technology (Czaja and Weingast, 2020).

While these age-related differences are well-established, individuals' characteristics, population composition and interface paradigms vary greatly over time. Therefore, there is value in re-examining age-related differences as in this paper, particularly in relation to interfaces that are currently in common use, such as smartphones, touch screen devices and tablet computers.

Measuring digital competence

Various population-level surveys examine technology access and use. For example, the ONS Internet Access surveys (Office for National Statistics, undated) and the Global Attitudes Surveys

(Pew Research Center, undated) ask participants about their technology access, frequency of technology use and the types of technology activities they do. This information provides a useful baseline. If someone lacks access to technology, then they will be excluded from interacting with many digital services. Furthermore, current use is an indicator of the kinds of technologies and applications that people are familiar with and relatively happy to use.

However, as described in **Factors affecting digital interface exclusion**, there are many other factors affecting digital competence. Thus, there have been various efforts to measure digital competence more directly. However, many of these focus on fairly complex ICT skills among youth or working age adults (see, for example, Ainley et al, 2016). Indeed, Law et al (2018, p6) define digital literacy as “the ability to access, manage, understand, integrate, communicate, evaluate and create information safely and appropriately through digital technologies for employment, decent jobs and entrepreneurship”.

One notable example of this work is the OECD’s international survey of digital skills (OECD, 2016), which used ICT tasks on a computer. However, the survey only included adults of working age and those reporting no prior computer experience or failing on a core ICT test did not do the computer skills module. In addition, the tasks were relatively complex and the results were banded into broad levels. This makes it difficult to determine participants’ competency at the basic skills involved in using less complex interfaces, or carrying out less complex tasks.

Some research has looked at measuring digital literacy amongst older adults. Oh et al (2021) review work in this area, identifying the eHealth Literacy Scale (eHEALS) as “the most frequently used instrument to measure digital literacy among older adults”. eHEALS asks participants to self-report their ability to do various e-health tasks, such as knowing “how to find helpful health resources on the Internet” (Norman and Skinner, 2006). More general instruments are the Computer Proficiency Questionnaire (CPQ) (Boot et al, 2015) and the related Mobile Device Proficiency Questionnaire (MDPQ) (Roque and Boot, 2018), which ask about ability on a wider range of digital tasks. These measures provide valuable information, but are based on self-report rather than actual performance. Furthermore, they examine overall ability rather than individual interface components and patterns.

Another approach is to examine knowledge of common computer symbols or terms, as in the Computer Literacy Scale (CLS) (Sengpiel and Dittberner, 2008) and Hargittai and Hsieh (2012)’s measure of web-use skills. The CLS was influential in the design of the digital competence tests in the survey reported in this paper. However, the scale itself was not used because it was felt that the symbols in it were not as relevant to more recent touchscreen interfaces, and that providing the symbols in more context elicits more realistic responses than asking about their meaning in isolation.

The study described in this paper adds to the previous work by assessing basic aspects of digital competence directly using a simplified paper prototyping method.

Interface patterns

Alexander (1979) proposed the idea of patterns to capture the knowledge underlying successful solutions to common architectural design problems. There are various pattern definitions but they are all centre around describing a proven solution to a recurring problem in a given context (Wilkins, 2003). Interface patterns, or interaction design patterns, apply the idea of patterns to digital interfaces. They potentially offer interface designers a way to efficiently reuse solutions to interface problems, and may provide users with fewer types of interaction elements to learn in order to operate those interfaces. Patterns are often related to the standardization encouraged by style guides (such as Apple’s Human Interface Guidelines) which provide users with a consistent set of interaction elements with which they can become familiar. A very simple example of a digital interface pattern is a button with an ‘X’ on it which closes, removes or deletes when activated.

Previous work has indicated that prior experience with technology affects a user’s digital competence (Blackler et al, 2010). Some of this prior experience informs users’ mental models for digital interface patterns, and thus the absence of this experience contributes to digital interface exclusion (Bradley et el, 2018). Those who do not use technologies with digital interfaces often or at all are at a significant disadvantage when faced with an interface pattern that is both unfamiliar and not explicit in availability or function.

Digital interface patterns differ from those experienced in the analogue world in some significant ways. Firstly, many digital interface patterns are constructed entirely on an electronic display screen, and so do not need to obey the laws of physics in their activation or response behaviours. Secondly, they are only experienced by people who use digital products and services, so people with low digital use do not develop mental models for how they behave. Thirdly, they may hidden from view (Hosking and Clarkson,

Table 1. Survey quotas and achieved frequencies. Full definitions of education levels are given in (Office for National Statistics, 2011b). Participants were defined as being "smart device savvy" if they owned and used a mobile technology device (smartphone or tablet) to access the internet more than once a week.

	Target %	Actual % in sample
Gender*		
Female	51	50.9
Male	49	49.1
Age		
16-24	15	15.1
25-34	17	15.7
35-44	17	14.8
45-54	17	16.9
55-64	14	13.6
65+	20	23.7
Social grade		
AB:	23	25.4
C1:	31	35.2
C2:	21	16.3
DE:	26	23.1
Technology experience		
"Smart Device Savvy"	70	71.6
Less "Smart Device Savvy"	30	28.4
Education (highest education level obtained)		
No qualifications	23 (15-30% was considered acceptable for recruitment)	15.7
Level 1-3/Apprenticeship	44 (35-55% acceptable)	55.7
Level 4+	27 (20-35% acceptable)	25.4

**Data for "Other" genders was not gathered in the UK 2011 Census, but an option for this was included in the questionnaire*

2018), e.g. they may require the user to hover, gesture or click on something to make them visible. In fact, some patterns are entirely gesture based. These hidden patterns require experience for a user to suspect they may be available, let alone use them.

The work described in this paper examines people's ability to use common digital interface patterns on a smartphone. This provides valuable insight into who can use these patterns and who is likely to be excluded from an interface which uses them.

Methods

The survey was developed by the authors and conducted by Cambridge Market Research, an independent market research company. The full questionnaire and dataset from the survey are available from an open access repository (Engineering Design Centre, 2021).

Recruitment

Participants were recruited from across the adult population (age 16 and over). Most (328 out of 338) participants were recruited on-street using a screening questionnaire to support quota sampling. This was done in 9 locations across England and Wales covering the North East, North West, South West and South East of England, Yorkshire, East Midlands, West Midlands and Wales. The locations were chosen to gain a good spread of participants from across England and Wales. Selected participants then completed the questionnaire in test centres at each location. Participants received a £10 high street shopping voucher to thank them for their participation.

On-street recruitment is useful for gaining a cross-section of the population, but undersamples people who do not leave the house frequently. Therefore, an additional ten interviews were conducted with participants who reported that they left the house once a week or less. These participants were recruited through a third-party recruitment agency, and were then interviewed in their homes by interviewers from the market research company. They received £20 in cash for taking part.

Sampling

The study employed quota sampling with quotas on gender, age, social grade, technology experience and education as shown in *Table 1*. The quotas for gender, age, social grade and education were based on data from the UK 2011 Census (Office for National Statistics, 2011a). The education quotas were broader because much of the variation in the population was expected to be covered in the other quota variables. A quota was set on technology experience because it was particularly important for this study that the full range of technology experience was covered. This quota was based on data from Ofcom (2018) and Pew Research Center (2017), UK results.

The achieved frequencies for age, gender, social grade and technology use were fairly close to the quotas, as shown in *Table 1*. Although the frequencies for education were broadly within the bands set for recruitment, they did not match the census data closely. Therefore, the results were weighted by broad education groups to match the census values shown in *Table 1*.

Table 1 also shows the demographic breakdown of the sample. Those aged 65+ are reported as a single group because this was the quota group used for the sampling. In more detail, 15.1% of participants were aged 65-74, 7.4% aged 75-84 and 1.2% aged 85 and over. The total age range was 16-94 years old.

Piloting and ethics

The questionnaire was piloted informally during development by the authors. A further six pilot interviews were conducted by the market re-

Table 2. Additional items in the questionnaire that examine attitudes towards technology

Please indicate the degree to which you agree/disagree with the following statements.

1. When I'm not sure what to do next on a technical system, I try out different things until something works.
2. I need to be shown how to use a technical system many times before I'm confident about using it.
3. I am uneasy about tapping or clicking on things that I don't recognise in case something breaks.
4. If I tap on the screen or press a button and something happens that wasn't what I expected, I can usually sort it out by myself.
5. If my current technical system works fine for what I want to do, I have no interest in getting a new one.

search company with participants with different technology experiences. As a result, the questionnaire was shortened slightly, the wording was modified and the section on attitudes to technology was split into two to avoid participant fatigue.

Ethical approval was granted by the University of Cambridge Engineering Department ethics committee. Informed consent was obtained prior to starting the questionnaire and participants could withdraw from the study or decline to answer questions at any time without penalty. Data was stored and processed anonymously and in accordance with GDPR regulations. Two interviewers were present at in-home interviews because some of these participants may have been more vulnerable. These participants were also offered the opportunity to have their own chaperone present if they desired.

Questionnaire

The questionnaire took around 20 minutes to administer. It was kept short to encourage participation from a wide range of participants. In order to provide a more holistic view of people's ability to interact with digital interfaces, it covered a range of factors that affect digital interface exclusion. It thus comprised modules on technology access and use, technology activities, attitudes towards technology, digital competence, capabilities (motor, sensory and cognitive) and demographics. This paper focuses on the modules of most relevance to understanding users' digital interface capability.

Module A: Technology access and use

Participants were asked multiple-choice questions about their access to and frequency of use of various kinds of technology. Questions were based on items in the Internet Access Survey 2017 (Office for National Statistics, 2017) to allow for comparison with national statistics. This previous survey asked about computer and internet use. Similar questions were added about the use of mobile phones, smartphones and tablet devices.

Module B: Technology activities

Participants were first asked whether they had performed various technology activities in the last 3 months. A second set of questions then examined activities that are often performed less frequently or relate to a deeper knowledge of technology devices. Participants were asked if they had done these in last 12 months. Full lists of activities are given in *Figures 6* and *7*.

These questions and their construction were based on items in Office for National Statistics (2017). The specific activities mentioned were adjusted to match particular interests of the overarching research project (general technology use and technology for public transport).

Module C: Attitudes towards technology

Overall attitudes towards technology were examined using the ATI (Affinity for Technology Interaction) scale (Franke et al, 2018). This examines "whether users tend to actively approach interaction with technical systems or, rather, tend to avoid intensive interaction with new systems". The ATI scale comprises 9 self-report items with a 6 point response scale from "completely disagree" to "completely agree".

To explore attitudes further, some additional questions were added using the same response scale (*Table 2*). Items 1 and 3 concerned the participant's willingness to explore an unfamiliar interface, which is often important for successful use of a novel system. A mean of these two items gives a combined "willingness to explore" score.

Table 3. Goals used in the interface tests

Interface	Goal
Fig 2(a): Mockup of a calendar application	Search for a particular event in the calendar Change the settings, such as the colours used in the calendar Create a new event in the calendar on the 6th July
Fig 2(b): Map screen from Google Maps	See a menu with more options
Fig 2(c): Location choice screen from Google Maps	Go back to the previous screen
Fig 2(d): Mockup of accommodation website	Change the number of adults in the search Make an onscreen keyboard appear so that you can enter a location in the search Set this webpage to be one of your bookmarks or favourites so that you can find it easily later on

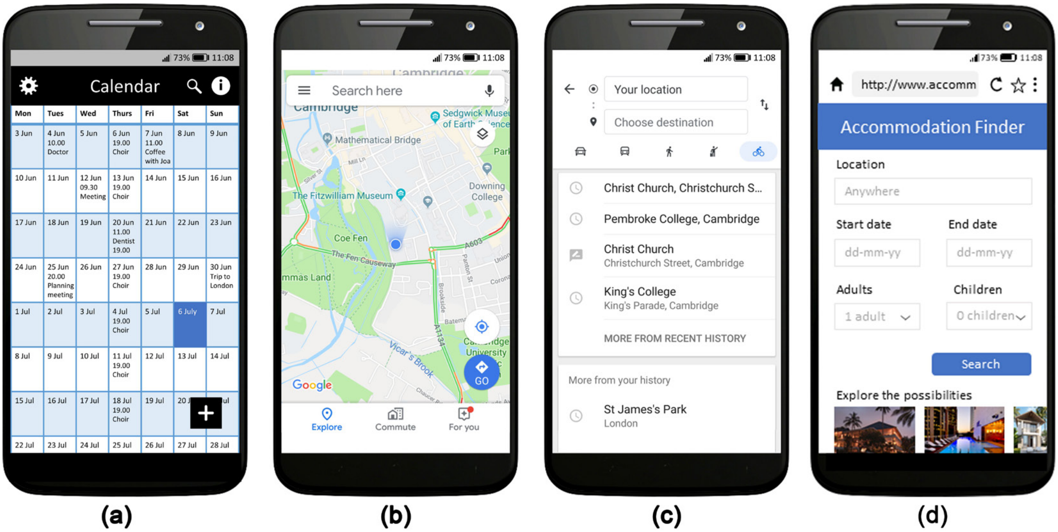


Figure 2. The interface pictures used in the tests: (a) a mock-up of a calendar application, (b) a map screen from Google Maps, (c) a location choice screen from Google Maps, (d) a mock-up of a website for finding accommodation. Larger versions of these pictures can be found at: http://www.inclusive-designtoolkit.com/digitalcompetence

Other items concerned confidence in using a new technology, self-reported ability to recover from errors and interest in technology for its own sake.

Module D: Digital competence

Module D assessed participants' performance on 8 basic digital interface tests. In each test, the participants were shown a picture of a smartphone interface on a paper showcard and asked what they would do to achieve a particular goal. The interfaces are shown in *Figure 2* and the goals are described in *Table 3*. In some cases, achieving a goal might require several actions. Participants were asked to indicate just the first action they would do, by gesturing on the showcard. The interviewer coded each response as one of a set of predetermined options such as: Tapped on the plus symbol, tapped (or pressed and held) on the 6th July, Something else, Said "I don't know" or Preferred not to answer. These pre-determined options were used to increase consistency in recording in a situation where full training of individual interviewers was not possible. Fuller descriptions of the tasks and response options and larger versions of the interface pictures can be found at: http://www.inclusive-designtoolkit.com/digitalcompetence.

This simplified paper prototyping method was based on the method used by the authors in a previous survey to examine performance on mobile phone menu interfaces (Bradley et al, 2012). This method was used to obtain a practical indication of digital competence while keeping the length and cost of the interviews down, enabling a larger sample size. The tasks were chosen to cover a range of basic smartphone interface patterns.

Results

The analysis was conducted in SPSS and the dataset was weighted to better match education levels in the population. All results reported in this paper use this weighting. Many of the results are presented by age group to examine the variation within the population. The 65+ age group is divided into two due to the large amount of variation in the older population.

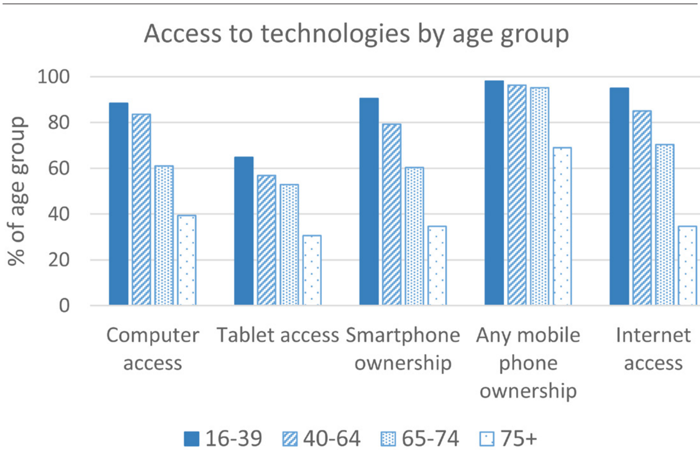
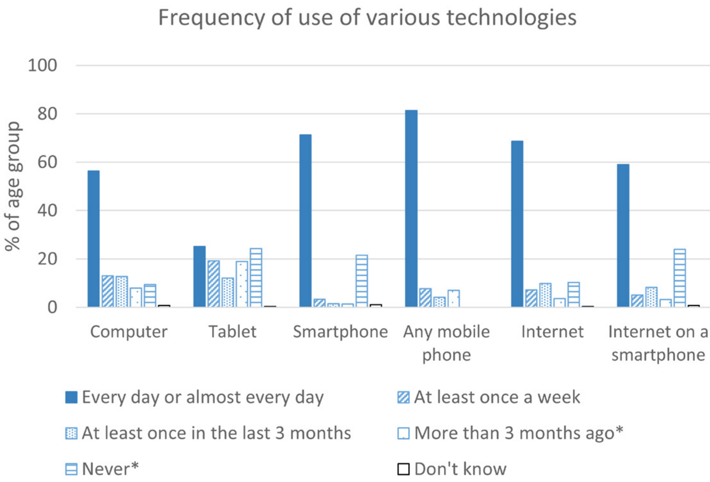


Figure 3. Access to various digital technologies by age group. Ownership of smartphones and mobile phones is used rather than general access because these are personal devices



* "More than 3 months ago" and "Never" were combined for "Any mobile phone use"

Figure 4. Breakdown of the frequency of use of various digital technologies

their knowledge. Note the usage pattern for smartphones, where almost all participants use them either daily or never. Only 6.2% of the sample reported any intermediate frequencies, including use in the past.

Technology use by age is shown in *Figure 5*. To allow a clearer graph, only use "every day or almost every day" is displayed.

Technology access and use

Results on technology access by age are shown in *Figure 3*. It is notable that a majority (69.0%) of those aged 75+ own some kind of mobile phone, while a much smaller percentage of this age group have access to each of the other technologies examined (39.3% for computer access, 30.5% for tablet, 34.7% for smartphone and 34.7% for internet).

In the sample as a whole, 18.0% own a basic mobile phone and do not own a smartphone. This is of relevance to the design of services that require a mobile phone connection (e.g. use texts or mobile phone calls) but do not require the full functionality of a smartphone.

Participants were also asked about the frequency with which they use technology (*Figure 4*). This provides a basic indication of their familiarity with these technologies, but not of the depth of

Technology activities

The percentage of each age group engaging in various technology activities are shown in *Figures 6* and *7*. *Figure 6* shows activities carried out in the last 3 months. All of these activities were reported by over 40% of the sample as a whole. Internet search and e-mail were the most common activities with 74.8% and 73.2% respectively. A large age variation can be seen, with more than half (54.6%) of those aged 75+ not engaging in any of these activities, compared to only 4.3% of those aged 16 to 39.

Figure 7 presents the results for a set of further technology activities that are often performed less frequently or relate to a deeper knowledge of technology devices. Participants were asked if they had done these in the last 12 months (see Section 2.4.2). As before, there is a large variation with age. 75.3% of those aged 75 and over had not carried out any of these activities, compared with 7.4% of those aged 16 to 39. The percentages of those installing apps on smartphones is of particular relevance for the design of smartphone services. Only 15.2% of those aged 75+ and 33.1% of those aged 65 to 74 had performed this task in the last year.

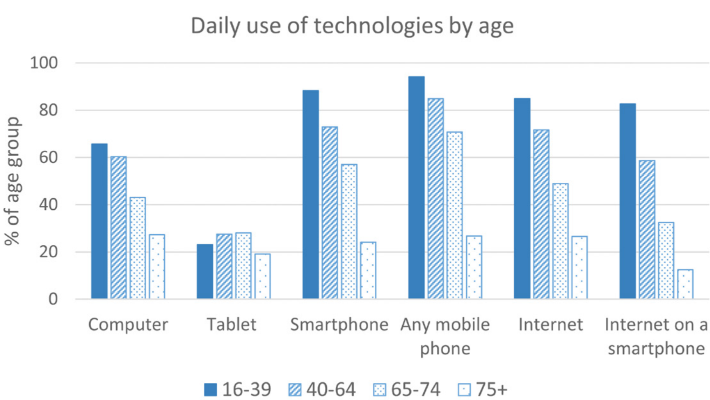


Figure 5. Percentage of age groups reporting use of various digital technologies every day or almost every day

Attitudes towards technology

The means and standard deviations for the attitude variables are shown in *Figure 8*. All of these variables decline with age, and the standard deviations indicate wide variation in all age groups.

ATI (Affinity for Technology Interaction) is a measure of personal resources for coping with technology, such as technology self-efficacy. Lower ATI values suggest lower resources and levels of engagement. The distribution of results is shown in *Figure 9(a)*. Unlike previ-

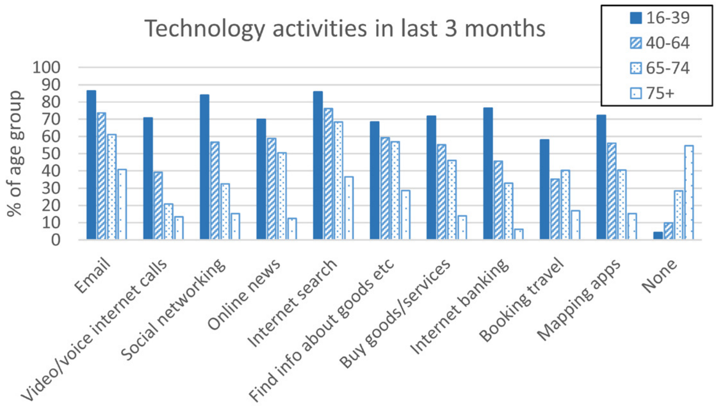


Figure 6. Percentage of age groups engaging in various technology activities in the previous 3 months

There was some difficulty coding the results for the search task. A large number (28.8%) of respondents did an action that was not one of the predetermined options. On further investigation, it seems likely that some respondents were attempting to swipe through the interface to find the event manually, rather than using the magnifying glass icon. This could result in successful (though lengthy) completion of the task. As a result, caution should be exercised when interpreting and using the results for search.

ous studies (Franke et al, 2018), the results are not normally distributed but show a slight skew towards lower affinities. To explore this further, the distribution is shown for different age groups in Figure 9(b,c,d). The youngest age group's responses (age 16-39) are skewed towards higher ATI values, while the other groups show a skew in the opposite direction, which is particularly marked in those aged 65+.

Digital competence

The proportion of each age group responding correctly to each of the 8 digital interface tests is shown in *Figure 10*. To calculate this, the researchers identified coded responses (e.g. "Tapped on the plus symbol") that they determined were likely to result in successful achievement of the relevant goal. For this purpose, responses of "don't know" were not considered to be correct. As well as indicating uncertainty, these responses may reflect a lack of willingness to explore an interface and, in practice, may result in the user giving up and failing to achieve their goal.

The total number of tests done correctly (out of 8) are shown in *Figure 11*. Due to the issue with the search task, participants with 7 or 8 tests correct can be considered to have a fairly high level of basic digital interface competence. This accounts for 41.4% of the whole sample, but only 12.4% of those aged 65-75 and 2.7% of those aged 75+. 36.6% of the sample scored 4 or less, indicating a low level of competence, and 20.9% had a very low level, with a score of 2 or less. These figures increase with age with 54.9% of those aged 65-74 having low and 36.1% very low competence. Among those aged 75+, a large majority (87.2%) had low competence and a majority (66.4%) had very low competence.

Correlations with age and gender

Correlation analyses between the technology variables and age and gender were conducted using Spearman's rank correlation coefficient as most variables were not normally distributed. They were performed 2-tailed with gender and 1-tailed with age, as a decrease in technology variables with age was hypothesized. As age, gender and digital competence (see Section 3.6) were examined on each variable, the significance threshold was reduced from $p<0.05$ to $p<0.01$. The results of correlations with age are shown in Table 4. None of the correlations with gender were significant at $p<0.01$, except for ATI (Affinity for Technology Interaction) which was $r_s = -0.165$, $p<0.01$.

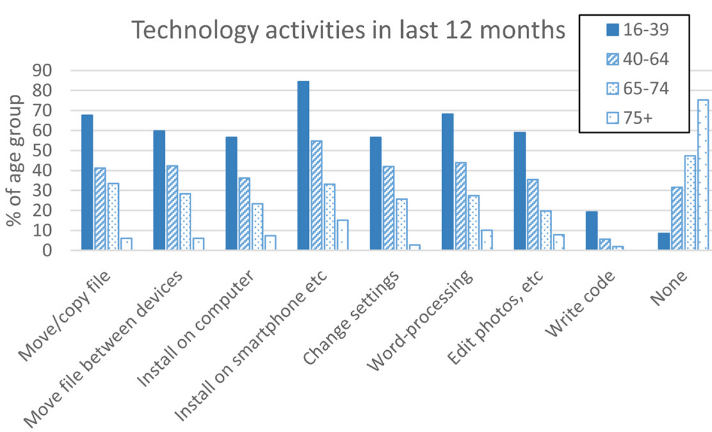


Figure 7. Percentage of age groups engaging in advanced digital technology tasks in the previous 12 months

Correlations with digital competence

Understanding what variables predict digital competence can provide further insight into digital interface exclusion. To

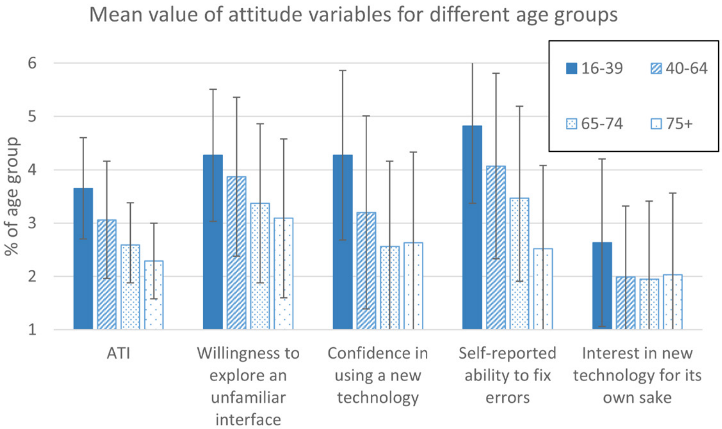


Figure 8. Mean values of attitude variables for different age groups. Error bars show standard deviation. The variables have been adjusted so that, in all cases, higher numbers correspond to more positive attitudes towards technology. Responses were given on a scale from 1 to 6, with a mid (neutral) point of 3.5

facilitate this, the following key variables were selected or created:

- Access to technology: The number of technologies the participant has access to (out of computer, internet, smartphone and tablet)
- Frequency of technology use: The number of technologies used on a daily basis (out of computer, internet, smartphone and tablet)
- Range of technology activities: The total number of technology activities (out of 18) that the participant reported doing (*Figures* 6 and *7*)
- The ATI score
- Willingness to explore an unfamiliar interface
- Confidence in using a new technology
- Digital competence: The total number of interface tests done correctly (out of 8)

Table 5 shows how the first 6 variables are correlated with digital competence. All have a significant correlation, although the strength of the correlation varies.

Discussion

Factors affecting digital interface exclusion

In line with previous work (e.g. Wagner et al, 2010; Goodman-Deane et al, 2020b), the survey found that many aspects were correlated with digital competence and thus with digital interface exclusion. These include technology access, technology use and various attitude variables.

The strongest correlation was with the range of technology activities conducted recently. This may be because a wider range of activities exposes the user to a wider range of interfaces and interface features. Previous work has suggested that "performance is affected by a person's level of familiarity with similar technologies" (Blackler

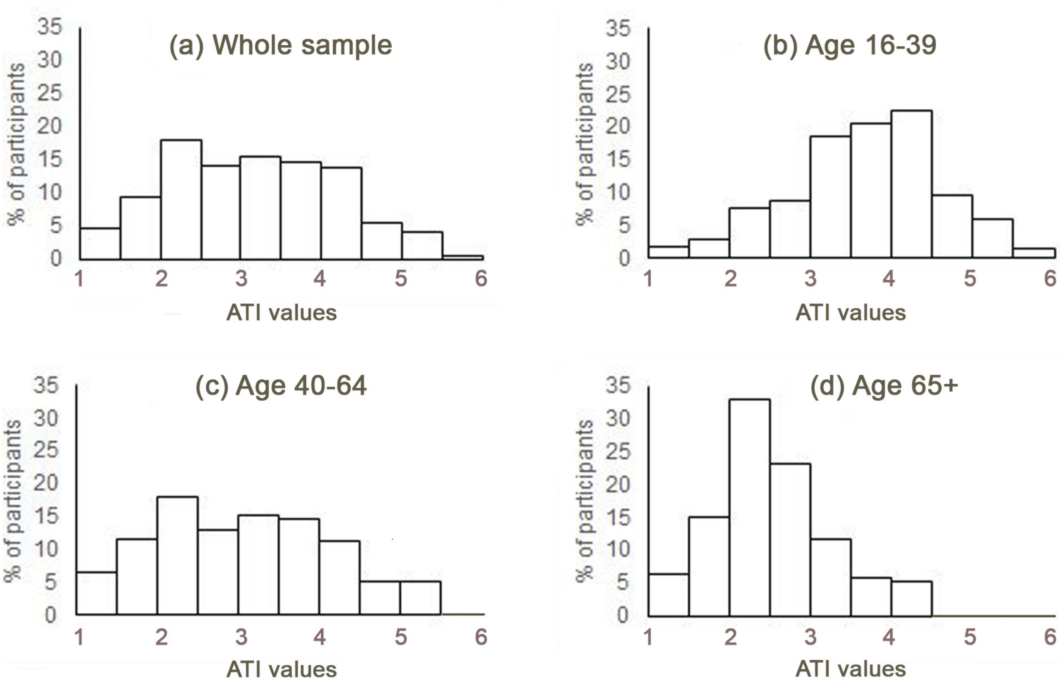


Figure 9. Distribution of ATI results for: (a) whole sample, (b) 16-39 year olds, (c) 40-64 year olds, (d) 65+ year olds

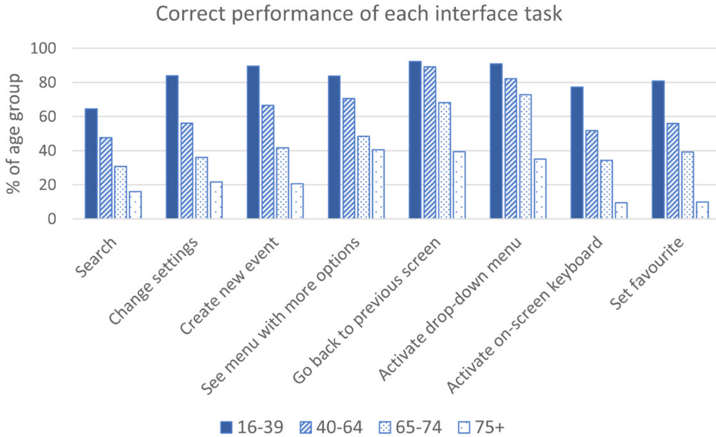


Figure 10. Performance on each of the interface tasks by age group. Note that a problem emerged with recording the results of the Search task, and caution should be exercised in interpreting those results

et al, 2010). However, previous experience can hinder as well as help, especially if the new technologies work differently (O'Brien et al, 2012). The study in this paper examined performance on very basic interaction patterns that operate similarly on many different interfaces. In this context, technology experience is likely to help rather than hinder.

Attitude variables are also very important for successful digital interface use. Reluctance to use a technology can lead to digital interface exclusion even if someone has access and ability. Various attitude variables were used in the study. In particular, ATI (Affinity for Technology Interaction) measures personal resources for coping with technology. This has been shown to have good reliability and correlate well with self-reported success in technical problem-solving (Franke et al, 2018). Another important variable is willingness to explore, which examines willingness to try out things on an unfamiliar interface. This potentially has a strong impact on success with digital interfaces where users need to explore in order to learn how to use the interface and develop mental models of how it works.

The study found that all of the attitude variables were correlated with age (to different extents) but only ATI was correlated with gender. In comparison, Franke et al (2018) found a weak correlation between ATI and age (r=-0.17, p=0.012). The correlation in the current study was much stronger and more significant (rs =-0.485, p<0.01). This could be because the current study included a quota on technology use to ensure a good representation from people with low levels of technology experience. This helps to reduce the self-selection bias whereby people with low attitudes towards technology are less likely to take part in a survey about technology. Franke et al (2018) also found a significant correlation between ATI and gender, in agreement with our survey.

Technology access and use also declined significantly with age. This is in agreement with previous work (e.g. Office for National Statistics, 2020). There are various possible reasons for this decline, including lack of motivation, lower self-efficacy and digital disengagement. In contrast, there was no correlation between these variables and gender. In comparison, some other studies have found gender differences in technology use (OECD, 2018). However, this varies greatly between different countries and is linked to income, education and socio-cultural factors. In fact, the OECD (2018) report little difference between men and women in the UK in terms of the proportion using the internet. Similarly, Hargittai et al (2019) stated that they found "no significant skill differences [in internet skills] among men and women" in their sample of older adults in the US. However, it is important to recognise that our results are specific to the UK, and other countries do have gender differences in terms of technology use and skills.

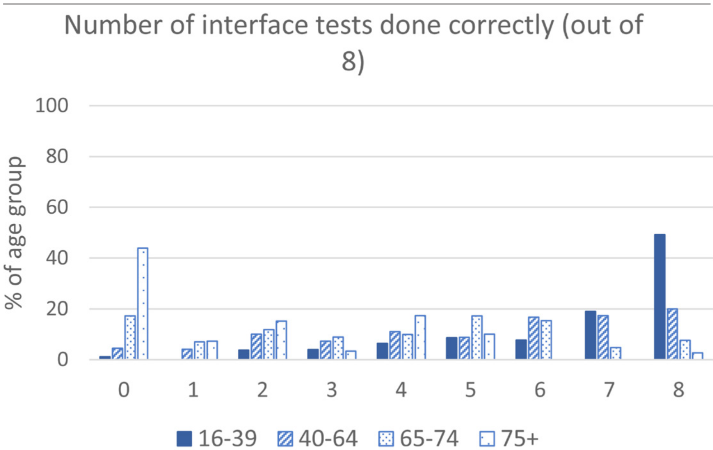


Figure 11. Number of interface tests performed correctly by age group

Digital competence

The survey found great variation in levels of digital competence.

Table 4. Correlations of technology variables with age. ns = not significant at p<0.001

Access to technologies (NB. a positive correlation indicates less access)

Computer access	Tablet access	Smartphone ownership	Any mobile phone ownership	Internet access
r_s=0.339, p<0.01	r_s=0.159, p<0.01	r_s=0.403, p<0.01	r_s=0.218, p<0.01	r_s=0.392, p<0.01

Frequency of use of technologies (NB. A positive correlation indicates less frequent use)

Computer	Tablet	Smartphone	Any mobile phone	Internet	Internet on smartphone
r_s=0.312, p<0.01	r_s=0.208, p<0.01	r_s=0.441, p<0.01	r_s=0.402, p<0.01	r_s=0.420, p<0.01	r_s=0.541, p<0.01

Number of technology activities

Number of 3 month activities	Number of 12 month activities
r_s=-0.466, p<0.01	r_s=-0.502, p<.01

Attitudes towards technology

ATI (Affinity for Technology Interaction)	Willingness to explore an unfamiliar interface	Confidence in using new technology	Self-reported ability to fix errors	Interest in new technology for its own sake
r_s=-0.485, p<0.01	r_s=-0.243, p<0.01	r_s=-0.399, p<0.01	r_s=-0.408, p<0.01	r_s=-0.248, p<0.01

Interface tests

Search	Change settings	Create new event	See menu	Go back	Drop-down menu	On-screen keyboard	Set favourite	Total correct
r_s=-0.334, p<0.01	r_s=-0.431, p<0.01	r_s=-0.459, p<0.01	r_s=-0.331, p<0.01	r_s=-0.338, p<0.01	r_s=-0.321, p<0.01	r_s=-0.429, p<0.01	r_s=-0.445, p<0.01	r_s=-0.553, p<0.01

37% of the sample scored 4 or less on the digital competence tests, indicating that they are likely to struggle on many smartphone (and other) interfaces. In fact, 21% scored 2 or less and are likely to find things extremely difficult. In contrast, 41% scored 7 or 8, indicating a fairly high level of basic digital competence. It should be remembered that the interface tests were very simple, and thus a score of 7 or 8 does not necessarily imply a high level of competence at using more complex interfaces. These results show that low digital interface competence is not a niche issue but one that affects large numbers of people.

Digital competence was significantly correlated with age. This agrees with other work on digital competence, which used self-report measures and symbol recognition tests (e.g. Roque and Boot, 2018; Hargittai et al, 2019). This survey adds to previous work by examining actual performance on basic interface tasks.

The very low levels of performance in older age groups are particularly notable, especially in those aged 75 and over. 36% of those aged 65-74 and 66% of those aged 75+ got 2 or fewer tests correct, indicating very low digital competence. In fact, 17% of those aged 65-74 and 44% of 75+s got no tests correct at all. In comparison, just 5% of those under 40 scored 2 or less, and only 1% got no tests correct. The results highlight a huge disparity in digital interface competence between younger and older age groups.

Examining digital competence directly provides a fuller understanding than just looking at technology access or use. Simply looking at the latter can give an overly positive picture of older adults' digital capabilities, especially if (as is commonly done) those aged 65+ are considered as a single age group. For example, the survey in this paper found that 41% of those aged 65+ used the internet daily or almost every day. However, only 33% scored 5 or above (out of a possible 8) on the performance tests, indicating a moderate or high level of digital competence. This figure drops to 13% in those aged 75+.

In contrast to age, there was no correlation between digital competence and gender. This is in

Table 5: Correlations of key variables with digital competence. All the calculations are done using Spearman's rank correlation coefficient (1-tailed)

	Access to technology	**Frequency of technology use**	**Range of technology activities**	**ATI**	**Willingness to explore an interface**	**Confidence in using a new technology**
Digital competence	r_s=0.507, p<0.01	r_s=0.517, p<0.01	r_s=0.674, p<0.01	r_s=0.463, p<0.01	r_s=0.339, p<0.01	r_s=0.438, p<0.01

line with the findings on technology access and use and with Hargittai et al (2019)'s work on digital competence.

Measuring digital competence

The survey used a simplified paper prototyping method to measure basic digital competence. This method has both advantages and disadvantages compared to testing on real interfaces. On the negative side, it does not replicate certain gestures very well, such as swipe or press and hold. In addition, it does not allow the user to explore an interface and try out different actions. This can be mitigated to some extent by careful selection of the tasks that participants are asked to do. For example, in the survey, tasks were chosen in which success was largely dependent on a single tap of something currently visible on the screen. Further work has explored how well these prototype tests correspond to performance on real interfaces, with initial results indicating a good correlation between these. There are also some advantages to the method. In particular, it is simple and can be rolled out large-scale in on-street surveys without specialized equipment.

As such, it may be more comparable to the use of questionnaire scales. Some of these ask participants to self-report their ability on digital tasks (see Oh et al, 2021). This enables the exploration of a wider range of and more complex technology tasks. However, it relies on self-report and does not provide the detail on individual interface components which is valuable for informing design. Other questionnaires ask about knowledge of computer symbols and terms (e.g. Sengpiel and Dittberner, 2008; Hargittai and Hsieh, 2012). While valuable, these provide a less direct assessment of digital competence and require participants to recall symbol meanings out of the context of an interface.

Addressing digital interface exclusion

The results on the individual performance tests indicate people's level of familiarity with some common interface patterns that form the basis of many digital interactions. By examining which of these patterns are present in a particular digital interface, we can use this data to build an understanding of who is likely to struggle with the interface and why (Bradley et al, 2018).

The levels of success on the individual tests vary, with 82% of the whole sample getting the backtracking test correct compared to 54% on the onscreen keyboard task. Levels of success on all tests are lower in older age groups, but the differences between tests are still apparent. 39% of those aged 75+ went back to the previous screen correctly, while 10% activated the onscreen keyboard correctly. It is thus important not to assume that because simply someone can use one interface pattern that they will also be able to use a different one. This applies even if those patterns seem to be of similar complexity, at least to a tech-savvy designer.

The reasons for the performance differences between tests are uncertain. Some patterns may be more intuitive than others. Another consideration is that some interface patterns (e.g. backtracking) are common on many digital devices, while others (e.g. onscreen keyboards) are only used on touchscreens. The former may be more familiar to people who have used computers but not touchscreens such as smartphones. This applies particularly to older people – 27% of those aged 75+ reported never having used a smartphone but had used a computer at some point, compared to 14% of the population as a whole. As a result, we suggest that particular care should be taken with patterns that are different on smartphones than on computers, such as bringing up an onscreen keyboard.

The data on basic digital competence could be combined with the results on attitudes and the technology activities that participants have performed to estimate the numbers likely to be excluded from more complex interfaces. Work on developing a method to do this is currently underway.

Limitations

There were some issues with coding the responses to the search task, meaning that caution should be exercised when interpreting the results for this task. As a result, the pre-determined response options to this task have been modified in later versions of the questionnaire.

Another limitation is the small size of the sample (n=338). Nevertheless, the use of quota sampling on a variety of variables means that the survey has good population coverage and is as representative as possible given its size. Thus, it can provide a good indication of how the factors affecting digital interface exclusion vary across the population. A revised version of the questionnaire is currently being used in larger samples across various European countries to provide more reliable data. Conducting the survey in a range of countries will also provide insight into how technology experience and competence vary between countries. It is expected that results will be very different in countries with different levels of education and development.

The fast pace of technology change also presents an issue, as survey results rapidly become dated. Nevertheless, these results can help designers to understand the current situation. The questionnaire has also been designed to be relatively simple and quick to administer, so that it can be used in the future to obtain updated information. In addition, it incorporates questions from other surveys that are conducted on a population level on a regular basis (e,g, Office for National Statistics, undated). It may be possible to use the data from new versions of these surveys to examine how aspects in this survey change over time.

Conclusions

This paper presents results from a survey that examined various factors that affect digital interface exclusion, including direct measures of basic digital competence. It found that surprisingly large proportions of the population have low or very low digital competence (37% and 21% respectively). Technology access, use, attitudes and competence all declined with age, with particularly low levels in those aged 75 and over.

It is thus important not to assume that users are familiar with digital interface patterns, especially when designing for target groups that include older people. This includes basic interface patterns that are commonly used in digital interfaces today. Particular care should be taken with patterns that are different on smartphones than on desktop computers, such as bringing up an onscreen keyboard. It is also important to take into account that many older people have low levels of willingness to explore an unfamiliar interface. For example, interfaces could guide users clearly through tasks rather than expecting them to try things out to learn what they do and how they function.

In further work, the survey results have been used to develop a set of personas to help designers understand the range of users' technology experience and competence (Goodman-Deane et al, 2021). In addition, a revised version of the questionnaire used in this survey is currently being conducted in other European countries as part of the Dignity project (Isinnova, undated). This provides a wider picture of digital exclusion. Further work will develop methods for assessing the level of digital exclusion of an interface based on how many people in the population lack the access, experience, attitudes and competence to use it successfully.

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