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Influencing technology adoption by older adults

Vicki L. Hanson *

School of Computing, University of Dundee, Dundee DD1 4HN, Scotland, UK

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A B S T R A C T

With the advent of a digital economy, an emphasis on digital products and services has emerged. Those who are not using current technologies will become excluded, however, from this revolution. Older adults represent one such group in danger of exclusion. In some cases, older adults have been disinterested in new technologies. In other cases, however, the technologies fail to take into consideration the strengths and weaknesses of older users that would promote this usability. This paper examines components of information search by younger and older adults. These are considered in terms of long-term implications of designing for older users, with current problems viewed as foreshadowing future trends.

1. Introduction

Much has been written about older adults' lack of adoption of current technologies. Studies published even within the past year show a lower degree of technology adoption by older adults than by those under the age of 65 (Ofcom, 2009; Jones and Fox, 2009). Moreover, for those older adults who do use computers, mobile phones, etc., the level of access is not equal to that of younger users. For example, older adults often access the Web using outdated equipment (often these are "hand me ups" from adult children who have upgraded). These older machines are limited in the types of applications they can run when compared with current machines.

A digital economy holds the promise of improved delivery and lower costs for services and products. Access to these products and services, however, rests on ability to use the required technology. At present, this move to digital interactions has resulted in a situation in which a large number of potential users are excluded from participation. Access to broadband coverage is a first requirement to being able to utilize digital services. Interestingly, such coverage has recently become a 'legal right' in Finland, perhaps heralding such moves by other countries (Finland makes broadband a 'legal right', 2010). Broadband availability, however, is only one aspect of what will be needed for widespread participation in a digital economy. Usefulness and usability of the services themselves are also crucial. Given the relative lack of uptake of new technologies by older adults, it is worth revisiting questions of usefulness and usability as factors directly influencing technology adoption (Davis, 1989; Zajicek, 2007).

1.1. Perceived usefulness

Formulations of the design process stress the importance of the *value* or *worth* of offerings (Cockton, 2005, 2006; Norman, 2005; Sellen et al., 2009). In this, the emphasis is on creating services and systems that users perceive as worthwhile – in short, systems that are useful. This strikes a responsive chord particularly for older users. Older users not inclined to adopt technology simply for the sake of being current (Ofcom, 2009; Zajicek, 2007; Horrigan, 2009; Melenhorst et al., 2006; Selwyn et al., 2003). Rather, the technology must address a need or interest. Simply stated, it must be perceived to be useful.

The idea of understanding user values by involving them from the earliest stages of development is not new. One well-stated description of this ideal was given by Gould and Lewis in 1985 who talked about the need to understand users when designing a new product (Gould and Lewis, 1983). Despite such recommendations that form the core of participatory research, Gould and Lewis found that these recommendations often were not followed by designers who undervalued the opinion of users or considered their own experience more relevant.

Older adults' views typically are not at the core of design decisions. The result is large numbers of older adults perceiving that current technologies serve no useful purpose for them. New technologies and new technology applications are primarily built by young(er) developers, taking into account the culture and skills of those developers. As has become apparent, this approach has resulted in a number of older adults being disengaged.

Coleman et al. (2010) recently reported on work that emphasized usefulness as a key motivator for technology adoption. These researchers interviewed a number of older adults (all over age 65) who had little or no interest in using computers. In these informal

* Tel.: +44 01382 386510; fax: +44 01382 385509.
E-mail address: vlh@computing.dundee.ac.uk

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interviews, people chatted about their lives and their technology experiences. Several of their informants had tried using computers, but gave it up for a variety of reasons. In general, they did not find that the effort to learn and keep up (constant software upgrades) was worth it for them. Most believed, however, that they could learn to use computers if they wished to do so. They simply indicated that they did not have the interest in investing the energy needed to learn about computers and computer applications. This was despite the fact that nearly all had needs for which technology could be used.

The context for use also is vital for older adults. The older adults interviewed by Coleman et al. said they had to understand how the technology would fit into their lives and how it would serve a need not otherwise met. In this respect it is important to understand that traditional technologies, such as the phone, are valued over new technologies such as Skype. While it is possible to argue benefits of Skype from a financial perspective, that argument only makes sense for people already digitally connected. For those not connected, the start-up costs (both the financial costs and the learning costs) are so unattractive as to not make the service interesting.

It is important to make technology that these potential older users deem worthwhile and, in some sense, is needed in their lives. It is clear that this population of non-users will not become adopters until we change their perceptions about the usefulness of technology or until technology itself changes to better address their interests and needs.

1.2. Usability of technology

Today's high-paced use of multi-channel forms of technology is a far cry from interaction norms of the past. It is not uncommon for teenagers to simultaneously be listening to music, have the television on, and participating in multiple conversations (text or IM) while perusing Facebook. For older users, such multi-tasking would be unthinkable. As neuroscientists investigate possible changes to the brain resulting from such multi-sensory multi-tasking (Small and Vorgan, 2008), computing professionals deal with questions of how to design for differing generational requirements.

Much of the work on older users of technology has focussed on the lack of technology experience, with an emphasis on technology training and designing for novices (Newell et al., 2006). This is the experience approach, with attention to the fact that many older adults are technology novices. Today's tech-savvy younger users, emphasizing their experience, do not expect to have difficulty with technology when they become old. Technology, however, is not static. In fact, technological changes are occurring at an accelerating pace, suggesting that technology 20 years from now may little resemble devices and interfaces currently available. While some changes are gradual and may not pose challenges for today's generations as they age, other changes may be major shifts or breaks with current systems, requiring that users understand completely new procedures for accomplishing currently unforeseen tasks. In such cases, it may be difficult for aging users, despite past technology experience, to use the new systems (Hanson, 2009; Monk, 2009).

In addition to lack of experience, older adults may also experience age-related perceptual, motor, and cognitive changes that affect their use of technology. It is well known that aging brings about changes in a person's abilities (Monk, 2009). For example, vision changes will cause most of us to begin to use glasses (often bifocals or trifocals) even if we have not previously done so. For others, vision changes will be more severe, creating obvious difficulties in learning and using technologies. Even the less severe vision losses create obstacles, however. Bifocals, for example, require the wearer sit at a computer in an awkward position, often resulting in shoulder and neck pain.

Age-related perceptual and motor changes have been extensively researched and both mainstream as well as assistive technologies has been developed to accommodate these changes. For example, the major Web browsers have facilities that allow users to enlarge text size of page content and it is not uncommon for individual websites to offer the option to change font size for their pages.

Emerging as a little understood although important factor in technology use for older adults is cognitive ability. Problems related to access and usability for people with vision, hearing, and physical disabilities are far from being solved, but are better understood than technologies needed for cognitive disability (Arch, 2009). Guidelines exist that describe how to enable Web content to make it accessible to people who have difficulty using a mouse or keyboard, people who have low vision, and people who are screen reader users (Brewer, 2003). Admittedly not all problems are solved for these users, but there is a basic consensus of the needs of these users.

In contrast, there is little consensus as to how to support the cognitive declines that accompany aging (Czaja and Lee, 2007; Craik and Salthouse, 2000; Park, 1992; Rabbitt, 2006; Willis and Schaie, 2005). In considering this topic, it seems one fruitful approach might be to reflect on different cognitive abilities considered part of *fluid intelligence* or *crystallized intelligence.* Both are part of a general intelligence as differentiated by psychologists, but the two are broad categories that cover separate cognitive abilities. Understanding the various cognitive abilities of older users has the potential to influence our design of technology.

Fluid intelligence refers to a set of cognitive abilities that includes short-term memory, speed of processing, and problem solving ability. Critically for older adults, these abilities are associated with aptitude for learning new technologies. Declines in fluid intelligence are common with age. While these declines vary from individual to individual, population data shows a steady decline of these abilities as we enter what would be defined as old age (Czaja and Lee, 2007).

Difficulties that older adults have with Web navigation (such as using browser Back, History, Bookmarks, and Search facilities) and dynamic content changes ("change blindness") can be understood as activities that tax fluid intelligence components of cognition (see for example Chadwick-Dias et al., 2007; Grahame et al., 2004; Meyer et al., 1997). Not surprisingly, measures of fluid intelligence abilities are strong predictors of Web use among this population (Czaja et al., 2006; Czaja et al., 2010). Older adults who measure high on tests of fluid intelligence engage in more types of Web activities (such as e-mail, games, news information, and shopping) than those who measure low on these tests.

Differentiated from fluid intelligence, crystallized intelligence commonly remains intact throughout one's lifetime. It is measured through tests of verbal ability and reflects knowledge that we have gained through education and experience. Recent work has suggested that crystallized intelligence abilities may help older computer users. Fairweather (2008) examined the navigation paths of a group of users (ranging in age from 18 to 73 years old) in a task requiring a search for job openings in an online newspaper. All participants had at least 1 year of experience with the Web. Results indicated that the older and younger participants were not differentiated by their success on this task, but they were differentiated by how they arrived at the solutions. Specifically, their paths through Web pages followed different courses. Fairweather noted that the solution for the task relied a great deal on participants' specialized knowledge, experience, and vocabulary about the domain, all of which are aspects of crystallized intelligence.

Other work has similarly suggested that the *type* of problem may affect the information seeking ability of older Web users (Sharit et al., 2008; Chin et al., 2009; Chin and Fu, 2010). Chin et al. (2009), for example, compared younger and older adults in two types of Web tasks. The first task was an ill-defined task that required participants to seek information about health questions. An example of an ill-defined task was "A person feels pain and stiffness in his/her body and has trouble moving around." Participants used the Web to gather more information regarding these symptoms, prevalence of illness, and any other related information. The second was a well-defined task in which participants were given a specific medical term and used the Web to find a page that contained this target term.

Chin et al. (2009) investigated performance in these two tasks in relation to results obtained in a battery of tests measuring fluid and crystallized intelligence. Their results indicated differences in ability due to task demands. Specifically, there was an interaction of age by task success. Younger adults had faster processing speed, better visual attention, larger working memory capacity and used a bottom-up, exploratory search strategy. They performed better than the older adults on well-defined tasks. In contrast, older adults scored lower on fluid intelligence measures, used more focused search strategies, made decisions more carefully, and spent more time processing, comprehending and integrating information. They performed better than the younger adults on the ill-formed tasks that relied in large part on abilities associated with crystallized intelligence.

2. Experimental studies: searching for information

The present research was designed to add to our understanding of the strengths and weaknesses that older adults bring to technology use. The specific instance of technology studied in the current research is that of seeking information on the Web. The work specifically examines complex problem solving using both well-defined and ill-defined problems.

Two experiments are presented in which younger (age 30 or younger) and older (age 60 or older) participants are given tasks and asked to search the Web to find the answers to these problems. In the first experiment, all participants began on a Web search page (Google) and information about their search queries was examined. In the second experiment, information seeking in both well-defined and ill-defined tasks was examined.

An eye-tracking apparatus was used to gather data about several aspects of participants' Web browsing behaviour (such as key clicks, times, and pages viewed). To date, there have been a limited number of studies that have used eye tracking with older adults. This early work suggests that older users differ from younger ones in terms of longer fixations, overall viewing time, and gaze distribution over more areas of a page – particularly navigation areas (Fukuda and Bubb, 2003; Tullis, 2007). The present work involved more complex Web browsing tasks, with an emphasis on problem solving results.

2.1. Experiment 1

Experiment 1 was designed as a typical Web search task. Participants in the study were asked to use a standard Web search engine and formulate a query to find the answer to a problem. Based on previous research, it can be anticipated that the older participants might be take longer to solve problems, visit more sites, and be less likely to find solutions than the younger participants (Sharit et al., 2008; Chadwick-Dias et al., 2007; Grahame et al., 2004; Meyer et al., 1997).

2.1.1. Method

Research participants were eight older adults and seven younger adults. Due to equipment failure, the data of one of the older participants was lost. Results, therefore, are reported for seven older adults (three of them male) and seven younger adults (five of them male). Older participants were more than 60 years old; younger participants were between 18 and 30 years of age. Older participants were recruited through a research pool established at the University of Dundee (SiDE: social inclusion through the digital economy, 2010). Younger participants were recruited through a university-wide advertisement for research participants, with some participants referred through friends who had participated. All participants reported that they were regular Web users.

Participants were individually tested in sessions lasting no more than one hour. In most cases, the sessions lasted less than half an hour as participants completed the tasks quite rapidly. Each session began with the experimenter explaining that the study, the lab set-up, and getting informed consent. Participants were told that their eye movements and input would provide the key information collected in the research and the eye tracking calibration process was explained. Participants were informed that they should sit comfortably and maintain their posture throughout the testing so that the equipment would register their eye movements.

The search tasks were run on a Tobii X120 Eye Tracker using the Internet Explorer (Version 7) browser. Eye tracking was re-calibrated for each participant before each task. Following calibration, each task involved the presentation of onscreen search task instructions. Participants were allowed to take as long as they wished to read the instructions. When they were ready to perform the search task, they were instructed to press the space bar to bring up the start page, google.co.uk.

Eye movements, viewing times, mouse clicks and key presses were recorded. The following four search problems were used:

- *Haiti:* "Using the Internet, find out how to contribute to the victims ofthe earthquake in Haiti."
- *Book:* "Search the Internet to find the cost of a book by Peter Irvine call *Scotland the Best*, published in 2007."
- *Weather:* "Search the Internet to find out the weather in Inverness forthe next 7 days."
- *Shopping:* "Find a winter coat in the sales that you might like."

Participants were instructed to press the Escape key when they had found the solution.

On initial inspection of the data, it became evident that two of these tasks produced spurious results. First, the weather question proved surprisingly difficult for both older and younger participants. While they easily found weather forecasts, few provided the 7-day forecast as their answer. Second, the question about purchasing clothing turned out to be highly influenced by each participant's interest in shopping. The older men, in particular, tended to simply stop after finding any coat for purchase. In contrast, the shoppers (primarily the younger participants – male and female) tended to scour page after page searching for the perfect coat. Thus, the strategies for this search seemed more influenced by shopping interests than by general search abilities. Therefore, the results of the weather and shopping questions were not included in further analyses.

2.1.2. Results

In all cases, participants found the correct solution in their search. Reported data, therefore, is on the number of pages viewed, page viewing times, mouse clicks, and eye gaze patterns. The eye tracking software also provided a video replay of performance on each task, allowing for detailed investigation of participants' paths through each problem.

The number of pages viewed by younger and older participants was similar, yet the older adults took longer in their searches. More detailed explorations of the data were undertaken to understand these findings.

Table 1
Shown are results for younger and older participants for the two search tasks in terms of mean number of urls visited, mean time on the initial search page (in seconds), and mean time in total on all other Web pages (in seconds).

	Mean # urls	Mean Sec search page	Mean Sec other pages
Younger	4.9	9.9	33.9
Older	5.0	23.6	61.1

Table 1 shows the mean number of pages (urls) viewed by the younger and older participant groups. This number includes the initial google.co.uk search page. An analysis of variance (ANOVA) on the between subjects factor of participant group (older, younger) and the within subjects factor of task (Book, Haiti) for number of pages found no significant main effect of the number of pages viewed by younger and older participants, $F(1,12) = .02$, $p > .50$.

In terms of time spent on the search task, times on the initial query (the starting google.co.uk page) and all other visited pages were analysed. Shown in Table 1 are the mean times on the opening search page and the mean total time spent on all other visited pages. For the initial search page, the ANOVA found that older participants took longer than the younger participants, $F(1,12) = 7.89$, $p < .05$. Although the mean times of all other pages visited appeared longer for the older adults, the large variability in times resulted in no significant difference in time to solution for the two groups of participants, $F(1,12) = 1.94$, $p < .05$.

Analysis of the video replays, mouse clicks, and key presses showed factors that distinguished the search behaviours of younger and older participants. The older participants were more likely than the younger ones to use the Google listbox and "Google Search" button. Younger users were most likely to type in their search terms then press the <enter> key. This difference in patterns can be seen in Figs. 1 and 2, showing relative gaze durations of younger and older participants on the Haiti task. As shown in Fig. 2 the older users spent a relatively long time looking at the beginning of the search field as they formulated their query. Mouse clicks are superimposed on these maps. These mouse clicks represent one click in error (on the insertion bar) for both a younger and an older participant, clicks on the "Google Search" button (three by older participants), and clicks on listbox items (one for and older participant and two for younger). In addition, one older participant clicked on their typed string to correct a spelling error.

Even when using the listbox, the younger participants did not exhibit the same response pattern. The two younger participants who used listbox suggestions did so by selecting from among the list of presented items, clicking on a desired string when they saw it appear in the list. In contrast, the older participants tended to continue typing until their typed string matched one of the search term strings from the listbox. When their typing was thus confirmed by a string from the listbox, they selected the term. In sum, while younger participants selected search terms from a large displayed list, the older participants continued typing until the list was narrowed to one item.

A couple of reasons are likely responsible for older participants' use of the listbox in this manner. One reason might be a perceived need by older users to get help in selecting search terms. From this group of older users, that did not seem the likely cause. Most did not have difficulty formulating queries under the experimental conditions and appeared to use the listbox as a type of confirmation for their queries. Another possibility is that difficulties with typing caused these participants to often rely on a strategy of selecting from choices. This last alternative gains support when looking at the keystrokes of younger and older users. The older participants more often corrected their typing and were slower in

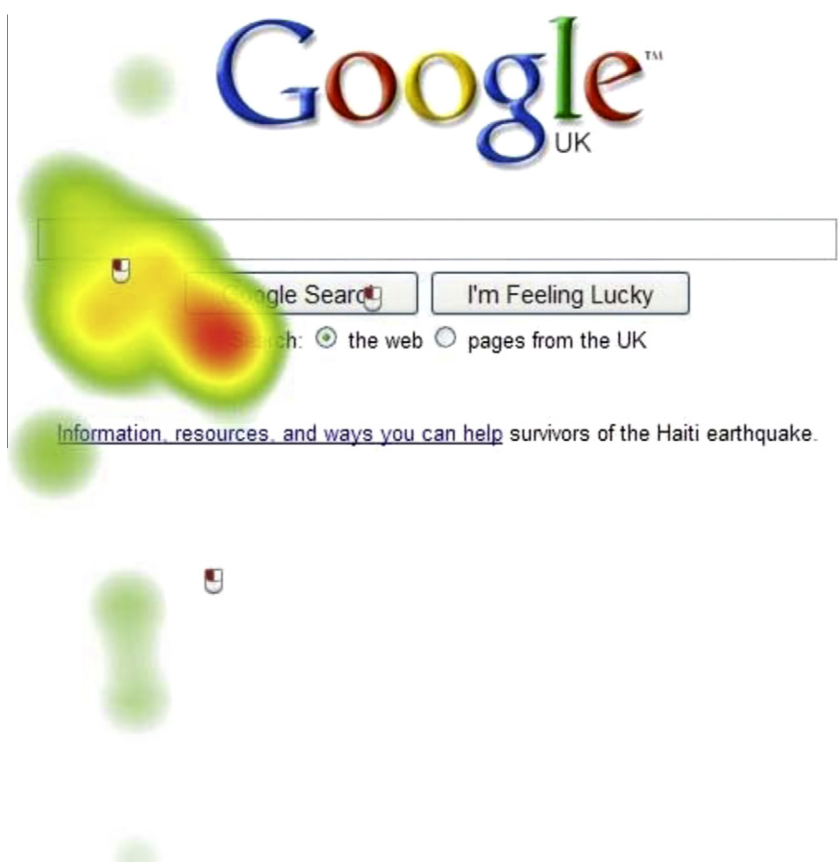

Fig. 1. Heatmap showing the relative viewing times of younger participants' viewing of search page in Haiti task. Also shown are left key mouse clicks.

Fig. 2. Heatmap showing the relative viewing times of older participants' viewing of search page in Haiti task. Also shown are left key mouse clicks.

their error-free typing than the younger participants. The longer times on the Google page are reflective of these typing difficulties. Finally, it is possible that the older participants did not realize that they could select from the larger listbox choices. If they thought that they had to click the Google Search button, they would not be able to do this until their choices were narrowed – a long listbox hides the search button.

The Haiti problem proved easier than the Books one. The ANOVAs showed main effects of problem for number of pages visited, $F(1,12) = 5.62$, $p < .05$, and time on the non-search pages, $F(1,12) = 7.7$, $p < .05$. As shown in Table 2, participants viewed fewer pages on the Haiti task than the Books task and, related to this, they took less time on the task. Interestingly, there was no significant time difference on the two tasks for the initial query (the google.co.uk page), $F(1,12) = 2.86$, $p > .05$. There were no interactions of group X task in any of the ANOVAs, all $p > .05$.

It is worth mentioning that none of the participants, younger or older, seemed to notice that the Google page at the time was displaying a link just below the search entry field related to the Haiti earthquake. Figs. 1 and 2 show this page with the link displayed for "information, resources, and ways you can help survivors of the Haiti earthquake." None selected it.

2.2. Experiment 2

Experiment 2 was designed to consider the issue of well-defined and ill-defined tasks. Using the same measurements as in Experiment 1, components of task completion are examined. It is expected that the performance of older and younger adults will be more differentiated on well-defined than on ill-defined tasks (Fairweather, 2008; Chin et al., 2009) (cf Sharit et al., 2008).

Table 2
Shown are results for the two search tasks in terms of mean number of urls visited, mean time to solution (in seconds), and mean time on initial search page (in seconds).

	Mean # urls	Mean Sec search page	Mean Sec other pages
Books	6.1	14.0	69.2
Haiti	3.7	19.6	25.9

2.2.1. Method

The search tasks were again run on a Tobii XI20 Eye Tracker using the Internet Explorer browser. Sessions were conducted as described for Experiment 1, except for the particular problems to solve. To become familiar with the equipment, a practice session was added. This practice session included four Web search problems, asking participants to find information on the university's School of Computing website. That data from these practice tasks was not analyzed. Following this, participants were presented six Web search problems. The order of problem presentation was varied for each participant.

Of the six problems, three would be described as well-defined and three as ill-defined. An example of the well-defined problem is the following: *"The Beatles came to Dundee in 1964. Using the Scottish Screen Archive find information about the film of this event.*"

An example of an ill-defined problem is: *"A person living in Aberdeen has some spare time and is looking to do some voluntary work. They have good people skills and an interest in the environment. Using the Guardian website find some job opportunities for them.*"

For each of the six problems, participants were given the starting url for the site mentioned in problem statement. That is, for the well-defined example above, the starting page was http://ssa.nls.uk/index.cfm For the ill-defined example, the starting page was http://jobs.guardian.co.uk/. A complete listing of the six problems is given in Appendix A.

Participants were instructed to bookmark their findings when complete. These bookmarks were cleared after each participant session.

Participants were five older adults all age 60 or greater (three males) and six younger adults ages 18–30. Due to equipment failure, the data of one of the younger adults was not recorded, resulting in five younger participants (three males). All were recruited in the same manner as those for the previous experiment.

2.2.2. Results

As in Experiment 1, older and younger participants were not differentiated by their accuracy in finding solutions. The older adults, however, sometimes took longer on the tasks, although they did not necessarily access more Web pages to get the

Table 3
Shown are results for younger and older participants for the two types of search problems in terms of mean number of urls visited, mean time to solution (in seconds), and the number of errors on the task.

	Mean # urls	Mean Sec to solution	# Errors
Well-defined			
Younger	7.2	177.5	2
Older	6.7	211.6	3
Ill-defined			
Younger	7.1	178.8	2
Older	9.1	231.8	2

solutions. Critically, the anticipated differences in solving well-defined and ill-defined problems were not found.

Table 3 shows the mean number of pages (urls) viewed, the mean time on task, and the number of failures to solve for the younger and older participant groups. ANOVAs resulted in no significant differences (all p's > .05) between the number of urls visited or number of errors (failures to solve) for the younger and older participants for either well-defined or ill-defined problems. In addition, there were no main effects to indicate that the older adults took consistently longer than the younger participants. There was, however, a significant interaction of age group by problem for times on the ill-defined tasks, $F(2,16) = 4.22$, $p < .05$. Specifically, for one of the three ill-defined problems the solution times of the older participants (Mean = 386.78 s) were significantly longer than those of the younger participants (Mean = 144.01 s), $t(8) = 2.61$, $p < .05$. The problem that elicited this time difference was the one about voluntary work given as an example above.

Finally, there was a main effect of problem for the ill-defined problems, $F(2,16) = 7.06$, $p < .01$. This main effect reflected the fact that across the two groups the Art problem took less time to solve than the other two ill-defined problems (see Appendix A).

3. Discussion

The experiments reported here examined behaviours distinguishing younger and older adults in their performance of tasks that required them to seek information on the Web. There is an emphasis in the literature on problems experienced by older adults when using technology. The current results found some differences in the performances of younger and older participants, but the overall impression is of competence among this older population. A number of performance measurements suggest this conclusion.

First, participants in both studies were able to find solutions to the search problems they were given. There were few failures among participants in either group. It can be argued that with harder problems such differences might become apparent. The types of problems used in these two experiments, however, were typical of the types of searches that people perform on the Web and the results were consistent other findings with experienced Web users (Fairweather, 2008).

Older adults, however, may take longer to find solutions. Consistent with previously reported work (Meyer et al., 1997), older adults in the present two experiments tended to take longer on tasks than did the younger participants. In Experiment 1, using tasks that began on a search page, it was found that time for the initial query on the opening search page differentiated younger and older participants. The older participants most often typed strings of words in the Google Search field until they got a match in the listbox, and then they clicked the Google Search button. The younger participants predominantly typed in a search string then pressed the <enter> key. In Experiment 2, using tasks that involved finding information from specific websites, it was found that the problem to be solved, not general page viewing times, differentiated younger and older participants. Taken together, these results show the emergence of a complex pattern in which a number of specific factors appear to influence the time taken by older adults in Web searches.

On the tasks used in these two experiments, the older participants did not need to browse more Web pages than the younger participants before finding a solution. This finding may well have been a function of their relative experience. In contrast are results from a study with novice Web users, Meyer et al. (1997). In that study, older participants were far less efficient than the younger participants, even after training, in finding information on the Web. They required more steps to solution, more often returning to the Home page and exploring all links than their younger counterparts. The results of the current study must all be interpreted within the context of the participant characteristics. Specifically, all study participants were recruited based on the fact that they were regular users of the Web. It is not necessarily expected that older adults who are technology novices would exhibit the same search behaviours. It remains for future work to understand the differences between novice and skilled older adults in such tasks.

Anticipated overall differences in well-defined and ill-defined problems were not found in Experiment 2. The number of participants in this experiment was small and potential differences may not have been detected. For one of the ill-defined problems, however, the older participants took significantly longer to solve than the younger participants. This is contrary to the expectations based on the Chin et al. who found better performance by the older than younger participants on ill-defined tasks (Chin et al., 2009). It is consistent, however, with Sharit el al. who found the opposite – that older adults performed more poorly than younger ones on ill-defined problems (Sharit et al., 2008).

It seems worth exploring in more detail the specific types of tasks that prove difficult for older adults and those that appear to allow older users to apply their knowledge to problem solutions. Fairweather' s ill-defined task required integrating experience and vocabulary to find a solution to an online job search (Fairweather, 2008). The problems of the present study were more far ranging in topic, but the particular difficulty exhibited by older adults was on the problem related to online searching for job information. The problems used by Chin et al. were all health-related ones (Chin et al., 2009). Although the authors controlled for health knowledge in their younger and older participants, it still may be the case that there were aspects of health experience that contributed to solving the ill-defined tasks that were not measured by the authors' health literacy questionnaire. For the Sharit et al. study (Sharit et al., 2008), the well-defined tasks required finding a website that dealt with specific age-related issues, while the ill-defined tasks involved health questions similar to those of Chin et al. Sharit et al. found overall knowledge to be a predictor of performance on their ill-defined, but not well-defined tasks. In sum, it seems that there is no ready answer to predict success in Web searching for older adults. The classification of well-defined (simple) and ill-defined (complex) tasks may be too simplistic, needing to be augmented by understanding the specific knowledge that individuals bring to a search task.

Although Tullis (2007) found that older users were more likely than younger ones to view numerous aspects of Web pages, the current work did not uncover the same pattern. In that study, older adults (ages 50–69) spent more time viewing nearly all Web pages than did the younger participants (ages 20–39). They spent more time viewing both upper and left-side navigation areas on pages than the younger users. They read more text on pages than younger users. Overall, they looked at parts of the Web pages that younger users seemed simply to ignore. It is difficult to make strong conclusions about this aspect of the current work, however, due to the differences in Web pages viewed. Unlike the Tullis study, participants did not view pre-defined pages. Participants viewed different pages depending on the search terms they entered, making direct comparisons of specific page viewing difficult.

Finally, given the limited number of previous studies that have reported on using eye trackers with older adults, it is worth mentioning procedural issues with older adults. Overall, the apparatus worked well with the older participants. Calibration between each problem task was necessary as participants tended to shift their position upon completion, particularly as they interacted with the experimenter. The one feature of the testing that did stand out, however, was a tendency by the older participants to shift from calibration position when the real task was presented. That is, the experimental procedure involved a brief calibration followed immediately by the problem task. Participants were told to sit comfortably and minimize position changes as the equipment was being used to follow their eye movements. Unconsciously, however, the older participants were prone to moving forward as the task started. The movement seemed to be an unconscious result of alerting or wanting to pay close attention to the experimental task. To help reduce this behaviour observed in Experiment 1, the number of practice trials was increased in Experiment 2. This additional practice did reduce the tendency to move when the task started.

4. Conclusions and future work

In considering technology use by older adults, the relationship between technology interest, experience, and usability is complex. Older adults who are interested in a particular aspect of technology are likely to put in the effort to learn it (Zajicek, 2007). Older adults, however, do not tend to use new technology just for the sake of using it. The technology must be perceived as filling a need in their lives and must be perceived as being usable.

The results of this study and the context for these studies can be used to add to a new formulation of technology use by older adults based on cognitive strengths and weaknesses. Understanding such interactions, rather than cataloguing deficiency and disability, may eventually prove crucial in being able to support the technology needs of older adults. Such investigations would provide important information to today's designers and to the future as designers seek to create inclusive systems.

It is recommended that future work bring more focus to the strengths of older users, rather than their weaknesses. If we are to build systems that better serve the growing numbers of older adults, it is important to understand what works well for this population. It is important to get this right. Despite the optimistic belief of users who are currently young, if the needs of older users are not addressed, the rapid rate of technology change coupled with age-related changes in all of us will likely leave not only today's older adults but also tomorrow's older adults digitally excluded.

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Appendix A

The six problem tasks used in Experiment 2.

Well-defined problems:

- **Titian:** *A famous painting by Titian has been bought for the nation and is to tour the country. Using the National Galleries of Scotland website find when it will be in Dundee. When you find the answer,bookmark the Web page.* Starting page: http://www.nationalgalleries.org/.
- **Falkland:** *What is the name of the family 'in keepership' of Falkland Palace? When you find the answer, bookmark the Web page.* Starting page: http://www.undiscoveredscotland.co.uk.
- **Beatles:** *The Beatles came to Dundee in 1964. Using the Scottish-Screen Archive find information about the film of this event. When-you find the information, bookmark the Web page.* Starting page: http://ssa.nls.uk/index.cfm.

Ill-defined problems:

- **Art:** *A person visiting London is particularly interested in Renaissance art. They will be visiting London in June. Using only the British Museum website, locate an exhibit that might be of interest to them. Bookmark the Web page.* Starting page: http://www.britishmuseum.org/.
- **Voluntary:** *A person living in Aberdeen has some spare time and is looking to do some voluntary work. They have good people skills and an interest in the environment. Using the Guardian website find some job opportunities for them. Bookmark relevant possibilities.* Starting page: http://iobs.guardian.co.uk/.
- **Australia:** *A person recently returned from travel in Australia and is feeling feverish and chilly. Using only the BBC website gather information about possible causes. Bookmark relevant information.* Starting page: http://www.bbc.co.uk/.

References

Arch, A., 2009. WAI guidelines and older Web users: findings from a literature review. <http://www.w3.org/WAI/WAI-AGE/comparative.html>.

Brewer, J., 2003. Web accessibility initiative. <http://www.w3.org/WAI>.

Chadwick-Dias, A., Bergel, M., Tullis, T., 2007. Senior surfers 2.0: a re-examination of the older Web user and the dynamic Web. In: Stephanidis C. (Ed.), Universal Access in Human Computer Interaction: Coping with Diversity – Proceedings of the 4th International Conference on Universal Access in Human–Computer Interaction, vol. 5. Proceedings of HCI International 2007, LNCS 4554. Springer, Berlin Heidelberg, pp. 868–876.

Chin, J., Fu, W., 2010. Interactive effects of age and interface differences on search strategies and performance. In: Proceedings of the 28th International Conference on Human Factors in Computing Systems, Atlanta, Georgia, USA, April 10–15, 2010, CHI'10. ACM, New York, NY, pp. 403–412.

Chin, J., Fu, W., Kannampallil, T., 2009. Adaptive information search: age-dependent interactions between cognitive profiles and strategies. In: Proceedings of the 27th International Conference on Human Factors in Computing Systems, Boston, MA, USA, April 04–09, 2009, CHI'09. ACM, New York, NY, pp. 1683–1692.

Cockton, G., 2005. A development framework for value-centred design. In Proceedings of ACM CHI Conference, Portland, Oregon, USA, April 2–7, 2005, CHI'05. ACM, New York, NY, pp. 1292–1295.

Cockton, G., 2006. Designing worth is worth designing. In Proceedings of NordiCHI, Oslo, Norway, October 14–18, 2006, NordiCHI'06. ACM, New York, NY, pp. 165–174.

Coleman, G., Gibson, L., Hanson, V.L., Bobrowicz, A., McKay, A., 2010. Engaging the disengaged: How do we design technology for digitally excluded older adults? In: Proceedings of the 8th ACM Conference on Designing Interactive Systems, Arhus, Denmark, August 16–20, 2010, DIS'10. ACM, New York, NY, pp. 175–178.

Craik, F.I.M., Salthouse, T.A., 2000. The Handbook of Aging and Cognition, revised ed. Erlbaum, Mahwah, NJ.

Czaja, S.J., Lee, C.C., 2007. Information technology and older adults. In: Sears, A., Jacko, J.A. (Eds.), Human–Computer Interaction Handbook: Fundamentals, Evolving Technologies and Emerging Applications, second ed. Erlbaum, Mahwah, NJ, pp. 777–792.

Czaja, S.J., Charness, N., Fisk, A.D., Hertzog, C., Nair, S.N., Rogers, W., 2006. Factors predicting the use of technology: findings from the center for research and education on aging and technology enhancement (CREATE). Psychology of Aging 21 (2), 333–352.

Czaja, S.J., Sharit, J., Hernandez, M.A., Nair, S.N., Loewenstein, D., 2010. Variability among older adults in Internet health information-seeking performance. Gerontechnology 9 (1), 46–55.

Davis, F.D., 1989. Perceived usefulness, perceived ease of use, and user acceptance of information technology. MIS Quarterly 13 (3), 319–340.

Fairweather, P.G., 2008. How older and younger adults differ in their approach to problem solving on a complex website. In: Proceedings of the 10th International ACM SIGACCESS Conference on Computers and Accessibility, Halifax, Nova Scotia, Canada, October 13–15, 2008, Assets'08. ACM, New York, NY, pp. 67–72.

Finland makes broadband a 'legal right', 2010. <http://www.bbc.co.uk/news/10461048>.

Fukuda, R., Bubb, H., 2003. Eye tracking study on Web-use: comparison between younger and elderly users in case of search task with electronic timetable service. Psychology Journal 1 (3), 202–228.

Gould, J.D., Lewis, C., 1983. Designing for usability—key principles and what designers think. In: Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, Boston, Massachusetts, United States, December 12–15, 1983, CHI'83. ACM, New York, NY, pp. 50–53.

Grahame, J., LaBerge, M., Scialfa, C.T., 2004. Age differences in search of Web pages: the effects of link size, link number, and clutter. Human Factors 46, 385–398.

Hanson, V.L., 2009. Age and Web access: the next generation. In: Proceedings of the 2009 International Cross-Disciplinary Workshop on Web Accessibility, W4A, Madrid, Spain. ACM, New York, NY, pp. 7–15.

Horrigan, J., 2009. Home broadband adoption 2009. <http://www.pewInternet.org/Reports/2009/10-Home-Broadband-Adoption-2009.aspx>.

Jones, S., Fox, S., 2009. Generations online in 2009. <http://www.pewInternet.org/PPF/r/275/report_display.asp>.

Melenhorst, A., Rogers, W.A., Bouwhuis, D.G., 2006. Older adults' motivated choice for technological innovation: evidence for benefit-driven selectivity. Psychology and Aging 21 (1), 190–195.

Meyer, B., Sit, R.A., Spaulding, V.A., Mead, S.E., Walker, N., 1997. Age group differences in World Wide Web navigation. In: CHI'97 Extended Abstracts on Human Factors in Computing Systems: Looking to the Future, Atlanta, Georgia, March 22–27, 1997, CHI'97. ACM, New York, NY, pp. 295–296.

Monk, A., 2009. Why do the older old have problems with new domestic technologies? <http://www.iden.org.uk/londonevent.asp>.

Newell, A.F., Dickinson, A., Smith, M.J., Gregor, P., 2006. Designing a portal for older users: a case study of an industrial/academic collaboration. ACM Transactions on Computer–Human Interaction 13 (3), 347–375.

Norman, D., 2005. Emotional Design: Why We Love (or Hate) Everyday Things. Basic Books.

Ofcom, 2009. Accessing the Internet at home: a quantitative and qualitative study among people without the Internet at home. <http://www.ofcom.org.uk/research/telecoms/reports/bbresearch/bbathome.pdf>.

Park, D.C., 1992. Applied cognitive aging research. In: Craik, F.I.M., Salthouse, T.A. (Eds.), The Handbook of Aging and Cognition. Erlbaum, Hillsdale, NJ, pp. 449–493.

Rabbitt, P., 2006. Tales of the unexpected: 25 years of cognitive gerontology. The Psychologist 19 (11), 674–676.

Sellen, A., Rogers, Y., Harper, R., Rodden, T., 2009. Reflecting human values in the digital age. Communications of ACM 52 (3), 58–66.

Selwyn, N., Gorard, S., Furlong, J., Madden, L., 2003. Older adults' use of information and communications technology in everyday life. Ageing and Society 23, 561–582.

Sharit, J., Hernández, M., Czaja, S., Pirolli, P., 2008. Investigating the roles of knowledge and cognitive abilities in older adult information seeking on the Web. ACM Transactions on Computer–Human Interaction 15 (1), 1–25.

SiDE: social inclusion through the digital economy, 2010. <http://side.computing.dundee.ac.uk/>.

Small, G., Vorgan, G., 2008. Surviving the Technological Alternation of the Modern Mind. Harper Collins, New York.

Tullis, T.S., 2007. Older adults and the Web: lessons learned from eye-tracking. In: Stephanidis, C. (Ed.), Universal Access in Human Computer Interaction: Coping with Diversity – Proceedings of the 4th International Conference on Universal Access in Human–Computer Interaction, vol. 5. Proceedings of HCI International 2007, LNCS 4554. Springer, Berlin Heidelberg, pp. 1030–1039.

Willis, S.L., Schaie, K.W., 2005. Cognitive trajectories in midlife and cognitive functioning in old age. In: Willis, S.L., Martin, M. (Eds.), Middle Adulthood: A Lifespan Perspective. Sage, Thousand Oakes.

Zajicek, M., 2007. Web 2.0: hype or happiness? In: Proceedings of the 2007 International Cross-Disciplinary Conference on Web Accessibility, W4A, Banff, Canada, May 07–08, 2007, W4A'07, vol. 225. ACM, New York, NY, pp. 35–39.