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Older Web Users' Eye Movements: Experience Counts

Robin Hill[1], Anna Dickinson[2], John Arnott[2], Peter Gregor[2], Louise McIver[2]

[1] Visual Cognition Laboratory, Psychology, University of Edinburgh, Edinburgh, EH8 9JZ, Scotland, UK.

[2] School of Computing, University of Dundee, Dundee, DD1 4HN, Scotland, UK.

[1] r.l.hill@ed.ac.uk, [2] {adickinson, jarnott, pgregor, lmciver}@computing.dundee.ac.uk

ABSTRACT

Eye-tracking is a valuable tool for usability research. Studies into the effect of age on eye-movement behavior tend to indicate a propensity for slower viewing and longer times spent examining information. This pattern is usually attributed to the general physiological and cognitive slow-down associated with normal aging. In this paper, however, across three different tasks based on computer and internet use (free-viewing, visual search, and browser interaction), we show that among older adults (n=18, age range: 70-93) computer experience appears to be a highly important factor in eye-movement behavior. We argue that as a consequence of the experimental environment used in modern eye-tracking studies, characteristics such as familiarity and experience with computers should be taken into account before conclusions are drawn about the raw effects of age.

Author Keywords

Ageing, eye-tracking, experience, web usability.

ACM Classification Keywords

H5.m. Information interfaces and presentation; H.5.2 User interfaces: *evaluation/methodology.*

General Terms

Experimentation, Measurement, Performance, Human Factors.

INTRODUCTION

Eye-tracking is widely used as a tool in usability and HCI evaluations. It has the potential to be especially useful when participants are older or lack contextual knowledge about computer systems, offering an unobtrusive means of examining cognitive and attentional processing. Research so far has seemed to demonstrate that older adults are slower and display different eye movement behaviors from those of younger people. The research reported here explores the link between experience and older adults' eye-movements in web usability research. Experimental data are provided (see below) which suggest that differences in eye movement behavior may be more strongly associated with experience than with age as a physiological process.

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EYE-TRACKING AND HCI

Interest in eye-tracking as an evaluation method in web usability has been enthusiastic. There are now courses for practitioners (e.g. at City University in London and De Montford University in Leicester), and the presentation of results by such specialists as Jakob Nielsen [22] as well as numerous academic articles [e.g. 11,16,31] demonstrate the popularity of the methodology.

This popularity in monitoring eye movements is hardly surprising: as Nielsen and Pernice point out in their 2009 book [22], recent developments have meant that the technology is now relatively inconspicuous, with no need for the uncomfortable bite bars and chin rests previously required to ensure accuracy and reliability. Moreover, eye-tracking, by giving the researcher a direct insight into where the user's attention is focused, allows direct access to usability flaws that are more likely to emerge from eye-tracking data than from discussions with users themselves. Essentially, the entire cognitive journey and time-course of a task, from start to finish, can be unwrapped and analysed; not just the end result.

Measures such as where a participant first fixates on a page, whether they notice the object they are seeking, and the way in which their gaze travels across the page are all useful measures of their interaction with the stimuli. A particularly useful measure of cognitive effort is fixation duration: the longer a participant spends looking at something, the more effort they are expending trying to recognize or understand it.

Eye-tracking is a powerful means of investigating cognitive processing by offering a spatio-temporal record of visual attention. There is however a danger of over-simplifying or ignoring some of the more valuable measures. The results can be difficult to analyze; heatmaps, for example, while providing interesting information at a glance, can run the risk of over-simplifying, as descriptive statistics can. This paper warns that eye-tracking results may have encouraged misleading conclusions about cognition and ageing.

Older adults, web usability and eye-tracking

An especially valuable application of eye-tracking usability is its use with older adults: older adults, particularly novices, are likely to have more problems than younger ones with conventional usability methods [see [14] for a review]. This is an issue in terms of cognitive focus (think aloud), memory (retrospective think aloud) and simply in terms of familiarity with terminology and "alien" technology. Conscious critique of a usability experience is very complex for an inexperienced user of computer systems. Ageing, as evinced by cognitive change, poorer motor control and sensory deficits, impacts on the ability to use computers [14]. The central focus of this research area has been the differences between older and younger adults in terms of visual behavior on websites. Despite the advantages that eye-tracking offers for research with older adults, the field is currently small and research reports are rather scattered. A small number of web usability studies have been carried out with older adults (people over 50).

One of the earliest studies involves an eye-tracking examination of railway timetables [15]. In the study, the authors classified younger (mean: 22.5) and older users (mean: 67) into 'beginner' and 'intermediate' groups. They concluded that older people made longer fixations, but that this was due to visual difficulties reading small text (point 10). Older users were also more vulnerable to usability flaws, which impacted significantly on the time it took to complete tasks.

A similar finding emerged from two studies looking at expert older users working at the investment company, Fidelity. The first study reported examined the behavior of expert older adults (50-69) in work who used the web daily, compared to their younger colleagues (20-39) [30]. Older adults spent longer viewing web pages and longer looking at navigation areas than their younger colleagues. Evidence from heatmaps suggests that the older participants also distributed their gaze more widely across the pages and read more of the text than younger users did. The second study, using the same eye-tracker, and examining preferences for web page presentation, reported that older users (the study looked at "baby boomers" (44-62) working at Fidelity) tended to fixate for longer on large images and search bars [5].

Zaphiris and Savitch [32] compared older (58-87) and younger (19-27) web users browsing health information sites of varying depth of hierarchy, and concluded, like [30], that older adults looked at more of the page and spent longer considering which link to choose. Notably, the researchers found no significant difference in reading speeds, suggesting that older adults were not simply slower than younger ones.

Josephson and Holmes [18], however, compared four age groups, children (mean age 10), teenagers (mean age 18), younger adults (mean age 38) and older adults (mean age 58), all of whom were experienced and regular web users, on a visual search task and found no differences between the groups. They suggest that "older adults who are avid Internet users are able to rapidly and accurately find information", with the implication that many of the differences that are categorized as due to "ageing" are likely to be, in fact, due to experience. It is also worth noting that their "older adults" were relatively young (range: 55-65).

There is scope for further and more detailed research in this area. Some of the existing studies show results in the form of heatmaps, rather than giving detailed spatio-temporal eye-movement metrics such as fixation duration and location. The eye-trackers used had relatively low sample rates, ranging from 30 Hz [15] to 60 Hz [18]. The older adults are defined in these studies as people older than 50 (indeed, older than 44 in [5]). Only one study had participants with a wide range of ages, including one participant of 87 [32]; because means are absent, however, the overall age distribution of their group is unclear.

Despite the small number of reports, outcomes have been relatively consistent. With one exception [18], researchers conclude that older adults are slower [5,15,30,32].

Older adults and eye-tracking in psychological studies

This conclusion fits with much of the existing psychological data that concludes that older adults exhibit age-related slowing that affects their eye-movement behavior: psychological eye-tracking literature has reported general slowing and decline with age [4]. This work should be viewed in context, however: a lot of the evidence (particularly in the earliest studies) was from reflexive saccades, which are essentially automatic and involve no higher order control. Older adults were slower to react to stimuli (reviewed in [1]). In terms of physiological and oculomotor behaviors, older adults are slower and their performance is more variable [1].

From an eye-tracking perspective, there is less data on older people's higher order cognitive control on real world information processing tasks. This is particularly significant as these are the sort of tasks where compensatory strategies might be expected to reduce the differences related to physiological slowing, and the sort of tasks that have real relevance for daily life.

In reading research, an area of higher order behavior where there has been preliminary research with older participants, older adults make more fixations, longer fixations (a mean of 260ms compared to 246ms for younger readers [26]) and more regressions (backwards movements to re-read text). These differences do not necessarily have a dramatic impact on reading performance and (at least where reading is "easy") are of little functional significance [20]: in other words, older adults are performing at a reasonable level (that is, they are successfully reading) but similar texts demand more effort, as demonstrated by longer fixation durations.

The web usability research is less established than the psychological research and it is difficult to quantify what increased cognitive effort might look like for older people using web pages. In existing web usability research with older adults, however, one study explicitly reports that older adults have longer mean fixation durations [15], although without supporting figures for these. Other research does not report fixation durations, although [5] gives "fixation data" which are presumably fixation durations (based on the background discussion of eye-tracking measures). It is indicated that fixations on screen elements such as large images and search bars were longer for older participants, although total mean durations and other statistical results are not presented.

Typical mean fixation durations

Previously reported mean fixation durations tend to be judged from work with younger adults, very often university students. Table 1 displays a summary of the "typical" mean fixation duration data over various tasks. Specific times depend on the complexity of the task and the stimuli, so in some cases the data are presented as a range rather than a single figure.

	Mean Fixation Duration
Silent reading	225-250 ms
Oral reading	275-325 ms
Visual search	180-275 ms
Static scenes	287 ms
Dynamic scenes	358 ms
Films	453 ms
Joint collaborative tasks	322 ms
Web search	230-293 ms[1]
General browsing (including instructions to remember content)	353-377 ms

Table 1. "Typical" mean fixation durations derived from previous research [6, 17, 23-25, 27, 28]

The summary information in Table 1 is provided to show contextualising times for fixation durations on different tasks. As the table shows, mean fixation durations range from 180ms on straightforward visual search tasks to 453ms when participants are looking at films. Web-based tasks tend to come between these two extremes, with free-viewing (when the participant is also trying to remember what they see) between 353 and 377ms, and search tasks ranging between 230 and 293ms.

Why are there differences between older and younger web users?

Although mean fixation duration differences between older and younger adults are commonly taken to reflect age-related cognitive slowing or other fundamental aspects of ageing, it has not been demonstrated that this is actually the case. As Loos and Mante-Maijer point out in their review of the literature [21], it is unclear whether the differences between older and younger adults looking at web pages exist because of age or because of some other factor such as cultural background, education or experience which studies have not controlled for. So far, older adults have been treated as a homogeneous group in the research, despite evidence that they are, in fact, extremely diverse [see [7] for example].

Indeed, many of the differences between older and younger adults appear to be experience-related [18]. The psychological literature demonstrates that observed differences may vanish with practice: for example, well-practiced younger and older adults perform similarly in anti-saccade tasks (where participants must deliberately suppress automatic behaviors) [13]; poor visual search strategies in older adults can be rectified with simple instructions and minimal practice [2], and reading efficiency training can greatly improve performance in older adults [29].

Thus 'difficulty' appears to be a function of situation novelty and amount of practice in tasks for older adults [3]: unfamiliar tasks are likely to benefit younger participants when compared to older people, but a relatively small amount of practice minimizes – and potentially removes – this advantage.

These conclusions from the psychological literature, as well as the findings of Josephson and Holmes [18] and the issues raised by Loos et al. [21], raise the question of the extent to which experience plays a role in older adults' eye movement behavior on websites: might the slowing observed in the literature be a function of experience as much as of age?

THE STUDY: BEGINNERS AND NOVICES LOOKING AT WEB PAGES

As discussed above, while several studies have examined the differences between older and younger adults, no one has yet looked at differences between older adults. In this paper we report the first study which has examined the eye-tracking behavior of older adults in terms of computer experience and begin the process of unpicking the differences caused by experience to add to the research data that looks at ageing.

In this study, complete novices are compared to people who have a small amount of computer experience in order to begin to explore whether experience makes a difference.

[1] Note: Cowen et al. report mean fixation durations for their study of mobile phone homepages [8]. The range reported is 394-553ms, undoubtedly an outlier in terms of other research data, suggesting that the stimuli were very complex – or that Cowen et al. are using a slightly different definition of the term.

Participants

18 participants (mean age: 77.5 years; range 70-93) were recruited through a local charity for older adults. All attended a single two-hour session at the laboratory. An interview on computer knowledge was used to divide participants into two groups. There were 12 novice computer users, people who had minimal, if any, experience with a computer and had not attained any level of independent computer use (mean age: 77; range 71-93). The remaining 6 participants (mean age: 78.5; range 70-90) were more experienced; they had enough experience to use at least one application independently. People in this group had some email experience or had used a word processor or had accessed the Internet. It is important to emphasise that they were in no sense “expert” users. All participants had normal or corrected-to-normal vision. Refreshments and transport were provided but there was no monetary compensation for participation.

Apparatus

An SR Research Eye-link II head-mounted eye-tracker (see Figure 1) running at a sample rate of 500Hz was used to monitor participants’ eye movements. Screen shots were presented on a 19-inch CRT monitor at a resolution of 1024 x 768. A digital dictaphone with a table-mounted microphone recorded the auditory data.

Figure 1. SR Research Eye-link II Eye-tracker.

Procedure

A brief interview was conducted outside the laboratory to confirm participants’ age and computer inexperience. Once inside the laboratory, the apparatus and procedure were explained and participants read and signed a consent form. Participants were required to sit at a normal viewing distance from the monitor and to wear any spectacles they would normally use for reading at that distance. A test screen of words in different sizes was presented to ensure minimum levels of eyesight proficiency and a test was used to identify participants’ dominant eye. The head-mounted eye-tracker was then placed on their head. Although only the dominant eye was tracked, participants’ vision remained binocular and normal viewing behavior was unimpeded.

Task requirements were reiterated and participants were informed that the basic instructions would be repeated before each experimental trial was initiated. Participants were also able to rest or take a break between trials. The experiment began with a manual calibration procedure that involved looking at a series of nine points which formed a 3 x 3 grid across the screen. The Eyelink software then re-presented these points in a different random order to validate the accuracy of the system. If this failed, the entire calibration was repeated until a successful validation was obtained. Each trial was initiated by a central fixation marker to ensure that the calibration remained accurate and representative; if inaccuracies were detected during the experiment then the calibration process could be repeated whenever necessary.

After successful calibration, a random colour pattern was presented for 2 seconds, encouraging the free movement of eyes around the screen and removing the bias of starting from a central position because of the fixation marker. These visual “white noise” screens also help limit any lingering working memory contamination arising from the previously displayed page.

Stimuli

This study is part of a larger project looking at the effects of browser interface design alterations on older novice viewing behavior. Participants saw two interface designs: a conventional Internet Explorer interface, and an experimental system consisting of a smaller toolbar placed at the bottom of the screen (minimal distraction and interface clutter). Full rationale and results for the beginner group (first stage) have previously been reported [9,10].

Building on previous eye-tracking research, which demonstrates the importance of content layouts in influencing eye movement behavior [e.g. 23], three different content designs were used. Screens from the Web were selected as stimuli. While the screen designs were standard, their content changed, so users had new information to look at and try to understand each time a new screen was presented. The three content structures were: Amazon search results, Google search results and ITV news stories.

These screens provided a range of characteristics, including a varying proportion of image and text, varying density of content, and varying placement of navigation controls. In order to avoid possible interference from the rest of the Windows set up, all screens were maximised so that the Windows toolbar/Start button was not shown on the screen.

Web page © Google

Figure 2. Example page from the study with novel browser interface (half of the pages were displayed with a conventional browser interface).

Each participant saw 42 unique screens; half of the screens displayed were shown with the Internet Explorer browser (7 of each content design), and half with the experimental interface (also 7 of each content design). An example is shown in Figure 2. Presentation was pseudo-randomised to control for any order effect. There were no differences between experience groups in terms of screens viewed.

Tasks

Participants completed three separate series of tasks: "free-viewing" tasks, search tasks, and browser tasks. The tasks were chosen to explore how older adults interacted with web pages. The free viewing task was intended to represent the first time that a participant saw a page, and their initial effort to make sense of what they were looking at. The search task represented a web user seeking items of relevance on the page. Finally, the browser tasks were used to explore the extent to which users understood the role of the browser interfaces, and the possibilities for changing text attributes or for using the browser to navigate. These tasks were all relatively 'naturalistic' in that they reflected the sort of behavior that a web user might display.

Task series 1: free-viewing

The first series of tasks that participants were asked to undertake involved looking at the screen silently for 20 seconds then re-examining the screen for a further 30 seconds while describing what they saw. The distinction between the initial examination and the subsequent description was intended to separate the cognitive effort of understanding from the cognitive effort of describing the screens [14]. Josephson and Holmes considered a 15-second exposure to be adequate time for a user to completely examine a web page [19]. The time was extended in this study by 5 seconds because participants, as older inexperienced computer users, were expected to respond more slowly to the screens presented.

To ensure that each participant understood the procedure there were three practice screens. The practice screens were composed of both pictures and text. As with the genuine experimental items, participants saw them for 20 seconds and then described them for 30. Neutral images rather than web pages were used in order to avoid introducing experimental items during the practice session. The experimenter or the participant could raise any difficulties or questions during the practice session. Following the practice session, there were twelve experimental screens.

Task series 2: search

The second series of tasks consisted of searches. Participants were asked to find a target word or image on the screen and to say whether the target was at the top or the bottom. Search tasks ranged from basic recognition (e.g. "is the word "education" on the next screen?") to tasks requiring more processing ("Do any of the birds mentioned on the next page end up in Britain?"). There were 18 screens in total and in half of the screens the target being sought was not present. Participants had 40 seconds to decide whether the target was present or not.

Task series 3: browser tasks

The third task series concerned overall impressions of the screen and browser tasks. Participants were asked six questions over twelve screens (each question was asked twice). Questions covered browser-relevant topics such as "What would you do if you wanted to make the text larger?" and "What would you do if, after you had been exploring the web for a while, you wanted to go back to where you started from?". Participants had 30 seconds in which to answer the question.

RESULTS

Both groups of participants completed all the tasks. Following the studies, mean fixation durations were calculated in order to explore cognitive effort over the three task series. Distinct differences emerged between the 'experienced' and 'inexperienced' groups.

An additional dependent variable is included in the results tables for comparative purposes: saccade amplitude. This is a measure of the size of the eye movements between steady fixations. Thus a large amplitude may reflect more global scanning behavior as found in scene perception (about 4°) while a smaller amplitude is more similar to reading-like behavior (about 2°) [25]. However, for the purposes of this paper the focus of discussion will remain on the fixation duration results.

Two sets of analyses were performed to confirm statistical reliability. The first involved fitting a Linear Mixed Effects Model for each task, treating the Experience Grouping variable as a Fixed Effect and participants as a Random

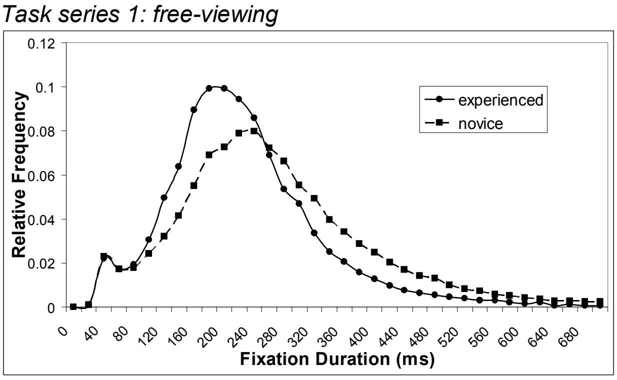
Effect. The second set involved a more conventional Repeated-Measures Analysis of Variance approach to ensure that individual differences did not skew the overall group profiles.

Plots and descriptive statistics for the entire distribution of data obtained during free-viewing task (19482 and 31961 observations for two participant groups) are in Figure 3.

The LME model, detailed in Table 2, treats the novice group as the baseline and indicates that when participants were asked to look at a screen and try to understand it, there was a 53ms facilitation on average per fixation for the experienced participants [t(15.982) = -3.918; p=0.001]. There was no evidence of a difference in saccade amplitude (the size of the movement of the eyes between fixations) between groups, however [t(15.977)=-0.131; p=0.897].

Figure 4 shows the distribution of fixation durations for the two groups of older users during a web-based search task, along with a summary of their eye-movement data.

Task series 1: free-viewing



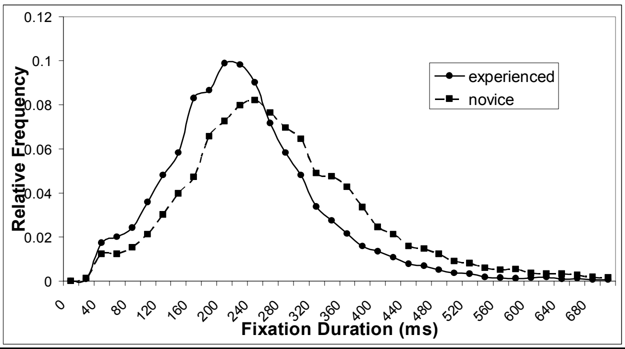
	Fixation duration		Saccade amplitude	
	Exp	**Novice**	**Exp**	**Novice**
Mean	221ms	273ms	4.23°	4.28°
Median	204ms	244ms	2.65°	2.60°
St. Dev.	116ms	155ms	4.68°	4.69°
N	19482	31961	19171	31311

Figure 3. Data summary for Free-viewing Task

			95% C.I.				
Parameter	**Estimate**	**Std. Error**	**Lower Bound**	**Upper Bound**	**df**	**t**	**Sig.**
Intercept	275.1	7.8	258.6	291.5	16.022	35.443	.000
Experienced	-52.6	13.4	-81.1	-24.1	15.982	-3.918	.001
Novice	0	0	.	.	.	.	.

Table 2. LME output for Free-viewing Task (milliseconds)

Task series 2: search



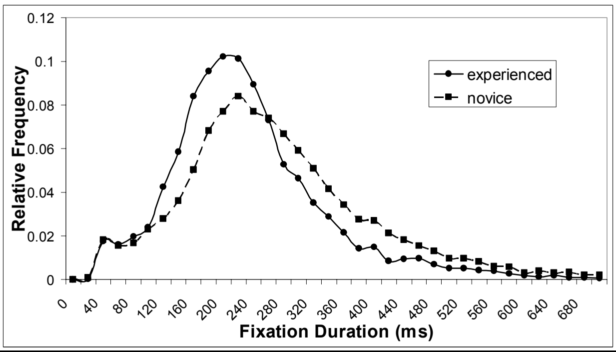
	Fixation duration		Saccade amplitude	
	Exp	**Novice**	**Exp**	**Novice**
Mean	221ms	272ms	4.43°	4.17°
Median	208ms	248ms	2.57°	2.64°
St. Dev.	111ms	144ms	6.49°	4.63°
N	7900	15423	7703	15025

Figure 4. Data summary for Search Task

			95% C.I.				
Parameter	**Estimate**	**Std. Error**	**Lower Bound**	**Upper Bound**	**df**	**t**	**Sig.**
Intercept	273.2	7.8	258.6	291.5	16.010	35.029	.000
Experienced	-53.0	13.5	-81.1	-24.1	16.006	-3.926	.001
Novice	0	0	.	.	.	.	.

Table 3. LME output for Search Task (milliseconds)

Task series 3: browser tasks



	Fixation duration		Saccade amplitude	
	Exp	**Novice**	**Exp**	**Novice**
Mean	229ms	276ms	5.12°	4.66°
Median	212ms	248ms	3.07°	2.75°
St. Dev.	119ms	166ms	5.88°	5.32°
N	6193	13461	6065	13195

Figure 5. Data summary for Browser Interaction Task

For search tasks, the LME model (Table 3) reveals a 53ms mean difference between experienced participants and novices [t(16.006)=-3.926; p=0.001]. The slightly longer "jumps" between fixations on average for the more experienced were accompanied by a higher variance (the median was lower) and the difference was not reliable [t(15.983)=0.462; p=0.650].

The differing shapes of the distributions for the two samples of data obtained during the Browser Interaction Task can be seen at the top of Figure 5.

Parameter	Estimate	Std. Error	95% C.I. Lower Bound	Upper Bound	df	t	Sig.
Intercept	278.3	8.9	259.6	297.1	16.042	31.399	.000
Experienced	-49.4	15.4	-82.0	-16.9	16.065	-3.217	.005
Novice	0	0	.	.	.	.	.

Table 4. LME output for Browser Interaction Task (milliseconds)

For the browser interaction, the model (Table 4) estimates a 278ms fixation duration, reduced by 49ms if a participant is classified as more experienced [t(16.065)=-3.217; p=0.005]. Again, the slightly longer jumps between fixations for experienced participants were actually highly variable in extent and non-significant [t(15.988)=0.799; p=0.436].

As a check to ensure that these findings were not explicitly due to stimuli being webpages, the viewing task (mirroring Task 1 above) for the practice materials was also analysed. These materials consisted of three normal photographs which had no computer-related or internet context, but were displayed using the same apparatus as the experimental stimuli. The results are entirely consistent with those found for Task 1 and hence the rest of the experiment: means of 223ms vs. 270ms for the two groups [LME difference t(15.879)=3.488; p=0.003]. There is therefore no evidence that our findings are restricted to webpages alone.

Combined statistical analysis

A second ANOVA was carried out to test across the mean fixation durations for each participant to ensure that the overall results were not skewed by individual differences. A 2 (Experience [between variable]) x 3 (Task [within variable]) repeated measures ANOVA was carried out. A main between-groups effect of Experience [F(1, 16)=15.720, p<0.01] indicates a reliable difference between the novice and experienced groups throughout the experiment. A lack of a main Task effect [F(2, 32)=0.073, p=0.930] confirms that the participant performance is consistent across all three tasks. Similarly, there was no interaction between the variables [F(2, 32)=0.592, p=0.559], confirming that the overall findings were not driven by one or two cells in the experimental design alone: individual novice durations were similar on all three tasks; more experienced participants also had similar durations across the tasks; but novices had reliably longer fixation durations compared to more experienced participants.

Summary

Overall, the results show that novice older users made fixations that were approximately 50ms longer (a 20-25% increase) than those made by (modestly) experienced older users, across all three conditions. The graphs also indicate that the difference is not just a simple shift in means, but that the two participant groups clearly have different overall distributions of fixation durations. The more experienced group has a much stronger leftwards skew and tighter spread, matching the general profile reported for younger adults; whereas the novice group had a more random appearance, with a lower, wider peak and greater symmetrical variance. This pattern is remarkably consistent across all the tasks performed. While more experienced users had slightly longer average saccade amplitudes when they were given a specific objective to carry out (Tasks 2 and 3), these distributions were too varied to verify the adoption of a more efficient scanning strategy. The close value for the saccade amplitude statistics implies that the size of the movements between fixations is homogeneous for the two groups, i.e. participants made similar movements around the screen regardless of experience. What was different was the length of time they remained stationary before moving on again.

DISCUSSION

Inexperienced older adults displayed an "older" profile in these eye-tracking tasks. Previous research has demonstrated that such a profile is associated with ageing [1,26] but it is also classically associated with confusion and uncertainty. Unpicking the interaction between ageing and inexperience needs significantly more research, but these results indicate that further research is desirable: inexperience is likely to be an important factor, possibly as important as age itself. Further investigation is necessary to explore the relative importance of age and experience, and to explore whether the basic level of experience reported here is sufficient – as these preliminary results suggest – to allow older adults to utilise the sort of compensatory strategies that ameliorate the age-related differences as reported in other higher order processing tasks [2,13,20,29].

For unconstrained free-scanning, experienced older users had an average fixation duration of 221ms, compared to novices' 273ms. Both groups had significantly lower mean fixation durations than the participants in Pan et al.'s [23] study (see Table 1), a difference that is likely to be attributable to the stimuli, as well as to the instruction to Pan's participants to remember what was on the screen. An alternative is to compare free-viewing in our study with silent reading in the existing eye-tracking research, for which "typical" fixation durations range from 225-250ms [24] and which place the more experienced group at the lower end of the scale, whereas the beginners are off the scale at the higher end.

Similarly, "typical" visual search fixation durations (including those for extremely complex tasks) range from 180-275ms, with web search apparently more complicated, ranging from 230-293ms: novices on both the reported search tasks (page search and browser interaction search) had mean fixation durations of 272 and 276ms, at the upper limits of the "typical" data [24], comparing to 221 and 229ms for the more experienced participants, at the lower end of the range.

The pattern is highly consistent through the three tasks: where contextualising data exists, a relatively small amount of computer experience is sufficient to produce a "typical" mean fixation duration – indeed, one that is at the lower end of the established range. By comparison, although the differences in time may not look dramatic at first (in relative terms it is a 20% to 25% difference, however, with 50ms being large in terms of neural activity and also longer than the duration of most saccadic eye movements), inexperienced older people were consistently at the higher end of the range of mean fixation durations.

Many details and differences in viewing behavior can sometimes be obfuscated by analysis techniques that over-aggregate the data. Heatmaps, for example, can reveal areas of high vs. low total viewing times, but do not show the order in which areas of the screen were attended, whether objects were re-fixated or held the eye for longer when initially encountered, etcetera. The heatmaps in Figures 6a and 6b do not reveal the differences reported earlier, for example. A more fine-grained spatio-temporal approach to analysing eye movements, such as distinguishing between patterns of individual fixations, offers a much richer understanding of what is going on inside a computer user's head. Different patterns will manifest for features that are attention-grabbing, attention-holding, ambiguous or perhaps just generally more interesting.

It is well established that practice on eye-tracking tasks can reduce, and even remove, the difference between older and younger participants [2,13,29]. Older people have less computer experience on average than younger people do, and many older adults have none. These results suggest that it is important to control for computer experience in eye-tracking tasks, since inexperience can increase task difficulty and misleadingly imply the presence of age-effects. Even indirect experience and familiarity, such as non-specific computer use, may have a profound effect on data collection.

The importance of this finding for usability research is considerable: where older people do self-paced tasks, the effect of even a small amount of computer experience could be substantial. The difficulty inherent in unfamiliar tasks brings greater cognitive load, but the level of experience necessary to overcome such difficulty is surprisingly small. Apparent age-effects may in some cases simply reflect inexperience, and with a little experience, compensatory strategies and other cognitive skills come into play. This underlines the importance of avoiding prejudicial judgment about the effects of ageing.

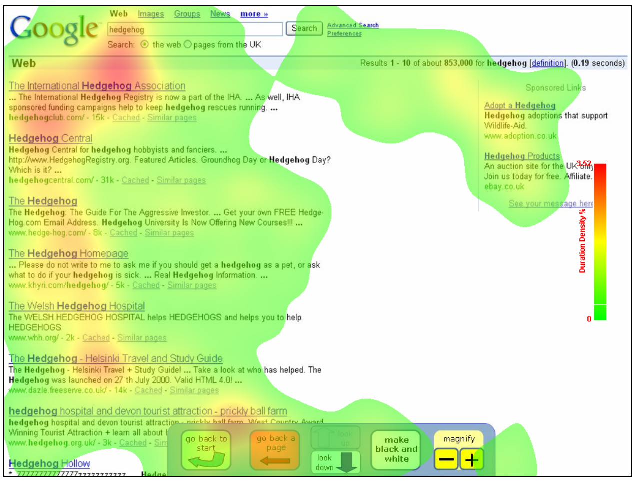


Figure 6a. Aggregate heatmap for experienced participants viewing search results for "hedgehog" (1146 fixations in total)

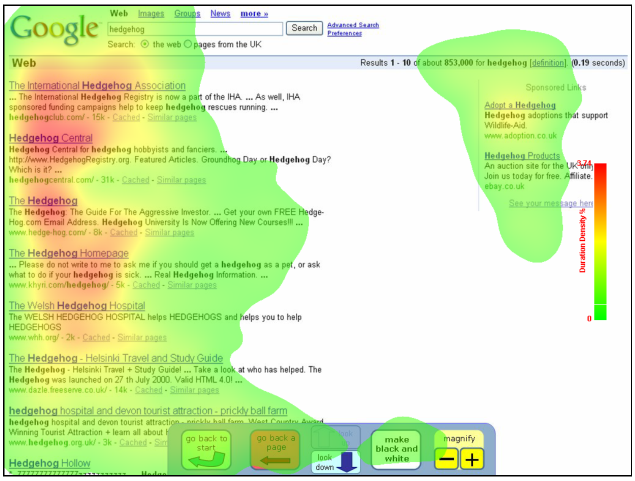


Figure 6b. Aggregate heatmap for novice participants viewing search results for "hedgehog" (2016 fixations in total)

For practitioners, it underlines the dangers of 'snapshot' studies where participants are only evaluated on one occasion. Since novices will behave in unique idiosyncratic ways there is a danger that this behavior will become equated with "older people". To rely on older participants with computer experience is one alternative, but it does effectively mean depending on a relatively small subset of the potential user group. It may be advisable to explore more longitudinal evaluation strategies with this user group instead.

Further, it is clear from these results that initial views of unfamiliar interfaces are associated with significant cognitive effort for older people; this emphasizes the relevance of work on familiarity in interfaces, and scaffolding and layering approaches to encourage older adults to gain a level of experience which will support further exploration and development of computing skills. For interface designers, applications need to facilitate the development paths that older people require to expand and consolidate their computing abilities.

As Fairweather notes in his analysis of users' problem-solving strategies, "...some of the effects of age, strong as they may appear, result from the level of knowledge these users had about how to solve the assigned problem using the web." [12]

CONCLUSION

Overall, our data suggest that having just a little experience of computer use is associated with a user's eyes moving around a computer monitor faster but without altering how far apart the eye movements were. In other words, even a small prior exposure to computers is linked with individuals not needing to spend so long looking at any location on the screen. This behavior was exhibited independently across tasks of varying complexity and cognitive demand, and where no formal training or familiarisation was involved.

In conclusion, on three web-viewing tasks, marginally experienced older adults displayed eye-movement behaviors consistent with "typical" behaviors, as measured by mean fixation durations. By contrast, less experienced computer users of similar ages displayed eye-movement behaviors that have generally been regarded as characteristic of all older people. This study suggests that behaviors previously identified as characteristic of ageing might be related instead to other factors, such as experience, and challenges assumptions about the effects of age as opposed to other aspects that divide the older age group. Age and personal experience remain highly correlated properties, which questions the merit of any over-simplified approach to improving the user experience for the older demographic.

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