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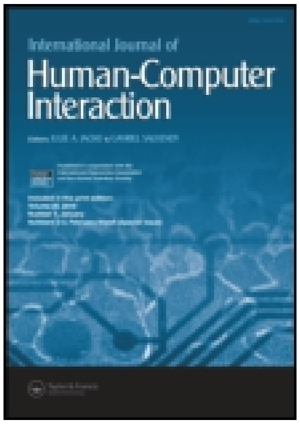

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Age-Related Differences in Eye Tracking and Usability Performance: Website Usability for Older Adults

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Cognitive decline is inherent with age. Despite known cognitive limitations, older adults are generally not taken into account during website design. Understanding age-related differences in website navigation is instructive for website design, especially considering the growing number of older adults who use the Internet. This article presents usability and eye-tracking data from five independent website usability studies that included younger and older participants. Overall results revealed age-dependent differences in eye movement and performance during website navigation on some of the sites. In particular, older participants had lower accuracy in one study and took longer to complete tasks in two studies compared to younger participants, they looked at the central part of the screen more frequently than younger participants in two studies, and they looked at the peripheral left part of the screen less frequently and took longer to first look at the peripheral top part of the screen than younger participants in one study. These data highlight the potential for age-related differences in performance while navigating websites and provide motivation for further exploration. Implications for website design and for usability practitioners are discussed.

1. INTRODUCTION

Although older adults use the Internet often, they report difficulty (Boechler, Foth, & Watchorn, 2006; Brandtzæg, Lüders, & Skjetne, 2010; Chadwick-Dias, McNulty, & Tullis, 2003; Hertzum & Hornbæk, 2010; Murata, 2006; Redish & Chisnell, 2004; Rogers & Badre, 2002). One aspect of website design that influences successful navigation is how navigational elements are arranged on the screen (e.g., Brandtzæg et al., 2010). Where Internet users predominantly look for navigation elements has major implications for successful website navigation. Yet website designers sometimes place elements critical to successful website navigation (such as top navigation and left navigation links or tabs) in the periphery rather than the central area of the screen. Cluttered peripheral information often results in performance difficulties for older adults (Ball, Beard, Roenker, Miller, & Griggs, 1988; Mackworth, 1965; Romano, Dennis, Howard, & Howard, 2007; Scalf et al., 2007; Scialfa, Kline, & Lyman, 1987; Sekuler & Ball, 1986; Sekuler, Bennett, & Mamelak, 2000; Williams, 1989). These difficulties can put older adults at a greater disadvantage in accomplishing tasks on websites compared to younger adults. If users rely on peripheral elements, such as the top and left navigation, to assist in where they next look on a web page, then as the periphery becomes less clear and more cluttered, performance for all users, and more noticeably older adults, suffers.

Upon first viewing a web page, older adults may take longer to look at peripheral elements due to cognitive-visual declines associated with aging. Specifically, declines in peripheral processing and useful field of vision (UFOV; i.e., the amount of the visual field a person can use easily and with accuracy) could lead to older users being less likely to see items located on the edge of the screen (Ball et al., 1988; Scalf et al., 2007; Scialfa et al., 1987; Sekuler et al., 2000). Decline in UFOV is a unique aspect of perception changed with age, independent of general age-related declines in vision such as nearsightedness and farsightedness (Ball, Owsley, & Beard, 1990). In addition to age, other factors can influence performance on tasks requiring a wide UFOV, such as increased task demand, the distance of task stimuli from the center of the screen, and presence of distracting elements on the screen (Ball et al., 1988). Real-world websites may present each of these additional taxes on UFOV.

Despite known difficulties older adults have navigating websites, it is not known whether the pattern of eye movements differs between younger and older adults when they search for information on websites. However, it is well known that eye movement deficiencies in older adults increase when visual fields are distracting and when information is presented in the periphery (Mackworth, 1965; Madden, Connelly, & Pierce, 1994; Romano, Dennis, Howard, & Howard, 2007; Scalf

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et al., 2007; Scialfa et al., 1987). These deficiencies have large implications for older users and website performance, as a great deal of important information on websites is located in the periphery (e.g., top navigation), and many websites are cluttered and distracting. Older users might not seek information in the periphery of a web page—because they do not see it due to reduced UFOV, or because they do not expect useful information to be there (e.g., due to less experience with websites compared to younger users). Tracking older adults' eye-movement patterns when navigating websites is a method of gathering data on this behavior. Understanding eye-movement tendencies of older adults when navigating websites is useful for website design, particularly considering the fast growing number of older adults who use the Internet (O'Connell, 2007; U.S. Census Bureau, 2005, 2009, 2010).

Although few empirical studies have examined aging and web performance (e.g., Chin & Fu, 2010; Hargittai, 2002; Kubeck, Miller-Albrecht, & Murphy, 1999; Stronge, Rogers, & Fisk, 2006), an even smaller number have used eye tracking as a method for examining age-related differences in performance (e.g., see conference proceedings from Loos, 2009, 2011; Romano, 2010; and Tullis, 2007). Here we used eye tracking to better understand which design features captured participants' attention as well as those that they failed to notice. Eye tracking captures where Internet users look as they navigate through a website. Measures included eye fixations, which are instants in which the eyes are relatively still and can indicate an area of interest to the user or that is difficult to understand (Goldberg & Kotval, 1999; Poole & Ball, 2005; Poole, Ball, & Phillips, 2004), elements that are more noticeable or more important (Jacob & Karn, 2003; Poole et al., 2004), and a users' efficient or inefficient search (Goldberg & Kotval, 1999). When using eye tracking in usability testing, we can categorize data by identifying areas of interest (AOIs) and examine the fixation patterns for predetermined AOIs.

Because few aging and Internet studies have used eye tracking to understand website navigation performance in older adults, we filled this gap by examining age-related differences in website usability using noninvasive eye tracking. Eye-tracking data were examined from five different website usability studies. In the initial usability study, age-related differences in eye tracking were noticed, and so we decided to examine four other usability studies that were ongoing at or around the same time. The goals of this article were to (a) examine age-related differences in eye movement and performance during website navigation; (b) examine whether age-related differences are related to website performance and satisfaction; and (c) based on pragmatic findings, provide recommendations for website design that account for putative cognitive limitations of older adults.

2. METHOD

We assessed eye-tracking data, user performance data (accuracy and efficiency), and satisfaction ratings from five independent website usability studies (Olmsted-Hawala, Beck, Murphy, & Ashenfelter, 2008; Olmsted-Hawala, Holland, & Romano Bergstrom, 2011; Romano, Holland, & Murphy, 2009; Romano & Murphy, 2008; Romano Bergstrom & Olmsted-Hawala, 2010). The a priori objectives for each of the studies did not include examining age-related differences; the objectives were to test the usability of the websites and to identify areas that needed improvement. In the first usability study, we discovered age-related differences, which led us to examine performance on other websites that were undergoing usability testing. Although many usability studies were occurring concurrently, we chose these five to examine based on their representativeness of other U.S. Census Bureau websites: a complex data dissemination site that housed a great deal of Census Bureau data, an economic data site, a business and industry site, and a non–Census Bureau online collaboration workspace for federal employees.

2.1. Participants

Participants were U.S. Census Bureau employees and contractors, or residents of the metropolitan Washington, DC, area. All participants reported being experienced with computers and the Internet, and all reported being naive to the tested website. See Table 1 for demographic information, including self-reported comfort with learning to use a website and with navigating the Internet. We categorized participants as "older" and "younger" post–data collection based on a visual review of age distributions. The specific age splits vary by study because we did not have a priori knowledge that we would be examining age-related differences and thus did not recruit accordingly.

Seven people (four younger and three older) participated in the first study (Romano & Murphy, 2008) and completed 10 information-search tasks. Six people (three younger and three older) participated in Usability Study 2 (Romano et al., 2009) and completed 10 information-search tasks. Five people (three younger and two older) participated in Usability Study 3 (Olmsted-Hawala et al., 2008) and completed 19 first-click tasks in which they made the "first click" that would subsequently lead to the information they were seeking if it had been a working website. Eleven people (seven younger and four older) participated in Usability Study 4 (Romano Bergstrom & Olmsted-Hawala, 2010) and completed five information-search tasks. Eight people (five younger and three older) participated in Usability Study 5 (Olmsted-Hawala et al., 2011) and completed seven information-seeking tasks. Each participant participated in only one study.

2.2. Procedure

Usability testing took place in the Human Factors and Usability Research Group's laboratory at the U.S. Census Bureau headquarters. Each participant sat individually in a 10×12 ft room, facing a one-way mirror and a wall camera, in front of a 17-in. LCD Tobii T-120 eye-tracking monitor.

TABLE 1
Participants' Mean (and Range) Characteristics

	Study 1: Economic Census Website		Study 2: Economic Census Site Redesign		Study 3: Business & Industry Website		Study 4: American FactFinder Website		Study 5: FedSpace Website	
	Older	Younger	Older	Younger	Older	Younger	Older	Younger	Older	Younger
Study sample size by age	3	4	3	3	2	3	4	7	3	5
Gender	1M/2F	2M/2F	1M/2F	2M/1F	0M/2F	2M/1F	3M/1F	2M/5F	1M/2F	1M/4F
Age	54 (51–59)	27 (23–31)	56 (53–59)	22 (19–27)	56 (50–62)	30 (24–37)	71 (65–75)	24 (19–27)	55 (52–57)	24 (20–29)
Years of education	17 (14–20)	18 (16–21)	15 (13–16)	13 (12–16)	15 (14–16)	18 (16–20)	16 (14–18)	16 (14–18)	18 (17–18)	17 (16–18)
Comfort learning a new website[a]	4.00 (2–5)	4.25 (4–5)	4.00 (3–5)	3.67 (3–4)	3.50 (3–4)	4.67 (4–5)	4.25 (3–5)	4.57 (3–5)	4.67 (4–5)	4.80 (4–5)
Comfort navigating the Internet[a]	4.30 (3–5)	4.50 (4–5)	4.33 (4–5)	4.33 (4–5)	4.00 (4–4)	5[b] (5–5)	5.00 (5–5)	5.00 (5–5)	4.67 (4–5)	5 (5–5)

Note. M = male; F = female.
[a]Scale is 1 (*not comfortable*) to 5 (*comfortable*). [b]Age-related differences at $p < .0001$.

In each study, we uniquely defined the top navigation bar as a peripheral AOI and a series of links in the center of the screen as the central AOI. In Studies 1 to 4, we defined the left navigation bar as the peripheral AOI. In Study 5, which had a different layout and rather than a left navigation bar the site had a right navigation bar, we defined the set of links on the right as the peripheral AOI. We assessed which AOIs attracted the most attention by examining fixation patterns and time to first fixate those areas. Fixations are instances where the eyes are relatively still, and gaze plots represent the total number of fixations in a uniquely defined area (Poole & Ball, 2005). Fixation patterns and time to first fixation were quantified and gaze plots were created using ClearView (Version 2.0) and Tobii Studio. Eye tracking was noninvasive and did not constrain normal head movements; consequently, participants could move freely in a limited area. During the usability tests, the test administrator sat in the control room on the other side of the one-way mirror. The test administrator and the participant communicated via microphones and speakers.

In each of the five studies, participants performed predetermined tasks. They read the task aloud, they thought aloud using a speech communication think-aloud protocol (Olmsted-Hawala, Murphy, Hawala, & Ashenfelter, 2010) while they navigated through the site to locate the critical information, and they stated their answer aloud. During each task, participants' eye movements were recorded. Dependent measures were eye-tracking outcomes (explained in detail in the results section), self-reported satisfaction ratings, task-completion times (i.e., efficiency) and task completion success (i.e., accuracy), and the independent measure was age group (younger vs. older adults).

After completing the usability test, each participant completed a user satisfaction questionnaire that was loosely based on the Questionnaire for User Interaction Satisfaction (Chin, Diehl, & Norman, 1998). The 10-item questionnaire consisted of semantic differential items that assessed participants' satisfaction with various elements of the website. For example, one item was "Information displayed on the screen," and participants chose a rating on a scale of 1 to 9 ranging from *inadequate* to *adequate*. Each session lasted approximately 1 hr.

Study 1 was on the Economic Census website (http://www.census.gov/econ/census07). The site was undergoing a redesign, so the goal was to perform a formative, iterative usability test. That is, an initial usability study was conducted to identify the usability problems with the existing site, recommendations were made to improve the usability of the site, the developers made changes to address the problems, and the revised site was tested again and appears here as Usability Study 2. The second round of testing was conducted to evaluate if the changes that the developers made (a) improved user performance and thus the usability of the site, and/or (b) led to further issues. Functionalities in both the original and the redesigned website included accessing U.S. national and local economic data, data release schedules, and user guides to understand and use Economic Census data. Of these functionalities, our tasks assessed locating specific information (i.e., contact information, definitions, data release dates, data, forms, information about manipulating and comparing data).

Usability Study 3 was also part of an iterative usability study and was conducted on the Business and Industry website (http://www.census.gov/econ/). This study was conducted on a low-fidelity prototype with a first-click usability technique (Wolfson, Bailey, Nall, & Koyani, 2008), whereby the participants were asked to click on the link where they expected to find the information, and the test administrator ended each task following the "first click." The site was an early HTML prototype with no working links. The page served as a main navigational conduit into multiple business survey data, which have different business information available at different geographic levels. The main functionality of the site was to direct users down the path that would lead to the information in which they were interested. Our tasks assessed whether the participant made the correct initial click that, if it had been a working site, would have led them to the information they were looking for. Tasks included obtaining information about data, finding definitions of Census terminology, and finding help in filling out the survey.

Usability Study 4 was on the American FactFinder website (http://factfinder.census.gov). It was part of a baseline study that was being conducted while ongoing iterative testing was taking place on a new version of the site (Romano Bergstrom, Olmsted-Hawala, Chen, & Murphy, 2011). Functionalities of the website included downloading tables and files, building tables, making comparisons, and viewing information and boundaries on a map. Our tasks assessed searching for a specific piece of information, comparing data over time, viewing ranked information, and locating data and boundaries on a map.

Usability Study 5 was on the FedSpace website (http://www.fedspace.gov). The study was conducted on a beta version of a new site that was being developed for federal employees to work collaboratively across agencies. Functionalities included (federal employees) connecting, creating, and sharing content and resources across agencies through Web 2.0 technologies such as blogging; creating or contributing to profiles and wikis; and adding to and sharing professional resources (bookmarking). Of these functionalities, our tasks assessed logging in and requesting membership, creating a wiki, adding a bookmark, updating account information (status updates), and finding and interpreting the rules of conduct for the site.

3. RESULTS

For each participant, we calculated two key eye-tracking outcomes: (a) the proportion of fixations per AOI on the main page of the site (i.e., number of fixations per AOI divided by the total number of fixations on all the AOIs), and (b) the time elapsed before the first fixation on each AOI. Then we calculated the mean of these outcomes for each age group within each usability study. We calculated the mean self-reported satisfaction ratings and task accuracy (percentage of successfully completed tasks) for each participant, and the mean for each age group, for each study. Efficiency scores were calculated for Usability Study 1, 2, 4 and 5[1] by taking the mean time to complete each task across tasks and participants, for successfully completed tasks only. See Table 2 for scores by study and age group.

For each study, two-tailed independent samples t tests were performed on each measure to compare the two age groups. Each usability study was examined separately because each website and the tasks for each usability study were different and thus not statistically comparable.

3.1. Usability Study 1: Economic Census Website

As indicated in Table 2, younger participants had a greater proportion of fixations on the peripheral left AOI than older participants, $t(5) = 2.77$, $p = .04$, $d = 2.01$, and older participants had a greater proportion of fixations on the central AOI than younger participants, $t(5) = 3.50$, $p = .02$, $d = 2.43$. There was no difference between the groups in proportion of fixations on the top AOI, $t(5) = 0.28$, $p = .79$. There were no group differences for time to first fixate the peripheral left AOI, $t(5) = 1.42$, $p = .21$; the peripheral top AOI, $t(5) = 0.33$, $p = .75$; or the central AOI, $t(5) = 1.31$, $p = .25$. As shown in Table 2, younger participants were more efficient overall, such that they completed tasks faster than older participants, $t(5) = 4.35$, $p < .01$, $d = 3.52$. There were no group differences for self-rated satisfaction, $t(5) = 1.02$, $p = .36$, or task accuracy, $t(5) = 0.00$, $p = .97$.

3.2. Usability Study 2: Economic Census Redesign

In the redesign, in which a button-like link that was in the center of the page (Central AOI) was removed, there were no significant group differences in proportion of fixations on the top AOI, $t(4) = 1.73$, $p = .16$; the peripheral left AOI, $t(4) = 0.80$, $p = .24$; and the central AOI, $t(4) = 0.25$, $p = .41$. There were also no group differences for time elapsed to first fixate the peripheral top AOI, $t(4) = 1.08$, $p = .34$; the peripheral left AOI, $t(4) = 2.05$, $p = .12$; or the central AOI, $t(4) = 1.00$, $p = .38$. There were no age differences for efficiency, $t(4) = 0.97$, $p = .39$; self-rated satisfaction, $t(4) = 1.11$, $p = .34$; or task accuracy, $t(4) = 0.32$, $p = .78$. Thus, older and younger participants performed similarly when the large button-like link was removed from the center.

3.3. Usability Study 3: Business and Industry Website

Like Study 2, there were no differences in proportion of fixations on the peripheral top AOI, $t(3) = 0.60$, $p = .60$; the peripheral left AOI, $t(3) = 0.51$, $p = .66$; and the central AOI, $t(3) = 0.38$, $p = .74$, and there were no group differences in time to first fixate the peripheral top AOI, $t(3) = 1.63$, $p = .20$; the peripheral left AOI, $t(3) = 1.54$, $p = .22$; and the central AOI, $t(3) = 1.4$, $p = .26$. As shown in Table 2, younger participants completed more tasks successfully than the older participants, $t(3) = 4.07$, $p < .05$, and there was no group difference for satisfaction, $t(3) = 0.01$, $p = .18$.

3.4. Usability Study 4: American FactFinder Website

There were no group differences in proportion of fixations on the left AOI, $t(9) = 0.13$, $p = .45$, or central AOI, $t(9) = 0.69$, $p = .26$, but, contrary to our hypotheses, there was a trend for older participants to have a greater proportion of fixations on the top AOI, $t(9) = 1.67$, $p = .07$. There was no group difference in time to first fixate the peripheral AOI, $t(9) = 0.28$, $p = .78$, except one older participant *never* looked at the left navigation. There were no differences between the groups in time to first fixate the central AOI, $t(9) = 0.83$, $p = .44$, and time to first fixate the peripheral top AOI, $t(8) = 0.83$, $p = .44$, except one younger participant *never* looked at the top AOI. As shown, the older participant (Panel C) had many fixations in the top AOI

[1]Efficiency scores were not calculated for Study 3 because the site was not fully functioning; thus, an efficiency measure would have been uninformative.

TABLE 2
Mean Proportion of Fixations Across Participants, Time Elapsed (in Seconds) to First Look at AOIs, Satisfaction Ratings, Accuracy, and Efficiency, by Study and by Age Group

	Study 1: Economic Census Website		Study 2: Economic Census Site Redesign		Study 3: Business & Industry Website		Study 4: American FactFinder		Study 5: FedSpace Website	
	Older	Younger	Older	Younger	Older	Younger	Older	Younger	Older	Younger
Proportion of fixations										
Peripheral: top	.25	.21	.15	.14	.04	.06	.16	.06	.18	.24
Peripheral: left (right in Study 5)	.27**	.68	.24	.25	.34	.28	.39	.41	.09	.17
Central	.52**	.08	.61	.61	.55	.67	.46	.53	.64**	.46
Time (ms) elapsed to first look at target										
Peripheral: top	124.61	93.59	382.33	70.67	267.97	9.53	69.50	214.83	49.28†	1.89
Peripheral: left (right in Study 5)	41.48	14.05	11.00	31.67	7.03	51.25	25.33	18.57	9.44	6.40
Central	25.63	4.17	2.00	3.33	14.28	2.56	9.75	24.86	6.87	0.82
Satisfaction (1 = low to 9 = high)	4.78	6.31	4.63	4.10	5.17	5.15	4.52	5.37	6.27	7.40
Task success	57%	58%	73%	70%	26%**	46%	40%	64%	82%	71%
Efficiency (average time in seconds to complete tasks)	3 min 11 s*	2 min 10 s	3 min 27 s	2 min 49 s	N/A	N/A	3 min 12 s	3 min 31 s	2 min 46 s†	1 min 48 s

*Significant age group difference at $p < .01$. **Significant age group difference at $p < .05$. †Significant age group difference at $p = .06$.

compared to the younger participant (Panel D). As shown in Table 2, there were no group differences in efficiency, $t(8)^2 = 1.48$, $p = .18$; self-rated satisfaction, $t(9) = 1.14$, $p = .28$; or task accuracy, $t(9) = 1.58$, $p = .15$.

3.5. Usability Study 5: FedSpace Website

Older adults had a greater proportion of fixations on the central AOI compared to younger adults, $t(6) = 2.95$, $p = .03$, $d = 1.99$. There were no group differences in proportion of fixations on the peripheral right AOI, $t(6) = 1.38$, $p = .22$, or peripheral top AOI, $t(6) = 0.95$, $p = .38$. For time elapsed to first look at the targets, younger adults fixated the peripheral top AOI sooner than the older adults, $t(6) = 1.86$, $p = .06$, and there was a trend for younger adults to fixate the central AOI sooner than older adults, $t(6) = 1.41$, $p = .11$. There was no difference in time to first fixate the peripheral right AOI, $t(6) = 0.81$, $p = .23$. Younger adults completed tasks faster than older adults, $t(6) = 2.34$, $p = .06$, and there was no difference in accuracy, $t(6) = 0.99$, $p = .36$, or self-rated satisfaction, $t(6) = 1.36$, $p = .22$.

3.6. Summary of Results

- The proportion of fixations on the central AOI was greater for older compared to younger participants for Studies 1 and 5.
- The proportion of fixations on the peripheral left AOI was greater for younger compared to older participants for Study 1.
- The time to first look at the peripheral top AOI was longer in older compared to younger participants for Study 5.
- Accuracy was higher in younger compared to older participants in Studies 3 and 5.
- Efficiency was higher in younger compared to older participants in Study 1.
- There were no group differences in self-reported satisfaction across all five studies.

[2]One participant answered all the tasks incorrectly, thus his data were not included in the efficiency measure.

4. DISCUSSION

In Study 1, younger participants had a greater proportion of fixations on the peripheral left AOI than older participants, and older participants had a greater proportion of fixations on the central AOI than younger participants. These results suggest that older adults do not attend to cluttered, peripheral information that is outside their narrowing UFOV; however, these results may also indicate that the button-like element in the center of the screen was distracting to older users. Whereas younger users, who are more familiar with the locations of the primary navigation elements on a web page, can ignore the button-like structure in the center of the screen, perhaps older adults cannot. This puts older adults at a disadvantage, causing them to take longer to complete tasks, as we confirmed in this study.

In the redesign of this site (Study 2), the button-like structure was removed, and there were no significant group differences in eye tracking. These data imply that the age-related difference observed in Study 1 may not be explained by the difficulty in processing peripheral information for older adults, but rather it implies that information in the center was distracting and thus impeded performance in Study 1. In Study 2, there were also no differences between the groups for efficiency, self-rated satisfaction, or task accuracy. Therefore, older and younger participants performed the same when the distracting element was removed.

In Study 3, similar to Study 2, there were no group differences in eye tracking. On this site, there were many links in the center and periphery. The web page tested was cluttered in all areas, both in the peripheries and in the central part of the screen. This could indicate that when web pages are too cluttered, older and younger users look all over the page for pertinent information, and both age groups alike are distracted. However, younger participants were able to complete more tasks successfully than the older participants (and the direction of results demonstrated that younger participants looked at the peripheral top navigation sooner than older participants); hence, younger adults were less affected by the cluttered screen.

In Study 4, there were no group differences in proportion of fixations on the left AOI or central AOI, but there was a trend for older participants to have a greater proportion of fixations on the top AOI, where useful information was *not* located. In most websites, the peripheral top displays primary navigation elements, but in this site there were images in that area. Although younger adults may have been able to assess the page and quickly determine that the top would not help them with their goals, it is possible that the useless, attractive graphics along the top were distracting to older users who could not ignore them. What was more important for users to succeed on this site was the left navigation, which was the primary way to access information. Although there were no significant age-related differences for the left navigation, one older participant *never* looked at this area. This is consistent with the older participants in Study 1 and is problematic, considering that this was the main way to access information on this site.

In Study 5, older participants had a greater proportion of fixations in the central AOI compared to younger participants. Consistent with Study 1, this may indicate that distracting information in the center of the screen draws older users' attention there, and it impedes their performance using elements on the rest of the screen. For time elapsed to first look at the targets, younger participants fixated the peripheral top AOI sooner than the older adults, which is where important navigation information was located. This likely led to the younger participants' greater usability performance: indeed, they completed tasks faster than the older participants.

These eye-tracking data highlight the potential for age-related differences in the pattern of eye movements while navigating websites and provide motivation for further exploration. Older participants had a greater proportion of fixations in the central part of the screen than younger participants in two of the five usability studies and a smaller proportion of fixations in the peripheral left part of the screen than younger participants in one study. In addition, older participants took longer to first move their eyes to the peripheral top part of the screen in one study. Together, these data suggest that older adults may spend *more* time looking at the center of a web page and *less* time looking at the peripheral elements of the screen. Therefore, we recommend that usability and visual science researchers design and test for age-related differences in the location of essential navigation elements, specifically comparing peripheral and central placement of items. In Studies 2 and 5, important content was presented in both the central area and the periphery simultaneously, and the success rate was high for both older and younger participants, suggesting that a "dual placement" condition may help tease out age effects. By implementing this recommendation as a part of standard website usability research, a body of results can be built to validate and refine the initial findings presented here.

Traditional usability methods enable researchers to examine users' behavior and attitudes. Eye-movement tracking is a noninvasive method that allows researchers to know where a person is looking at any given time. Although this is not a direct measure of what a person is attending to, research has shown that there is a relationship between where a person's eyes move and attention (e.g., Roberts, Fillmore, & Milich, 2010; Schriver, Morrow, Wickens, & Talleur, 2008; Yoder & Belmonte, 2010). Here we infer from eye-tracking data that when websites have distracting visual elements, older users will look at those areas more than the rest of the screen. This is potentially problematic when primary navigation tools are located only in one area, as they often are, in the periphery.

Regarding usability metrics, although we did not find age-related differences in satisfaction in these five studies, it may be due to the laboratory setting. The age-related differences in accuracy and efficiency that we found, if experienced in real-world website use, could lead to greater frustrations because users in the real world are trying to accomplish tasks in which they have a sincere interest. Further, older adults' satisfaction with websites may decrease if information they need to navigate a website is located in the periphery, a region to which they may not easily attend. Similar effects may exist on real-world efficiency and accuracy.

4.1. Limitations

A caveat to these analyses is the small number of participants in each study. Although typical usability studies recruit only five to eight users (Nielsen, 1994; Nielsen & Landauer, 1993), this limits the statistical analyses and generalizations we can make. However, our significant findings and the direction of our non-significant findings are consistent with previous research that has shown age-related decline in cognition, such as processing information in the periphery. Future experimental research with larger sample sizes is necessary to further test the effects of location of items on website screens on user experience.

In this series of studies, we were unable to control the specific web design (i.e., how much information was in a particular location) of the websites that were tested. To infer about the effects of design on user performance and satisfaction, future researchers should systematically control the layout of the website. It is possible that the complexity of websites in conjunction with known UFOV decline plays a role in where users look and spend their time on a page. We recommend future eye-tracking studies on websites of differing complexity. Such studies could lead to insight on further design recommendations for older adults.

5. CONCLUSION

Older adults are the fastest growing group of Internet users, and older adults who use the Internet have the potential to connect with information and people, which gives them a greater sense of control and ownership over life choices. Indeed, successful navigation of websites has the strong potential to lead to an increase in the quality of life for older adults. However, older adults often report difficulties using websites.

Website design should be centered on the end user, including older adult users, so that they can access information and maintain independence with as much ease and satisfaction as younger adults do. It is important to consider issues associated with aging as design teams develop and modify websites. By taking older adults' limitations into account, design teams can accommodate all users who are accessing or sharing information on the Internet. As people live longer, and as the number of older adults is increasing, improving quality of life for older adults must also include improving the usability of the different technologies with which they interact.

5.1. Website Design Takeaways

- Consider repeating important content in the center and the periphery.
- Use a clean and decluttered layout.
- Reduce unduly distracters that may draw older users' eyes to a part of the screen that does not provide adequate information.

5.2. Usability Practitioners Takeaways

- Include older adults in user experience research.
- Include eye tracking in user experience research to learn where users are looking.
- Include tasks in usability testing that assess various page of the page, including peripheral navigation elements and central parts of the screen.

5.3. Impacts on Practice

- As people are living longer and using technology more, and as more information moves to the web, designers must create sites with both younger and older users in mind.
- Creating usable websites is pertinent to allow users to get the information they are seeking and to encourage return visits.
- With the emerging technologies of Web 2.0 and beyond, navigation is changing. Critical links and features could be lost on older user if their needs are not accounted for.
- The five sites tested only touched on emerging data visualization capabilities. As the next generation of information and data web pages emerge, the importance of testing with older users is heightened because key navigational elements and ways to interact with the sites and data may be in locations that do not take natural age-related declines into consideration.

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