Age Differences in Search of Web Pages: The Effects of Link Size, Link Number, and Clutter

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Reaction time, eye movements, and errors were measured during visual search of Web pages to determine age-related differences in performance as a function of link size, link number, link location, and clutter. Participants (15 young adults, $M = 23$ years; 14 older adults, $M = 57$ years) searched Web pages for target links that varied from trial to trial. During one half of the trials, links were enlarged from 10-point to 12-point font. Target location was distributed among the left, center, and bottom portions of the screen. Clutter was manipulated according to the percentage of used space, including graphics and text, and the number of potentially distracting nontarget links was varied. Increased link size improved performance, whereas increased clutter and links hampered search, especially for older adults. Results also showed that links located in the left region of the page were found most easily. Actual or potential applications of this research include Web site design to increase usability, particularly for older adults.

INTRODUCTION

The Internet has sparked a revolution in the last decade, producing significant changes in the ways companies do business and individuals perform their daily tasks. Although the first "boom" of prosperity for new Internet businesses ended with the 1990s, its popularity and use show no sign of abating. As the frequency of Internet use and the number of individuals using it increase, it will become more important for the medium to provide information in an efficient and usable manner. This is especially true for older adults, whose needs and capacities differ significantly from those of younger users.

Currently, older adults constitute the fastest growing Internet user group (Lindberg, 2002; Morrell, 2002; Silver, 2001). One factor that may explain this trend is the aging population. It has been estimated that by 2030 there will be 70 million older Americans, roughly twice as many as there are today (Welle, 2002). As this population grows, so too will the number of older adults using the Internet.

The Internet provides a number of benefits for older adults. It is used as a means of communication via E-mail, chat rooms, discussion groups, direct messaging, and so forth. A SeniorNet Survey on Internet Use (2002) reported that 94% of seniors who use the Internet do so to stay in touch with friends and relatives. The Internet also contains a wealth of medical information that can be particularly useful for the older adult when health becomes a greater issue and concern. According to the same SeniorNet survey, 70% of senior Internet users gather health information on line. Current news and events was the only other category that at least 70% of seniors indicated they access via the Internet. Going on line has also been shown to improve health and well-being (Lansdale, 2002).

A common use of the Internet is navigation of the World Wide Web (WWW), an Internet facility that links documents (i.e., Web pages) remotely and locally in hypertext forms (Nielsen, 2000). Compared with younger users, older adults experience more frequent problems using the WWW, including difficulty finding broken links, viewing graphics, finding new information, and revisiting pages or sites (Graphic,
Visualization, and Usability Center [GVU], 1998). Thus, although older adults are generally willing and able to use computers, they often have more problems than do their younger counterparts (see also Czaja & Lee, 2001).

The most common affordances used to facilitate Web search and navigation are graphical and text links. Graphical links are as varied as the needs and creativity of developers allow. In contrast, text links are constrained visually by the nature of the alphabet and semantically by linguistic convention. Also, standards exist to ensure text links have common characteristics. Often they are presented in blue, underscored type, are segregated by function from other page information, and can be given a color change (often to a short-wavelength violet or purple) once accessed to indicate their previous use. In principle, these conventions allow users to search and navigate the Web more easily, but relatively few studies have systematically examined the effects of link characteristics on Web performance, and this is particularly true for older adults.

The purpose of this study was to examine some of the characteristics of links on Web pages that influence search. We chose to focus on Web pages for three reasons. First, data have shown that the WWW is the most frequently used Internet facility (GVU, 1998). Second, difficulty with navigation is one of the largest problems for WWW and hypertext users and is characterized by problems in searching for information and in getting lost while navigating (Conklin, 1987; Hammond & Allison, 1989; Kim & Hirtle, 1995; Nielsen, 1990; Vora & Helander, 1997). Third, older adults consistently demonstrate poorer performance in visual search (see Madden & Whiting, 2003) and on many computer tasks (Czaja & Lee, 2001; Kelly & Charness, 1995) and thus may be more susceptible to problems while conducting WWW searches.

One of the more critical features influencing Web navigation is link salience. In the present context, salience refers to the conspicuousness (Engel, 1971) of the links, which is influenced by a number of factors, including relative size, color, and contrast. Because enhancing salience increases the probability of quickly and easily isolating relevant information, high-salience targets mitigate the interfering effects of nontarget information (Scialfa, Esau, & Joffe, 1998; Treisman & Sato, 1990; Wolfe, 1994; Wolfe, Cave, &Franzel, 1989). A time-honored means of increasing the salience of text material is to vary print size. Changing the print size of links can ease search by allowing the links to segregate more easily from other text (Hartley, Trueman, & Burnhill, 1979). Additionally, increased text size can improve reading speed through the well-known relation of acuity demands to reading ease (Aberson & Bouwhuis, 1997). Type-setters have, for example, used changes in print size to indicate subsections of text (Hartley & Jonassen, 1985), and Bernard, Lida, Riley, Hacker, and Janzen (2002) have shown that when participants read on-line documents, 10-point fonts were read significantly more slowly than fonts at the 12-point size. Because changing print size is easy to implement, it is a prime candidate for improving the usability of a Web site.

Improving link salience via increased print size has special significance for older adults. The presenting acuity of older adults is often poorer than that of younger Web users (Gittings & Fozard, 1986), and their limitations in spatial vision are exacerbated when the glasses they wear are not designed for the distance and gaze angle of their workstations. As a consequence, reading speed and accuracy are reduced and visual fatigue is more likely. Although increased print size does not eliminate the blur that results from inappropriate optical correction, it does reduce the effects of blur by lowering the spatial frequency of the material. Thus one would expect older adults to benefit from increased print size (Echt, 2002). In addition, because older adults have deficits in both texture segmentation (Scialfa & Hamaluk, 2001; Scialfa, Hamaluk, Skaloud, & Pratt, 1999) and search for targets with low salience (Scialfa et al., 1998), larger print might help them in the initial localization of target links.

Location also plays a role in visual search. People find things most easily when the items are in a consistent and expected location that is near the point they are fixating or attending. For example, Theeuwes (1996) reported that visual search for roadway signage was carried out more quickly and with fewer eye movements when the target signage was in expected
locations. Eccentricity effects are quite common in visual search (Scialfa & Joffe, 1997; 1998; Owsley, Ball, Sloane, Roenker, & Bruni, 1991), although the effects can be reduced through practice (Scialfa & Joffe, 1998). In addition, many attentional paradigms have shown that information is processed best when it is near the current focus of attention (see Madden & Whiting, 2003; McDowd & Shaw, 2000).

For English-language readers, eye movements and attentional allocation follow a canonical scanpath that is dictated by the written language, starting in the upper left and reading rightward until the end of the print line. At that point a large-amplitude saccade brings the reader to the beginning of the next line (Rayner, 1978). Thus targets in the upper left are much more likely to be found quickly (Megaw & Richardson, 1979), and information processing shows a bias to the right of the current fixation, most likely because attentional allocation is needed to facilitate saccades (Vitu, 1991). Oculomotor and attentional dynamics in Web-based search are complicated by the facts that less systematic scanning and browsing are often interspersed with reading (Nielsen, 2000), that Web material has a higher concentration of nontext material than prose does, and that information does not follow the relatively blocked format that is common with the printed word. Still, location effects can be seen in Web search. For example, LaBerge, Ho, and Scialfa (2003) reported that the detection of changes in Web pages was more likely to occur within the text body than outside it.

Location effects are exacerbated in older adults. Because of age-related reductions in peripheral acuity and contrast sensitivity (see Kline & Scialfa, 1997), targets located away from central vision are less likely to be processed. Inappropriate optical corrections for near work and drooping eyelids (i.e., ptosis) will probably lead to age deficits in the superior visual field. Attentional allocation is also more restricted in older adults, as reported in several studies of the useful field of view (Owsley et al., 1991; Scialfa, Kline, & Lyman, 1987; Scialfa, Thomas, & Joffe, 1994). Additionally, age differences in search are greatest when targets are presented at an unknown or inconsistent location (Plude & Hoyer, 1985). Thus we expect that older adults will find search more demanding when target links are placed in noncentral locations that are distant from their attentional focus.

Search can be rendered trivially simple or extremely difficult by varying the amount of nontarget information (i.e., clutter) in which the targets are embedded. Clutter effects — which are often operationalized as the number of nontargets and, less often, manipulated via changes in background complexity and homogeneity — generally lead to increased errors, eye movements, and reaction times (Drury & Clement, 1978; Ho, Scialfa, Caird, & Grau, 2001; Schieber & Goodspeed, 1997; Wolfe, 1994; Wolfe et al., 1989). This arises in part because clutter can hinder the texture segmentation that allows potential targets to be localized and also because some subset of the nontargets are processed in a serial, self-terminating manner prior to target acquisition.

All clutter is not created equal. Humans are amazingly adept at ignoring nontarget information if it occurs in a location that is irrelevant to the task. For example, when searching for traffic signs, one's attention is rarely attracted by clouds or lane markings. Also, people can ignore distractors that are dissimilar to the target they seek (Ho, Siakaluk, & Scialfa, 2003). When people search for links on the Web, clutter may have a general interfering effect, but it is more likely the case that search is hampered as the number of links increase because these are the objects that draw processing resources (Lin, 2001).

Findings regarding age-related differences in clutter effects are mixed. Basic research carried out over the past 40 years (Madden & Whiting, 2003; Rabbitt, 1965) indicates that older adults are slowed disproportionately in their search when the number of distractors increases. Similarly, applied research on hypertext reading has revealed that performance deteriorates as the number of links increases, especially for older adults (Lin, 2001). However, at least for simple search tasks, older adults are as capable as their younger counterparts in ignoring objects that do not share salient target features, such as color and shape (Ho & Scialfa, 2002). In some studies, older adults did not show larger clutter effects when searching for traffic signs in digitized images of driving scenes (Ho et al., 2001;
McPhee, Ho, Dennis, Scialfa, & Caird, in press; but see Schieber & Goodspeed, 1997). In sum, we might expect older adults to be more hampered in searching for pages that contain a large number of similar links, whereas predictions regarding the general effects of clutter are less certain.

The intention of this study was to compare the abilities of older and younger adults in performing a visual search task on a Web page. The task involved determining the presence of a blue, underlined hyperlink, the most common means of indicating potential targets in sequential Web search and general browsing. This study manipulated link size, location, number of distracting links, the amount of clutter, and presence of the target hyperlink. During one half of the trials, link size was enlarged from a 10-point to a 12-point font size to increase salience. Target location was distributed among the left, center, and bottom portions of the screen. Clutter was measured according to the percentage of used space, including graphics and text. Finally, the number of links was varied.

Targets in a smaller font were expected to lead to slower reaction times, more eye movements, and increased errors. We also expected to find that search was more difficult when there was great clutter and a larger number of distracting links. Search was anticipated to be best for links presented in the middle of the page (Laberge et al., 2003). Of greatest relevance, it was hypothesized that older adults would show greater effects of presence, location, and links but that age differences would be reduced with larger link size. Tests of the Age × Clutter interaction were more exploratory in nature because of the inconsistency of archival data.

METHOD

Participants

Participants were divided into two groups based on age. In the younger group, 15 adults ranging in age from 20 to 31 years (M = 23.27, SD = 3.37) were recruited from the undergraduate research pool from the Department of Psychology at the University of Calgary. All of the participants in the younger group were compensated with a bonus credit that amounted to an additional 1% toward one of their psychology undergraduate courses. The second group consisted of 14 older adults ranging in age from 55 to 62 years (M = 57.29, SD = 2.13). The older adults were recruited from the city of Calgary and the surrounding communities and were compensated $10.00 (Cdn) for their participation.

Everyone was screened for general health, vision, and computer experience. The average self-reported health rating on a 5-point Likert scale (1 = very poor, 5 = excellent) was 4.15 (SD = 0.60), and this did not differ between young and old adults, F(1, 25) = 0.02, p = 0.89. All participants had visual acuity of at least 20/24 at the test distance of 60 cm. With corrective lenses, the younger group had an average acuity of 20/14, whereas the older group had an average acuity of 20/20. Contrast sensitivity for spatial frequencies ranging from 2 to 16 cycles per degree fell within normal ranges for each person’s age group (Scialfa et al., 1988). Older adults were significantly worse than younger adults in their color vision, t(27) = 2.95, p = .006, and one older participant was excluded from the analyses to follow because of poor color perception.

The younger adults spent an average of 15.47 hr/week using a computer, with 7.89 hr of that time on the WWW. The older adults spent an average of 18.39 hr/week on a computer, with 2.96 hr of that time on the WWW. The age differences between the times spent on a computer per week were not significant, F(1, 27) = 0.33, p = .57; however, the difference between the times spent per week on the WWW was significant, F(1, 26) = 7.48, p = .01. Computer anxiety was measured using a scale developed by Raub (as cited in Ellis & Allaire, 1999). Participants responded to 10 statements on a 5-point Likert scale (1 = strongly disagree, 5 = strongly agree), on which higher scores indicated more anxiety. Computer anxiety was calculated by averaging responses to the 10 statements. Both the younger (M = 2.01, SD = 0.65) and older groups (M = 2.19, SD = 0.49) reported low anxiety overall, and there was no difference between the groups, F(1, 26) = 0.73, p = .40.

Apparatus and Stimuli

Stimuli were presented using a 486 personal computer equipped with a 15-inch (38-cm) Sony
Trinitron monitor (set at 1024 × 768 pixel screen resolution), the Eyegaze Development System (EDS; Cleveland & Cleveland, 1992), and software provided by LC Technologies, Inc. (Fairfax, VA). Eye movements and fixations were recorded with a Sanyo infrared-sensitive camera using a pupil center-corneal reflection technique (Young & Sheena, 1975). In this technique, eye movements and fixations were determined by measuring the reflection of low-level infrared light (880 nm) from the participant’s eye. A chin rest ensured a standardized viewing distance of 60 cm. For more information on the EDS, see Scialfa et al. (1994).

The search stimuli were created using free templates obtained from the World Wide Web (http://freesitetemplates.com, http://www.freewebtemplates.com) and inserting content regarding health, travel, news, sports, and general interest material. Web pages were then converted to PCX format. Targets were produced by creating a copy of a hyperlink from the converted Web page. A total of 192 graphics, 96 Web pages, and 96 target screens were created. The 96 Web pages consisted of 48 different templates, with each template repeated twice. The first template contained the standard salience links, which were in a 10-point, blue, underlined, Verdana sans serif font. The second version was the high-salience condition, in which the size of each link was enlarged to 12-point font.

Clutter was measured in pixels as a percentage of the available page space that was occupied by text or graphics. Occupied space was measured by outlining the text or graphics in pages and counting the pixels within those outlined areas. Thus the white space within text was added to the estimate of used space. Background color was not counted as occupied space. Available page space did not include the header or toolbar, which were constant across all pages. Web page clutter varied from 21.7% to 35% for the low-clutter condition (M = 29.1%, SD = 4.08%) and from 44.7% to 68.0% for the high-clutter condition (M = 54.4%, SD = 6.74%). Examples of low- and high-clutter pages are presented in Figure 1. Pages also varied in the number of blue underlined links. One half of the pages contained a low number of links (M = 10.5, SD = 1.37), and one half of the pages contained a high number of links (M = 21.5, SD = 1.89).

The visual search task was divided into four blocks, each consisting of 24 trials. Two of the blocks were used for the 10-point condition, and two of the blocks were used for the 12-point condition. Within each block, there were 12 target-absent trials and 12 target-present trials. For each of the 12 target-present trials, four targets were present in each of three locations: left, center, and bottom. Each block of trials consisted of 12 Web pages with low clutter and 12 with high clutter, and each block of trials contained 12 pages with a low number of links and 12 pages with a high number of links.

Acuity was determined using Postscript-generated Landolt Cs that followed a logMAR scale. Contrast sensitivity was evaluated using the Vistech Contrast Test System 6500 near charts, and color vision was assessed with a Titmus color perception test based on the Ishihara color plates. All vision tests were performed with the participants’ presenting corrective lenses.

**Procedure**

Prior to their involvement in the study, participants signed an informed consent document. Next they provided demographic information and completed several questionnaires assessing general health, previous or current visual problems, and computer experience and anxiety. Visual function (i.e., acuity, contrast sensitivity, and color vision) was assessed then.

In the experiment proper, participants were given instructions for the search task and allowed four practice trials. Each block of search trials began with an EDS calibration in which the observer had to fixate on a dot that was displayed sequentially in several locations on the screen. Once the calibration was successful, the first target screen was displayed. Participants fixated the center of the screen, where the system displayed the target they were to locate in the screen to follow. When they were ready, the participants pressed any key on the keyboard, and the Web page appeared. If the trial target was present in the Web page, observers pressed the j key on the keyboard. If the target was not present, they pressed the j key. Accuracy feedback was given after every trial. A plus sign was displayed if the participant was
correct, and a minus sign was displayed if the participant was incorrect. Figure 2 contains a depiction of the trial sequence. Participants were asked to respond as quickly as they could while keeping their accuracy as high as possible, and they were allowed to rest between blocks.

Two orders of stimulus presentation were created for the low-salience and high-salience pages. Within each order, presence, clutter, and link number were randomized within blocks. To avoid a confound involving practice effects, one half of the observers in each age group saw the 10-point displays first and the other half were shown the 12-point displays first.

RESULTS

Before inferential analyses began, several modifications to the data set were made in order to increase the reliability of effects at both the individual and aggregate levels. First, all responses to one Web page were eliminated from the data set because that page had greater than 70% errors for both the younger and older
groups. The remaining reaction time (RT) and fixation number data were trimmed on an individual basis by eliminating trials that were ±2 SD from the mean for a particular experimental condition.

The data for all participants were then screened for outliers. Two older participants were identified as outliers because their scores were greater than 2 SD from the group mean for a large portion (25%-65%) of the cells in the experimental design. To determine if these outliers affected the results unduly, we ran the analyses twice, once including the outliers and once excluding them. Because the results were unchanged substantively, we report the analyses including these participants.

Three dependent measures were analyzed: errors, RT, and fixation number. Two separate mixed-model analyses of variance (ANOVARs) were performed for each dependent measure. The first analyzed age (2), size (2), links (2), clutter (2), and presence (2). The second evaluated age (2) and location (3) effects. Target-absent trials were excluded from the second analysis because target location cannot be a factor on a target-absent trial. In all the analyses, a Geisser- Greenhouse correction was used to protect against violations of sphericity (Maxwell & Delaney, 1990); however, the reported analyses show the degrees of freedom associated with the unprotected test. All follow-up tests were conducted using a Bonferroni correction.

Errors. More errors were made on pages with a large number of links, $F(1, 27) = 7.46, p = .011$ (low link = 4.24%, high link = 6.47%) and on target-present trials, $F(1, 27) = 43.14, p < .001$ (target absent = 2.13%, target present = 8.52%). These main effects were, however, qualified by a significant Links × Presence interaction, $F(1, 27) = 15.86, p < .001$. As can be seen in Figure 3, target-absent trials showed no difference in errors as a function of link number, $t(28) = 1.23, p = .23$, whereas on target-present trials, more errors were made— that is, more targets were missed—when search pages contained more links, $t(28) = 3.84, p = .001$. This is a common finding in the visual search literature. None of the other main effects or interactions was significant ($ps > .05$). The second Age × Location analysis revealed no significant effects.

Reaction time. RT was analyzed only for trials on which a correct response was made. Responses were slowed by 515 ms under the 10-point font size condition as compared with 12-point condition, $F(1, 27) = 11.75, p = .002$, and were also slowed by a high number of links, $F(1, 27) = 464, p < .001$ (low links = 3891 ms, high links =

Figure 3. Error rates as a function of target presence and number of links.
1513 ms), High levels of clutter were associated with slower response times, \(F(1, 27) = 83.98, p < .001\) (low clutter = 4284 ms, high clutter = 4696 ms), as were target-absent trials, \(F(1, 27) = 139.78, p < .001\) (target absent = 5800 ms, target present = 3100 ms). Finally older adults (\(M = 5531\) ms) were slower overall relative to the younger group (\(M = 3510\) ms), \(F(1, 27) = 37.12, p < .001\).

Several higher-order effects bear mention. There was an Age \(\times\) Links interaction, \(F(1, 27) = 22.13, p < .001\), because older adults were slowed by an average of 1508 ms when more links were present, as compared with a slowing of 950 ms for the young participants. The Clutter \(\times\) Age interaction was also significant, \(F(1, 27) = 8.17, p = .008\), with older adults being slowed an average of 573 ms by high clutter and the younger participants slowed by only 252 ms. Older adults also made slower responses under target-absent conditions relative to younger participants, as evidenced by the significant Presence \(\times\) Age interaction, \(F(1, 27) = 11.95, p = .002\). On average, older adults responded 3526 ms slower when the target was absent than when it was present. In comparison, younger adults were slowed by only 1910 ms. Clutter also interacted with font size, \(F(1, 27) = 5.82, p = .023\). Counterintuitively, the clutter effect on RT was larger when font size was large (small size = 367 ms, large size = 456 ms). However, even in the high-clutter condition, the RTs for large-font pages were faster than any RTs in the small-font condition. The Links \(\times\) Presence interaction was significant, \(F(1, 27) = 16.17, p < .001\), and showed that the link number effect was greater on target-absent trials (target present = 831 ms, target absent = 1511 ms).

A number of three-way interactions were also significant. The Size \(\times\) Presence \(\times\) Age effect, \(F(1, 27) = 5.70, p = .024\), showed that older adults were slowed most by small font sizes when the target was absent. The Size \(\times\) Presence \(\times\) Links interaction was also significant, \(F(1, 27) = 5.38, p = .029\). The greatest increase in RT attributable to increased links occurred when the target was absent and font size was large. Size and presence also interacted with clutter, \(F(1, 27) = 8.94, p = .006\), with larger clutter effects associated with target-absent trials and small font sizes. Finally, the Links \(\times\) Presence \(\times\) Age interaction was significant, \(F(1, 27) = 6.22, p = .019\). In the target-absent condition, there was an increase in RT from low to high clutter for both the high-link and low-link pages. In contrast, in the target-present condition there was a clutter effect only when pages contained a large number of links.

These effects were qualified by a significant four-way interaction of Links \(\times\) Clutter \(\times\) Presence \(\times\) Age, \(F(1, 27) = 6.58, p = .02\). Examination of Figure 4 indicates that on target-present trials, age differences arose only when a large number of links were embedded in pages containing a great amount of clutter. In contrast, on target-absent trials, age deficits in search were found in all conditions. This more uniform pattern of age differences on target-absent trials may result from greater cautiousness on the part of older participants (see Ho & Scialfa, 2002, for a similar argument).

One might argue that the continuous nature of the clutter and link variables dictates a regression approach to the analysis of their effects. The restricted range of link number within either level of this variable precluded such an analysis for this variable because a restricted range will attenuate a correlation, even when it is substantial. For the clutter variable, however, we regressed RT on the continuously measured percentage of clutter. This was done at the individual level in both the ordinal low-clutter and high-clutter conditions. The slopes reflecting the clutter effect were then used in a mixed-model ANOVA to determine if the effects of clutter differed across age groups or within the ordinal low- and high-clutter conditions. The results of this analysis indicated that the clutter effect was larger in the high-clutter condition, \(F(1, 27) = 6.34, p = .018\). The age effect was marginally significant, \(F(1, 27) = 4.14, p = .052\), but it was younger adults who showed the larger effect. The Age \(\times\) Clutter interaction was also marginally significant, \(F(1, 27) = 3.13, p = .088\), because neither age group showed a clutter effect in the low-clutter condition but younger adults showed a larger clutter effect in the high-clutter condition.

Although this pattern may seem inconsistent with the ANOVA results in which older adults showed larger clutter effects, it should be kept in mind that in the ANOVA fundamentally
different questions are being addressed. In the ANOVA, age differences in average clutter effects are compared within each clutter condition. In the regressions, age differences in sensitivity to differences in clutter are being examined within each clutter condition. Thus it may be that older adults did not exhibit a large slope in the high-clutter condition because they were already at ceiling.

The analysis of age and location revealed a main effect of age, $F(1, 27) = 40.57, p < .001$, and location, $F(2, 54) = 24.70, p < .001$ (see Figure 5). Older adults took longer to respond overall, and the fastest RTs were observed for targets in the left portion of each Web page. These main effects were qualified by an Age × Location interaction, $F(2, 54) = 11.12, p = .002$. Follow-up tests showed that young and old did not differ in RT for targets in the left location, $t(27) = 1.59, p = .12$, but older adults were significantly slower for targets in the middle, $t(27) = 6.73, p < .001$, and bottom locations of the Web pages, $t(27) = 5.60, p < .001$.

**Fixation number.** Fixation data were missing for 1 older adult because of problems with calibration, and the data were analyzed only for trials in which a correct response was made. Older adults made an average of six more eye movements than did the young, $F(1, 26) = 11.52, p = .002$, and more fixations were made when font size was small, $F(1, 26) = 12.67, p = .001$ (small font = 19, large font = 17). Greater oculomotor involvement was associated with high-clutter pages, $F(1, 26) = 51.65, p < .001$ (low clutter = 17, high clutter = 19), a high number of links, $F(1, 26) = 94.19, p < .001$ (low links = 16, high links = 20), and target-absent trials, $F(1, 26) = 191.01, p < .001$ (target absent = 23, target present = 12). Age also interacted with the number of links, $F(1, 26) = 6.54, p = .017$, and clutter, $F(1, 26) = 6.55, p = .017$. In both cases, older adults showed a greater increase in fixation number from low to high link (young = 3, old = 5) and clutter levels (young = 1, old = 2) relative to younger participants. The Age × Presence interaction was also significant, $F(1, 26) = 6.47, p = .017$, because as compared with the young group, older adults made more fixations...
under target-absent than target-present trials (young = 9, old = 13). Presence also interacted with links, $F(1, 26) = 7.04, p = .013$, with a greater increase in fixation number occurring when the target was absent (target absent = 5, target present = 3).

These main effects and two-way interactions must be interpreted in light of two significant three-way interactions. The first was the interaction of Size $\times$ Links $\times$ Presence, $F(1, 26) = 15.55, p = .001$ (Figure 6). For target-absent trials, the main effect of font size was significant, $F(1, 27) = 7.74, p = .01$, as was the main effect of links, $F(1, 27) = 51.06, p < .001$. However, the Size $\times$ Links interaction was also significant, $F(1, 27) = 6.97, p = .01$, because the link effect was larger for large-font than for small-font pages. For target-present trials, only the main effect of size, $F(1, 27) = 9.69, p = .004$, and the main effect of links were significant, $F(1, 27) = 44.98, p < .001$.

The second significant three-way interaction was Size $\times$ Clutter $\times$ Presence, $F(1, 26) = 4.55, p = .043$ (Figure 7). Follow-up tests for target-absent trials found significant main effects of size, $F(1, 27) = 7.74, p = .01$, and clutter, $F(1,
27) = 52.94, p < .001. The Size × Clutter interaction was not significant (p = .44). For target-present trials, the main effect of size was significant, F(1, 27) = 9.69, p = .004, and so was the Size × Clutter interaction, F(1, 27) = 6.54, p = .016.

The Age × Location ANOVA revealed significant main effects of age, F(1, 26) = 9.44, p = .005, and location, F(2, 52) = 19.64, p < .001 (see Figure 8). Older adults made more fixations overall, and the fewest fixations were made for targets in the left portion of each Web page. These main effects were qualified by an Age × Location interaction, F(2, 52) = 7.39, p = .002. Follow-up tests showed that young and old did not differ in fixation number for targets in the left location, t(26) = 0.39, p = .70, but older adults made more fixations for targets in the middle, t(26) = 3.54, p = .002, and bottom locations of the Web pages, t(26) = 3.21, p = .004.

DISCUSSION

One purpose of this study was to examine the influence of several characteristics of Web pages that affect visual search. The results are encouraging in their consistency with effects seen in more basic, laboratory-based research. Search performance was enhanced when links were larger, when there was less clutter and fewer competing links, and when target links were located in the left region of the page. Search was also easiest when a target was present, indicative of the nonparallel and self-terminating nature of the task. Because the effects were generally seen in both RT and fixation number, it is clear that there are both oculomotor and attentional components to the task, and that these components can be influenced by page design.

A primary motivation for the present work was to examine the effects of these Web characteristics on age differences in search performance. The age differences we observed were also hypothesized from past basic (Madden & Whiting, 2003) and applied research (Echt, 2002; Lin, 2001). Older adults were as accurate as their younger counterparts, as would be expected when there is a long period of time available to search the pages (Harpur, Scialfa, & Thomas, 1995). Their speed of response (and, in large part, their overt search as well) was hampered more by many of the factors we manipulated. The Age × Presence interaction is, in part, a reflection of deficits in processing speed but is also a reflection of more conservative criteria on the part of older observers (Ho & Scialfa, 2002). On target-present trials, older observers were slowed to a greater degree than were the young participants when there were a greater number of links and more clutter. This may be a reflection of the fact that as clutter increases in amount, so too does the probability that clutter shares some features with both target and nontarget links. Because older adults have more difficulty with search as noise becomes more confusable with the target, they would experience greater difficulty in the high-clutter conditions with a large number of links.

The greater link effect seen in older adults has been shown in applied research (Lin, 2001) and also in basic studies that examined age differences in visual search when the number of distractors was varied (Plude & Hoyer, 1985; Rabbitt, 1965). Older adults' greater clutter effect seems inconsistent with recent reports of

![Figure 8. Fixation number as a function of age and target location.](image-url)
age invariance in clutter effects for traffic sign search (Ho et al., 2001; McPhee et al., in press), but there are two strong candidate explanations for the apparent discrepancies.

First, although we treated clutter and link number as separate factors, it should be remembered that nonlink clutter was often text material and cannot be as easily ignored as non-text clutter. It may well be that older adults' greater clutter effect is a reflection of this similarity between targets and some of the clutter information. Second, in both Ho et al. (2001) and McPhee et al. (in press), older observers had more domain knowledge than their younger counterparts, but this was not true in the present study. Domain knowledge is a strong predictor of Web search (Laberge & Sciolla, 2003) and may well protect the older adults from the normally deleterious effects of clutter. Finally, older adults showed larger location effects than did the young, being penalized if links appeared away from the left portion of the screen. This may reflect their more restricted useful field of view (see Owsley et al., 1991; Sciolla et al., 1994), a greater reliance on expectancy, or the effects of poor optical corrections.

Importantly, although increasing salience (i.e., link size) facilitated performance generally, it did not eliminate the age deficits in search. There was, to be sure, an Age × Size × Presence interaction on RT, in which age differences in the slowing effects of target-absent trials were diminished when links were enlarged. However, increasing link size did not produce Web pages that eliminated age differences in either clutter or link number effects. The relatively low impact of link size may be the result of a weak manipulation, but a 33% increase in print size is considerable, and it is unlikely that much greater increases would be tolerated because they will impact other dimensions of page layout. Rather, if found to be generalizable, our data suggest that simple changes in Web design such as increasing print size will not be terribly helpful for older users and that other means of increasing the visibility of links (e.g., changes in location or color) will be necessary.

Design Considerations and Recommendations

Both physical and cognitive declines affect the ability of an older person to use technology (see Kline & Sciolla, 1997; Madden & Whiting, 2003), including computers and the Internet. However, design considerations can improve usability for them while at the same time benefiting other age groups. To facilitate improved search, hyperlinks should be salient and in locations expected by the common user. Increasing the salience of links or important information will help all users and can be accomplished by increasing relative size, changing used and unused link colors so that they contrast with the background, and grouping links so that they segregate en masse from other information. Matching user expectancies will also ease search. For example, placing menu items on the left side or using common standards (such as underlined text to mark a hyperlink) will assist people in finding and recognizing them. Additionally, decreasing clutter and the number of links will improve a person's ability to sort through a Web site, and this is especially true if that person is an older adult.

Limitations of the Current Study

Two major limitations must be taken into consideration of the current study. First, because of equipment specifications, the monitor position was not ideally suited to the optical correction of participants. The monitor was placed at a distance of 60 cm and at a constant vertically centered gaze angle to accommodate the equipment used for eye tracking. All participants were measured for sufficient acuity at that distance; however, corrective lenses, especially bifocals, were not prescribed for that distance. In particular, the height and distance of the monitor meant some head movements were needed by older adults to bring different portions of the monitor in focus. Undoubtedly, this slowed their responses and likely led to the observed interaction of age and location. One might make the argument that the older adults should have been tested with optical corrections that were specific to the test distance. Although this would certainly have benefited them, such an approach would have poor external validity because, like our participants, most older users come to their workstations with glasses designed for everyday use.

The second limitation is that many of our
older adults had difficulty with the color vision test we used. It is not possible with the Titmus test to describe more precisely the color deficits they exhibited or to link them to task performance. However, it is widely known that age deficits in color vision are exacerbated for short-wavelength hues (see Kline & Scialfa, 1997). Because the links in our study were indicated in short-wavelength colors, some of the age differences we observed may be attributable to older adults' color deficiencies. If this is the case, it is likely to generalize to many current Web sites because links are commonly indicated in shorter-wavelength colors (Nielsen, 2000).

Research Needs and Future Directions

Various guidelines written for design have acknowledged that older adults constitute a significant user group, yet few such guidelines have been systematically and empirically tested. Most of them are deductions from basic research regarding physical and cognitive aging. If they are to come into wider use, more human factors research is needed to assess their utility in applied settings, such as Web page design. There are two obvious areas for future research. First, if improving Web search for older adults through changes in print size is not a panacea, then what design features are better? Given the well-known age-related deficits in short-wavelength color vision, is it sensible to manipulate the now-conventional link colors of blue and purple? Can other visual features that facilitate segmentation (e.g., blocking links) or attentional allocation (e.g., using transients to highlight links) be more effective in easing the search task for older people? What would be the influence, both implicit and explicit, of holding constant the location of links across both pages and sites? Clearly, a good deal of systematic work is needed to answer these questions.

The second major research theme concerns individual differences, including those correlated with age, that influence Web performance. LaBerge and Scialfa (2003) recently reported that factors such as Internet and domain knowledge lead to faster and more efficient search of Web sites. Is it possible that this expertise can mitigate the effects of perceptual and cognitive aging that can render Web navigation frustrating for the older user? If so, what types of training programs are needed in order to allow them to use emerging technologies with greatest ease?

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REFERENCES


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