Link Colors Guide a Search

Tim Halverson and Anthony J. Hornof
Department of Computer and Information Science
University of Oregon
Eugene, OR 97403-1202 USA
{thalvers, hornof}@cs.uoregon.edu

ABSTRACT

While much basic research exists on the effects of various visual properties on visual search, the application of such research to real-world tasks is lacking. The purpose of this research is to address the lack of empirical validation for design guidelines that affect visual search. One common design element used in Web interface design is link color. The general research question asked is how text color affects visual search. This research demonstrates, with reaction time and eye movement analysis, the dramatic but imperfect control a designer has on guiding the attention of users with text color. Experimental support for the differentiation of visited link colors is presented, along with analyses of the advantages provided by differentiating link colors.

Categories & Subject Descriptors: H.5.2 [Information Interfaces and Presentation]: User Interfaces – evaluation/methodology, screen design, style guides; H.5.4 [Information Interfaces and Presentation]: Hypertext/Hypermedia – user issues

General Terms: Design; Experimentation; Human Factors; Verification

Keywords: Hypertext links; visual search; eye tracking; web page design

INTRODUCTION

Visual search is an important part of human-computer interaction research. It is through visual search that most people locate the content and controls for many computer tasks. Yet, it is not well understood how the implementation of many application and Web page design guidelines affect visual search. While many guidelines exist for application and Web interface design, practitioners must often rely on intuition or guidelines that have little or no empirical support [see 4 for many examples].

Varying hypertext link color is a common Web design technique. Unvisited links are colored differently than visited links, with the colors commonly set to blue and red (or purple), respectively [5]. The idea is that the colors will helps user to focus their search on just unvisited links and to thus increase the efficiency of the search. Figure 1 shows an example of a task that benefits from link colors.

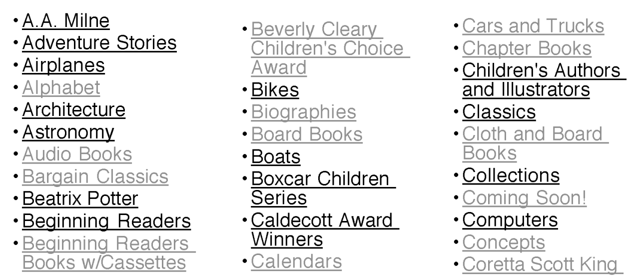

Figure 1. Imagine yourself looking for a book for your friend's child on this website. You have already visited all the gray links. Which new topic would you visit next? (Adapted from www.powells.com)

The use of text color to differentiate visited and unvisited links is one example of a guideline that is intuitively sound and has some support from observational studies [5, 9], but lacks empirical work showing the power of this practice. While a large body of basic research on the effects of color on visual search exists [1, 2, 7, 8, 10, 12], it does not directly address the application of the above guideline. There are few if any previous studies of visual search of colored text. The current study investigates the visual search of structured layouts where only a subset of text, based on the color of text, need be searched. The effect of differentiating visited and unvisited links based on color is investigated by varying the ratio of blue and red words, and by including layouts in which red words were replaced by blank space. The following hypotheses will be tested in this study:

> **H1:** When visually searching for a blue target word among blue and red words, the search time increases with the number of blue words.

H2: Visual search for a blue target word is faster among blue words alone than among blue and red words.

METHOD

Participants

Twenty-four people, 11 female and 13 male, ranging in age from 19 to 55 years of age (mean = 25.1) from the University of Oregon and surrounding communities participated in the experiment. The participants were screened as follows: 18 years of age and older; experienced using graphical user interfaces (such as Microsoft Windows or Macintosh); no learning disability; normal use of both hands; and normal or corrected-to-normal vision. Participants were paid $10, plus a bonus that ranged from $2.53 to $9.20 based on their performance.

Apparatus

Visual stimuli were presented on a ViewSonic VE170 LCD display set to 1280 by 1024 resolution at a distance of 61 cm that resulted in 40 pixels per degree of visual angle. The experimental software ran on a 733Mhz Apple Power Macintosh G4 running OS X 10.2.6. The mouse was an Apple optical Pro Mouse, and the mouse tracking speed was set to the fourth highest in the mouse control panel. Eye movements were recorded using an LC Technologies Eyegaze System, a 60 Hz pupil-center/corneal-reflection eye tracker. A chinrest was used to maintain a consistent eye-to-screen distance.

Stimuli

Figure 2 shows a layout from one trial. All trials contained six groups of left-justified, vertically-listed words on a white background. The groups contained five words of 18 point Helvetica font with 0.65 degrees of vertical angle between the centers of adjacent words (0.45° for word height, and 0.2° for blank space). The groups were arranged in three columns and two rows. Columns were 7.5 degrees of visual angle from left edge to left edge. Rows were separated by .65 degrees of visual angle. All distractor words were either blue or red. The target word and precue were always blue. Red-green-blue saturation percentages were 0-0-67 for blue and 67-0-0 for red.

Figure 2. Layout with 10 blue words (drawn here as black), and with red words present. The precue "STAFF" would have disappeared when everything else appeared. All angle measurements are in degrees of visual angle.

All participants searched seven types of layouts: One layout contained 30 blue words, two layouts contained 20 blue words, two layouts contained 10 blue words, and two layouts contained 1 blue word. In the pairs of layouts with the same number of blue words, all non-blue positions were filled with red words (for a total of 30 words) in one layout and left blank in a second "complementary" layout.

The words used in each trial were selected randomly from a list of 765 nouns generated from the MRC Psycholinguistic Database [11]. No word appeared more than once per trial. The words in the list were selected as follows: three to eight letters, two to four phonemes, above-average printed familiarity, and above-average imagability. Five names of colors and thirteen emotionally charged words were removed. The target word was randomly chosen from the list of words used for each trial. The participant was precued with the target word before each layout appeared. The precue appeared at the same location every time, directly above the top left word in the layout, in 14 point Geneva font.

Procedure

Participants were informed verbally and in written instructions that the target would always be blue. Each trial proceeded as follows: The participant studied the precue; clicked on the precue to make the precue disappear and the layout appear; found the target word; moved the cursor to the target word; and clicked on it.

The trials were blocked by layout type. Each block contained 30 trials, preceded by five practice trials. The blocks were counterbalanced using the balanced Latin square technique. To separate visual search time from mouse pointing time, the point completion deadline was used [3].

RESULTS

Search Time

The search time was analyzed using a repeated-measures ANOVA. As can be seen in Figure 3, participants found the target faster in layouts with fewer blue words than in layouts with more blue words, $F(3,21) = 379$, $p < .001$. Participants also searched identically-configured layouts faster when the red distractors were absent, $F(1,23) = 32$, $p < .001$. There is an interaction between the number of blue distractors and the presence of red distractors, $F(3,21) = 23$, $p < .001$. In other words, the presence of red words slowed search more when there were more red words present.

Normalizing for the number of blue words per layout, a repeated-measures ANOVA was performed. Participants spent less time searching (per blue word) in layouts with more blue words, $F(3,21) = 187$, $p < .001$. Participants also spent less time searching when red distractors were absent, $F(1,23) = 69$, $p < .001$. Moreover, there is an interaction

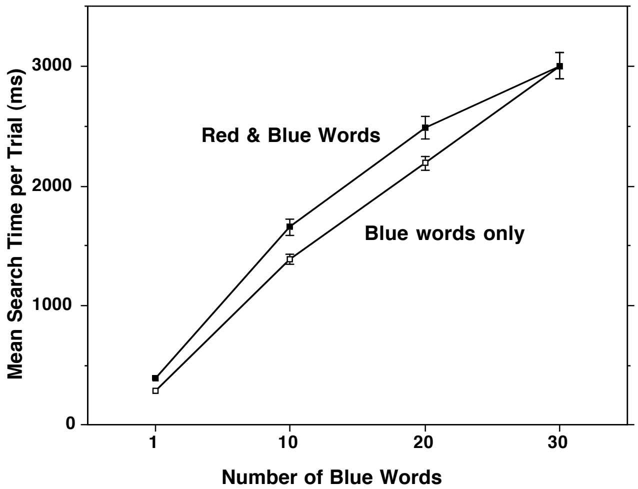

Figure 3. Mean search time per trial. Error bars indicate ±1 standard error.

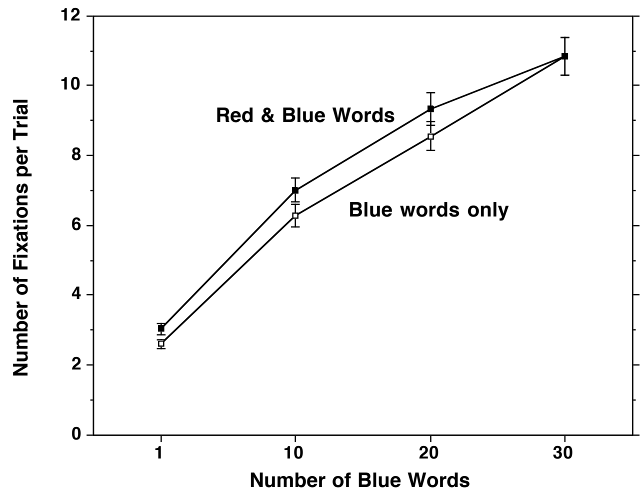

Figure 4. Mean number of fixations per trial. Error bars indicate ±1 standard error.

between the number of blue distractors and the presence of red distractors, $F(3,21) = 23$, $p < .001$. Again, it is seen that the presence of red words slowed the search more when there were more red words present.

The effects seen in the previous analysis may have been due in part to some constant startup or completion cost per trial. All of the effects found in the last analysis remained after subtracting a constant start-up and finishing cost (approximated by the search time of the one blue word trials) from the search time per trial before normalizing for the number of blue words. Participants spent less time searching (per blue word) in layouts with more blue words, $F(2, 22) = 25$, $p < .001$, participants spent less time searching when red distractors were absent, $F(1, 23) = 10$, $p = .005$, and the presence of red words slowed search more when more red words were present, $F(2, 22) = 5$, $p = .012$.

Eye Movements

Fixation durations were analyzed with a repeated-measures ANOVA. When the data for trials with one blue word are not considered, fixation durations are equivalent across all layouts (all $p > .05$). When trials with one blue word are added, participants fixated longer when fewer blue words were present, $F(3,21) = 23$, $p < .001$; participants fixated longer when red words were absent, $F(1,23) = 25$, p = < .001; and the presence of red words shortened fixations, $F(3,21) = 8$, $p = .001$. A second analysis was conducted to examine the relationship between fixation duration and the number of blue words within 1 degree of visual angle from the center of fixation. No significant differences were found (all $p > .05$).

The number of fixations per trial was also analyzed with a repeated-measures ANOVA. All the effects found with search time also appear in the number of fixation data. Figure 4 shows the results. Participants made more fixations in layouts with more blue words, $F(3,21) = 379$, $p < .001$. Participants also made more fixations when red words were present, $F(1,23) = 33$, $p < .001$. Further, the effect of red words was greater when more red words were present, $F(3,21) = 20$, $p < .001$.

Another analysis examined the destination words for saccades that were greater than and less than 7.5 degrees of visual angle (which is the distance between 2 columns of words) in layouts with red and blue words, specifically examining whether blue words were the destination more often than would be observed in saccades to random words. More long than short saccades were observed, $F(1,23) = 958$, $p < .001$, and blue words were more likely to be the destination of a saccade, $F(1,23) = 370$, $p < .001$. In addition, long saccades were less likely to end on a blue word, $F(1,23) = 329$, $p < .001$. However, blue words were still the destination significantly more often than chance, $F(1,23) = 14$, $p < .001$.

DISCUSSION

Search time increased as the ratio of blue to red words increased. This supports this study's first hypothesis – when searching for a blue target word among blue and red words, the search time increases with the number of blue words. These results are similar to other research on conjunctive visual search [6, 7, 12], and shows that this phenomena holds in a more ecologically valid task in which the stimuli are words in structured layouts.

The results also support this study's second hypothesis – visual search for a blue target word is faster among blue words alone than among blue and red words. Further, the eye movement data shows that this is mainly due to the number of fixations required per layout. It appears as if visual search strategies vary more based on the location rather than the duration of fixations.

One explanation for more fixations when red words are present is that, just by their presence, the red words provided more visual objects that could be used as the destination of saccades. The eye movement data support this possible explanation in that the likelihood of fixating a blue word rather than a red word decreased for longer saccades. However, the eye movement data also demonstrate that distinct link colors are very useful in guiding a search. This is true because they assist the programming of eye movements to relevant, unvisited links even when they are greater than 7.5 degrees of visual angle away from the current fixation, despite evidence that color (hue) perception is degraded at and beyond this angle.

Implications for design

The results of this experiment are directly relevant to design guidelines for link colors of Web pages [4, 5]. For tasks in which Web users need only search for relevant links to pages that have not been visited, this study shows that the visual search can be made very efficient if visited links are clearly discernable based on color. As the data show, layouts with thirty blue links – akin to Web pages that do not differentiate unvisited and visited links – take longer to search.

However, the finding that the presence of red words slows search time significantly suggests that the guideline to differentiate links by text color might be improved. One possible improvement that could be made is differentiating visited links by luminescence in addition to color. Basic research has shown that color is not easily discernable in the periphery, but luminescence is. As was seen in the eye movement data, link color is useful in the periphery of the display for this task, but a difference in luminescence may increase the benefit of differentiating visited links.

CONCLUSION

This research investigates the effect of link color on visual search of a structured, two-dimensional menu. It extends previous, basic research to a more applied task by investigating text color with ecologically valid stimuli.

This study offers empirical support for the design recommendation to differentiate visited and unvisited links by color. Further research may be needed to ensure that these findings hold when links are surrounded by or embedded in content, and to validate the recommendation made here to differentiate links further with differences in luminescence. In addition, research may be warranted on the effects of other visual features used to differentiate links from other text, such as underlining.

While this study has helped to advance the validity and understanding of Web design guidelines, there is need for more such work, especially for guidelines that affect visual search as every element of a page layout may impact the efficiency and ease of visual search. Though many guidelines for existing practices have been validated with user testing, little has been done to deepen the knowledge practitioners need to produce novel, yet efficient, layouts.

ACKNOWLEDGMENTS

This research is supported by the Office of Naval Research grant N00014-02-10440 and the National Science Foundation grant IIS-0308244. Both grants are to the University of Oregon with Anthony Hornof as the principal investigator.

REFERENCES

1. Brawn, P. and Snowden, R.J. *Can one pay attention to a particular color?* Perception & Psychophysics, 1999. 61(5): p. 860-873.
2. Christ, R.E. *Review and analysis of color coding research for visual displays.* Human Factors, 1975. 17(6): p. 542-70.
3. Hornof, A.J. *Visual search and mouse pointing in labeled versus unlabeled two-dimensional visual hierarchies.* ACM Transactions on Computer-Human Interaction, 2001. 8(3): p. 171-197.
4. National Cancer Institute *Research-Based Web Design & Usability Guidelines.* 2002. http://www.usability.gov/guidelines/index.html
5. Nielsen, J. *Top Ten Mistakes in Web Design.* 1999. http://www.useit.com/alertbox/9605.html
6. Poisson, M.E. and Wilkinson, F. *Distractor ratio and grouping processes in visual conjunction search.* Perception, 1992. 21(1): p. 21-38.
7. Shen, J., Reingold, E.M., and Pomplun, M. *Guidance of eye movements during conjunctive visual search: The distractor-ratio effect.* Canadian Journal of Experimental Psychology, 2003. 57(2): p. 76-96.
8. Shih, S.-I. and Sperling, G. *Is there feature-based attentional selection in visual search?* Journal of Experimental Psychology: Human Perception & Performance, 1996. 22(3): p. 758-779.
9. Spool, J.M., et al. *Web Site Usability: A Designer's Guide*. 1997, North Andover, MA: User Interface Engineering.
10. Treisman, A. *The Perception of Features and Objects*, in *Visual Attention*, R.D. Wright, Editor. 1998, Oxford University Press: New York. p. 26-54.
11. Wilson, M.D. *The MRC Psycholinguistic Database: Machine Usable Dictionary, Version 2.* Behavior Research Methods, Instruments, and Computers, 1988. 20: p. 6-11.
12. Zohary, E. and Hochstein, S. *How serial is serial processing in vision?* Perception, 1989. 18(2): p. 191-200.