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Contents

Volume 47 Number 8 22 June 2004

- 821 **Judging the urgency of non-verbal auditory alarms: a case study**
G. R. Arrabito, T. A. Mondor and K. J. Kent
- 841 **Ergonomics modelling and evaluation of automobile seat comfort**
M. Kolich and S. M. Taboun
- 864 **Performance requirements of physically strenuous occupations: validating minimum standards for muscular strength and endurance**
M. S. Sothmann, D. L. Gebhardt, T. A. Baker, G. M. Kastello and V. A. Sheppard
- 876 **Tangential load sharing among fingers during prehension**
T. C. Pataky, M. L. Latash and V. M. Zatsiorsky
- 890 **The effect of surface waviness on friction between Neolite and quarry tiles**
W.-R. Chang, R. Grönqvist, M. Hirvonen and S. Matz
- 907 **The effects of link format and screen location on visual search of web pages**
J. Ling and P. van Schaik
- 922 **Book reviews**

The effects of link format and screen location on visual search of web pages

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Keywords: Usability; Internet; Visual search; Navigation; Hyperlinks.

Navigation of web pages is of critical importance to the usability of web-based systems such as the World Wide Web and intranets. The primary means of navigation is through the use of hyperlinks. However, few studies have examined the impact of the presentation format of these links on visual search. The present study used a two-factor mixed measures design to investigate whether there was an effect of link format (plain text, underlined, bold, or bold and underlined) upon speed and accuracy of visual search and subjective measures in both the navigation and content areas of web pages. An effect of link format on speed of visual search for both hits and correct rejections was found. This effect was observed in the navigation and the content areas. Link format did not influence accuracy in either screen location. Participants showed highest preference for links that were in bold and underlined, regardless of screen area. These results are discussed in the context of visual search processes and design recommendations are given.

1. Introduction

Navigation accounts for 90% of all recorded web browser actions (Tauscher and Greenberg 1997). The most common method for navigating web pages is through the use of hypertext links (hyperlinks). Hyperlinks offer a significant advance over paper-based media as they allow users to decide upon whether and how they interact with a web page (Treloar 1999). Moreover, usability issues require serious consideration because when faced with a difficult to use web site, users are likely to abandon these sites in favour of sites which are more usable (Nel *et al.* 1999, Nielsen 2000). This reaction is predictable: some difficult to use websites may be so because of poor screen design and this can in turn result in decreased task performance by users in terms of both speed and accuracy (Näsänen *et al.* 2001, Streveler and Wasserman 1984).

Researchers, such as Galitz (1997) have outlined some of the user interface design parameters that may affect use of visual display systems. However many of these, particularly those related to the display of text, have yet to be investigated systematically. This is a significant flaw: only a small amount of empirical research on the use of web sites has been published (e.g., Diaper and Waelend 2000, Sears 2000). Such research has shown support for the idea that web pages designed according to cognitive principles lead to higher levels of comprehension than those

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that are not (Dalal *et al.* 2000). The current study focuses on the parameters used to format hyperlinks.

In order to exploit fully the potential of hyperlinks in web sites, links need to be formatted so that task performance and user experience is maximized. Therefore, an important focus of researchers' attempts to improve the usability of web sites should be upon the format of these links. Links may be located in the navigation areas of web pages (e.g., in frames) as well as within the main, content, area of the page. Such links are often incorporated in the midst of normal text and provide users with opportunities to move to other locations to obtain further information about a particular topic. Although some researchers have examined some of the factors influencing users' interactions with web links (e.g., Ling and van Schaik 2002), few have investigated the way in which links are represented in web pages, and none have focused on whether links placed within the content area of a web page are utilized in the same way as those placed within the navigation area.

Links may exist in a variety of formats. The most common convention is for web page designers to use the colour blue for hyperlinks, sometimes underlining these blue links as well as, less frequently, presenting these links as bold text. Although users may prefer the application of such conventions (Nielsen 1999a, Gee 2001), current guidelines governing the production of web pages are only rarely based on empirical research (Tullis 1997, Nel *et al.* 1999, Venkatraman 2000).

Although some variables, such as colour, can be used to enhance the effectiveness of graphical displays (Christ 1975, Murch 1985), varying the format of hyperlinks has received little empirical focus (Nielsen 1999b). Gee (2001) recommends that all links should be underlined to enable ease of navigation. One researcher has gone further and suggests that such links can be colour coded to give extra topic-related information to users navigating a page (Bernstein 1999). However other researchers suggest that such an approach risks giving a 'fruit salad' look to the web page which may lead to decreases in performance (Marcus 1997, Murch 1985).

Information retrieval is a key activity in using the Web. This activity invariably involves visual search, which consists of two basic stages (Scott 1993, Wolfe 1994). Initially all screen locations are processed in parallel, but only a limited amount of information is extracted. Subsequently, a second stage restricts itself to areas of the visual field that are of interest. Visual conspicuity is one factor that influences the process of selecting objects or words. Conspicuity can be defined as a combination of an object's properties, relative to its background, which attracts attention and is therefore seen. Conspicuity can be based on colour, shape, size, orientation and other properties of the display. If a target object is made visually conspicuous, search time can be up to 83% faster (Nygren 1996).

Several researchers have suggested that screens should be structured in an organized manner to improve visual search and therefore usability (Graf and Krueger 1989, Comber and Maltby 1997, Galitz 1997, Marcus 1997, Tullis 1997) and some research has indicated that elements such as colour can be used to enhance the effectiveness of graphical displays (Christ 1975, Murch 1985). However, the effect of varying the format of hyperlinks has received little empirical focus (Nielsen 1999b).

The choice of link format used in web pages should be determined by the perceptual and cognitive constraints of users as well as their preferences, rather than solely the preferences of web designers. Well-chosen formats will enhance performance, poorly chosen ones will decrease performance and could increase the probability of visual fatigue (Galitz 1997). Web links can be specified in a variety

of formats, including colour, font and use of underlining or bold text. It has been argued that the use of particular colours will improve discrimination (Christ 1975, Marcus 1997), and thus the visual impact of an interface; for example black text will stand out when placed on a white background. Use of these in a web page may enable users to perceive text more easily through the presence of clear differential contrast, and therefore enhance visual search, in comparison with other combinations of colours. Similar results may be found for variations in link format, although any preferences of users for particular formats may not necessarily be correlated with task performance. It is possible that so long as there is a sufficient difference between the format of the link and the surrounding text, the links will stand out and be immediately obvious to someone scanning a page (see Treisman and Gelade 1980, for an explanation of this phenomenon). If this is the case, then it should not matter how similar the formats of normal text and hyperlinks are (e.g., same font, level of bold, use of underlining), so long as they differ on a single dimension they will remain easy to discriminate. This is currently the case in web browsers where the default colours are black for normal text and blue for links. An important issue is whether such a default is the best way to present a combination of link and normal text information in the content area of a web page. In addition, it is unclear whether the current default of blue plain-text links presented in the navigation area is the optimal method of presentation. If altering the properties of links by changing the style sheet that is applied to all the pages in a web site does improve search time or accuracy by giving higher levels of conspicuity, then in terms of web designers' time, this would be a very low cost way of improving web usability.

The use of colour in navigation frames has a different purpose to that in the content area of a web page. Generally, the background should not be 'emphasized' in screen components. However, a higher contrast should be reserved for screen components to which attention should be drawn (Galitz 1997), such as in the case of an initial scanning of a navigation frame when a user first arrives at a site. This use of contrast (such as underlining, italics, bold) would aid visual search of links to key topics in a web site, particularly if this search is aided by (a) clear delineation between navigation and content area, (b) the effective use of format to draw attention towards a specific area of the screen, and (c) permitting a user to scan through the information presented in the navigation area to find the information sought quickly. Research has shown that higher contrasts between text and background colour in the navigation area lead to faster searching and are also rated more favourably (Ling and van Schaik 2002).

In the content frame, hyperlinks are presented throughout the text, unlike in the navigation area where they are often presented as a list, and with no non-link information competing for attention. These differences in presentation may lead to differences in attentional demands; in addition to links, the content frame also contains normal text that needs to be scanned although in the navigation area, only links are presented and no normal text. To stand out sufficiently from the normal text in the content area, links may need to be more noticeable (e.g., in bold or underlined) than in the navigation area, where there is no such need to compete with non-link information. Furthermore, more noticeable links may have a larger advantage in content pages because a larger screen area needs to be scanned. Thus, the content area may benefit more from the use of a more conspicuous format for hyperlinks than the navigation area.

Visual discrimination and choice are component processes of visual search in web usage. In a discrimination reaction task, participants make a response to one particular stimulus and not to other simultaneously presented stimuli (Mayer 1992). This type of task has been used to assess the effects of contrast and frame location in web pages on visual search task performance (van Schaik and Ling 2001). Following on from earlier research, the current study employed a choice reaction task which required one response to the presence of a stimulus and another response to the absence of the stimulus. This mimics the use of web pages more closely, where users respond to the presence of target information in one way (for example, by following an appropriate link in the web page), but respond differently to the absence of this information (such as going back one step in the web browser).

Subjective measures can be more sensitive to differences in display quality than performance measures (Pastoor 1990). Therefore subjective measurement of display quality is required in addition to performance measurement (see Ling and van Schaik 2002). Furthermore, Tractinsky *et al.* (2000) developed and validated an aesthetics evaluation scale which they used to test the relationship between the visual appeal of a computerized system (an ATM) and its usability. Tractinsky *et al.* found strong correlations between the system's perceived aesthetics and its usability, which persisted even after users had made use of the system. In other words, they found that there was a strong link between interface aesthetics and 'a priori' perceptions of ease of use' (Tractinsky *et al.* 2000: 140). This scale has since been used for the evaluation of web pages (van Schaik and Ling 2003). The investigation of whether such a relationship between aesthetic considerations, preference and usability (performance) measures was a further aim of the present study, which used Tractinsky *et al.*'s scale to evaluate the subjective quality of the display.

In the present study, performance was compared in both the navigation and content area between blue links that were either plain text, underlined, bold or bold and underlined. The present study aims to investigate whether particular combinations of link format are associated with higher levels of performance (measured in terms of accuracy and speed), as well as finding out whether they are also subjectively superior.

2. Method

2.1. Experimental design

The experiment used a two factor mixed measures design. The repeated measures factor was the formatting of blue hyperlinks: with four levels: plain text (no underlining, no boldening), bold text, underlined text and text that was both bold and underlined. The independent measures factor was the area of focus on the web page, which also had two levels: navigation area and content area (see below).

2.2. Participants

There were 49 participants, consisting of 42 females and seven males. Of these, 20 took part in the search navigation area condition, and 29 took part in the search content area condition. Most participants (57%) were under 21 with a further 20% between 21 and 25; those remaining were aged between 26 and 50.

All participants had experience of using the World Wide Web (WWW; see table 1). Almost all participants had been using the web for more than 1 year (96%) with the rest having more than 6 months' experience. Frequency of using the web varied

Table 1. Familiarity with and frequency of Web use

	Percentage
Length of time	
> 6 months	4
> 1 year	96
Frequency	
> 1/day	26
1/day	27
> 1/week	30
> 1/month	2
< 1/month	14

from more than once a day to less than once a month, with a majority (53%) using the WWW at least once a day.

2.3. Materials and apparatus

Web pages were created in HTML and displayed using Microsoft Internet Explorer web browser version 6.0 and then saved as graphics image files. The web pages consisted of two frames, a larger frame (85%, the content area) and a smaller frame (15%, the navigation area) containing five hypertext links, all of which were left-aligned and matched for length in each of the trials (figure 1). The navigation area always appeared on the left of the screen. In the content area, links appeared in the text in five locations, distributed evenly down the web page from top to bottom. Location of the target link (when present) was counterbalanced across the trials, so links appeared in all the possible locations an equal number of times. Hypertext links were presented in either bold or normal text, with underlining or no underlining, although the links were always blue (colour code #0000FF). The rest of the text was always black (colour code #000000) and the background in both areas was white (colour code #FFFFFF). The font used for both normal text and hyperlinks was Arial 12. The text used for the content area of the web pages was taken from a source with which it was felt all participants would be unfamiliar, the doctoral thesis of one of the authors (J.L.). The same web pages were used for both the navigation area and content area conditions.

In the experiment, the images were presented using the SuperLab experiment generator software which ran on personal computers (Intel Pentium, 333 MHz, 64 Mb RAM, Microsoft NT4 operating system, 14 inch monitors). The screen dimensions were 1024 × 768 pixels; contrast and brightness were set to optimal levels.

2.4. Procedure

The experiment was carried out in classrooms with 15 to 20 participants taking part concurrently. They first completed a practice series consisting of eight trials, followed by a series of 72 experimental trials presented in random order.

Participants were first presented with a set of on-screen instructions. Participants were told that they were going to take part in a visual search task involving mock web pages and that they had to try and find a hyperlink in a screen of text. If the link was present on the page, they had to press the 'p' key, and if it was absent then they had to press 'a'. Depending on the group to which they had been

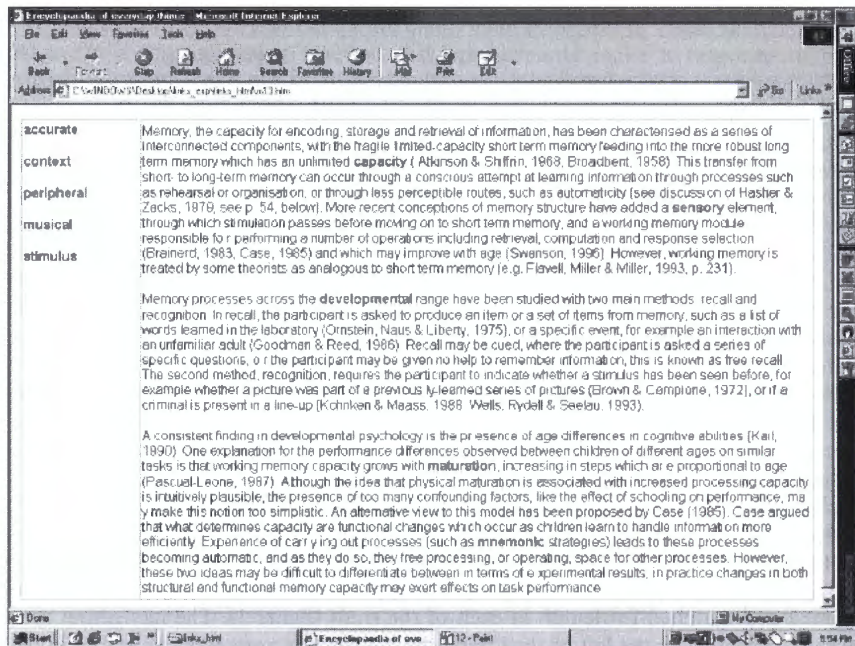


Figure 1. Typical web page used in the experiment.

allocated, they were also instructed to attend to the links in either the navigation or the content area.

After reading the instructions, participants pressed the 's' key on the keyboard to proceed. A series of trials was presented. In each trial a blank white screen (shown randomly for 1000, 1500 or 2000 ms with a mean of 1500 ms) was presented, then a black target word on a white background (always 1000 ms, in Arial, size 48, in the centre of the screen), followed by a blank white screen (shown randomly for 1000, 1500 or 2000 ms with a mean of 1500 ms) and then a web page. The target word was either present or absent from either the list of links (in the navigation area condition) or in the links distributed in the text (in the content area condition). Participants responded by pressing the appropriate keys to indicate whether the target was present or absent from the web page. A participant's response triggered the start of the next trial. If a participant had not responded after 5000 ms, then the next trial would start automatically. In the practice trials, the four possible combinations of bold and underlining each appeared twice.

After completion of the experimental trials, participants completed a series of questions presented by computer. The questions covered demographic details (age, sex, use of the WWW), and preference for link characteristics. For this, using the procedure employed by Ling and van Schaik (2002), participants were presented with all possible paired combinations of the links, one at a time, and asked to choose which they preferred. Participants were also asked a series of seven aesthetic questions about each of the link formats. These questions were taken from

Tractinsky *et al.* (2000), and prompted participants to evaluate the links in terms of beauty, comprehension, complexity, legibility, meaning, order and overall impression. Each link format was rated on these dimensions using a 7-point scale. Participants were thanked at the end of the experiment and then fully debriefed.

3. Results

For the purpose of analysis, the task performance data were divided into hits and correct rejections, which were each examined in terms of accuracy and speed (i.e., reaction time). In addition, participants' preference for and judgement of aesthetic value of web pages was analysed. Analysis of variance (ANOVA) and tests of simple effects were used to assess the effects of screen area and link format in terms of differences in mean scores on task performance and subjective measures; *post hoc* analysis was conducted to test for differences between types of link format. Furthermore associations between and within performance and subjective measures were established. The significance level was set at 0.05 for statistical testing.

3.1. Analysis of hits

3.1.1. *Accuracy*: A hit was defined as a correct response to a target word that was present in the navigation or content frame of a subsequently presented web page and the percentage of hits was calculated. Neither link format, $F(3, 141) < 1$, nor screen area, $F(1, 47) = 2.77$, $p > 0.05$, had an effect on hits (see table 2). However the interaction effect between link format and screen area was significant, $F(3, 141) = 10.03$, $p < 0.001$ (see figure 2).

Simple effect tests showed that the effect of link format was significant for both the navigation area, $F(3, 57) = 3.74$, $p < 0.05$, and for the content area, $F(3, 84) = 7.38$, $p < 0.001$. Further simple effect tests showed a significant difference between navigation and content areas for bold links, $t(47) = 6.02$, $p < 0.005$. Simple comparison tests with Sidak correction showed no significant differences between link codes for the navigation area; however, for the content area significant differences were found between bold and plain ($p < 0.05$), and bold and bold-underlined ($p < 0.001$).

3.1.2. *Speed*: Reaction times for hits were examined. The effects of link format, $F(3, 141) = 10.63$, $p < 0.001$, and screen area, $F(1, 47) = 6.53$, $p < 0.05$, on reaction time for hits were significant (see table 3) as well as the interaction effect, $F(3, 141) = 15.41$, $p < 0.001$ (see figure 3).

Simple effect tests showed that the effect of link format was significant for both the navigation area, $F(3, 57) = 6.18$, $p = 0.001$, and for the content area, $F(3, 84) = 20.72$, $p < 0.001$. Further simple effect tests showed significant differences between navigation and content areas for plain links, $t(47) = 3.64$, $p < 0.005$, and underlined links, $t(47) = 4.21$, $p < 0.005$. Simple comparison tests with Sidak correction for the navigation area showed significant differences between plain and bold-underlined and between bold and bold-underlined (both $p < 0.05$); for the content area significant differences were found between plain and bold ($p < 0.005$), plain and bold-underlined ($p < 0.001$), bold and underlined ($p < 0.001$) and underlined and bold-underlined ($p < 0.001$).

3.2. Analysis of correct rejections

3.2.1. *Accuracy*: A correct rejection was defined as a correct response to a target word that was absent in the navigation or content frame of a subsequently presented

Table 2. Percentage of targets correctly identified (hits)

Screen area	Plain		Bold		Underlined		Bold-underlined		Overall	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Navigation	93.89	(9.86)	97.22	(7.96)	91.67	(7.10)	88.89	(11.40)	92.92	(5.94)
Content	91.19	(11.26)	84.29	(6.98)	90.80	(10.32)	94.64	(7.04)	90.22	(5.28)
Overall	92.29	(10.69)	89.57	(9.73)	91.16	(9.07)	92.29	(9.41)	91.33	(5.66)

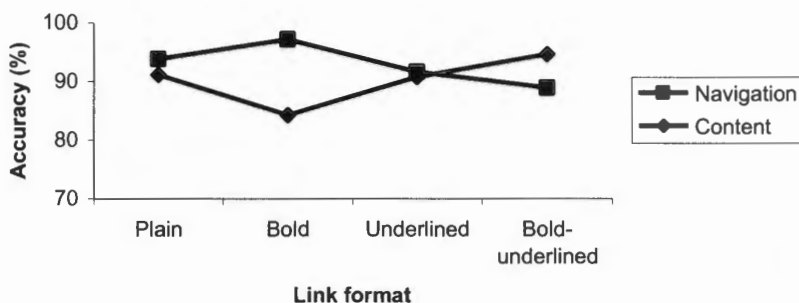


Figure 2. Interaction between link format and screen area for hits.

Table 3. Reaction times for hits (ms)

Screen area	Plain		Bold		Underlined		Bold-underlined		Overall	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Navigation	1433	(386)	1398	(450)	1444	(375)	1555	(393)	1458	(388)
Content	1797	(313)	1535	(255)	1837	(279)	1561	(263)	1682	(228)
Overall	1648	(386)	1479	(350)	1677	(373)	1559	(318)	1591	(320)

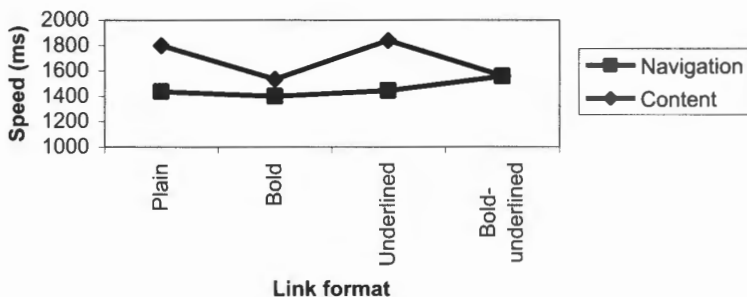


Figure 3. Interaction between link format and screen area for reaction times for hits.

web page and the percentage of correct rejections was calculated. There were no main effects on correct rejections of either link format, $F(3, 141) = 1.20$, $p > 0.05$, or screen area, $F(1, 47) < 1$, (see table 4). However, there was an interaction between link format and screen area, $F(3, 141) = 2.75$, $p < 0.05$. Simple effect tests showed that there was no effect of link format for either navigation, $F(3, 57) = 1.71$, $p > 0.05$, or content area, $F(3, 84) = 2.32$, $p > 0.05$. Further simple effect tests showed no difference between navigation and content areas.

3.2.2. Speed: Reaction times for correct rejections were examined. The effects of link format, $F(3, 141) = 6.60$, $p < 0.001$, and screen area, $F(1, 47) = 18.97$, $p < 0.001$, on reaction time for correct reactions were significant (see table 5). The interaction effect was also significant, $F(3, 141) = 11.82$, $p < 0.001$ (see figure 4).

Simple effect tests showed that the effect of link format was significant for the content area, $F(3, 84) = 19.30$, $p < 0.001$, but was not significant for the navigation

Table 4. Percentage of targets correctly rejected

	Plain		Bold		Underlined		Bold-underlined		Overall	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Screen area										
Navigation	98.89	(4.97)	98.33	(4.07)	95.56	(7.56)	96.67	(5.22)	97.36	(3.31)
Content	96.55	(6.02)	97.32	(7.06)	98.85	(3.44)	95.40	(8.14)	97.03	(4.63)
Overall	97.51	(5.68)	97.73	(5.99)	97.51	(5.68)	95.92	(7.06)	97.17	(4.11)

Table 5. Reaction times for correct rejections (ms)

	Plain		Bold		Underlined		Bold-underlined		Overall	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Screen area										
Navigation	1631	(478)	1731	(438)	1671	(454)	1649	(505)	1671	(455)
Content	2293	(394)	2101	(328)	2184	(351)	2036	(292)	2154	(322)
Overall	2023	(538)	1950	(415)	1975	(467)	1878	(433)	1957	(447)

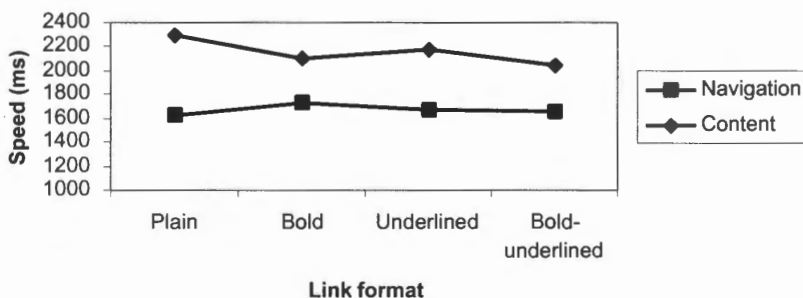


Figure 4. Interaction between link format and screen area for reaction times for correct rejections.

area, $F(3, 57) = 2.12$, $p > 0.05$. Further simple effect tests showed significant differences between navigation and content areas for plain, bold, underlined and bold-underlined links, $t(47) = 5.29$, $t(47) = 3.38$, $t(47) = 4.46$, all $p < 0.005$, and $t(27.76) = 3.39$, $p < 0.05$ respectively. Simple comparison tests with Sidak correction for the content area showed significant differences between plain and bold ($p = 0.001$), plain and underlined ($p < 0.05$), plain and bold-underlined ($p < 0.001$), bold and underlined ($p < 0.05$), and underlined and bold-underlined ($p < 0.005$).

3.3. Associations between performance measures

Speed (reaction times) for hits and correct rejections were significantly correlated, $r = 0.88$, $r = 0.68$, $r = 0.85$ and $r = 0.69$, all $p < 0.001$, for plain, bold, underlined and bold-underlined links respectively. Hits and correct rejections were weakly, but statistically significantly, correlated for bold links, $r = 0.29$, $p < 0.05$, but not for other types of link format. There was no significant correlation between speed and accuracy for either hits or correct rejections.

3.4. Analysis of subjective measures

3.4.1. *Preference*: The percentage of times participants chose a particular link format over the other codings was calculated as a measure of preference. The effect of link format on preference was significant, $F(3, 141) = 86.86$, $p < 0.001$, but not the effect of screen area, $F(1, 47) = 2.21$, $p > 0.05$, (see table 6). The interaction effect was close to significance, $F(3, 115.30) = 2.71$, $0.05 < p < 0.10$ (see figure 5).

Table 6. Preference (percentage of times preferred)

Screen area	Plain		Bold		Underlined		Bold-underlined	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Navigation	8.33	(21.89)	63.33	(28.41)	4.47	(0.57)	50.00	(22.94)
Content	5.75	(12.81)	71.26	(19.36)	4.82	(0.78)	33.33	(15.43)
Overall	6.80	(16.64)	68.03	(23.53)	4.68	(0.72)	40.14	(20.39)

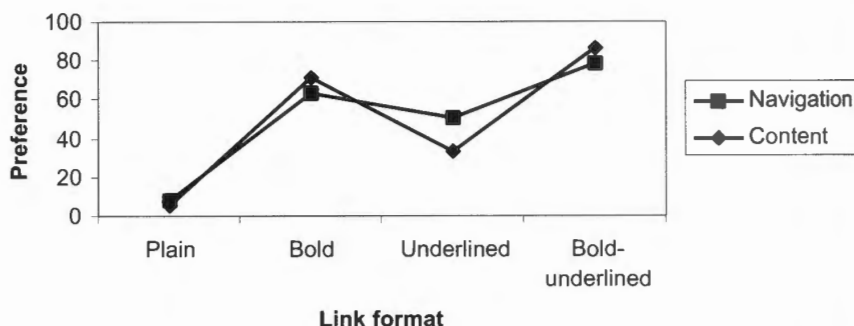


Figure 5. Interaction between link format and screen area for preference.

Simple effect tests showed that the effect of link format was significant for both the navigation area, $F(3, 57) = 20.60$, $p < 0.001$ and for the content area, $F(3, 84) = 97.51$, $p < 0.001$. Further simple effect tests showed a significant difference between navigation and content areas for underlined links, $t(30.68) = 2.84$, $p < 0.05$. Simple comparison tests with Sidak correction for the navigation area showed significant differences between plain and bold, plain and underlined, plain and bold-underlined (all $p < 0.001$). Further simple comparison tests for the content area showed significant differences between all pairs, $p < 0.001$, except between bold and bold-underlined.

3.4.2. Aesthetic value: The aesthetics scale was checked for reliability. The instrument was found to be reliable for each of the types of link format, Cronbach's alpha = 0.79, 0.83, 0.73 and 0.73 for plain, bold, underlined and bold-underlined links respectively.

The effect of link format on aesthetic value was significant, $F(3, 141) = 11.10$, $p < 0.001$, but the effect of screen area was not, $F(1, 47) = 2.97$, $p > 0.05$ (see table 7). There was a significant interaction effect, $F(3, 141) = 3.90$, $p = 0.01$ (see figure 6).

Simple effect tests showed that the effect of link format was significant for both the navigation area, $F(3, 57) = 3.15$, $p < 0.05$ and for the content area, $F(3, 84) = 14.68$, $p < 0.001$. Further simple effect tests showed a significant difference between navigation and content areas for bold links, $t(47) = 3.20$, $p < 0.01$. Simple comparison tests with Sidak correction for the navigation area showed no significant differences between types of link format for the navigation area; however for the content area significant differences were found between plain and bold ($p = 0.001$),

Table 7. Aesthetic value (7-point Likert scale)

Screen area	Plain		Bold		Underlined		Bold-underlined		Overall	
	M	(SD)	M	(SD)	M	(SD)	M	(SD)	M	(SD)
Navigation	4.17	(1.00)	4.35	(0.99)	4.47	(0.74)	4.88	(0.68)	4.47	(0.57)
Content	4.40	(0.96)	5.26	(0.96)	4.43	(0.99)	5.19	(0.95)	4.82	(0.78)
Overall	4.31	(0.97)	4.89	(1.06)	4.45	(0.89)	5.06	(0.85)	4.68	(0.72)

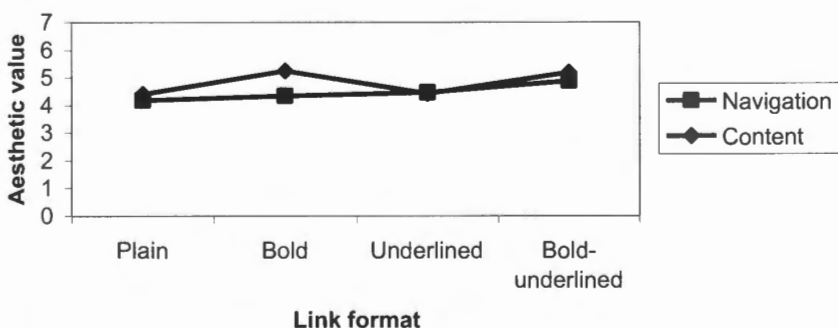


Figure 6. Interaction between link format and screen area for aesthetic value.

plain and bold-underlined ($p < 0.005$), bold and underlined ($p = 0.001$), and underlined and bold-underlined ($p < 0.001$).

3.5. Associations between subjective measures and performance measures

Preference and aesthetic value was not correlated for any of the types of link format. The following correlations between subjective measures and task performance measures were significant: percentage of hits with preference for plain links, $r = -0.35$, $p < 0.05$, percentage of hits and preference for bold-underlined links, $r = 0.49$, $p < 0.001$ and aesthetic value and reaction time for hits for bold links, $r = 0.30$, $p < 0.05$.

4. Discussion

This study examined the effect of link format on visual search of web pages. There were several salient findings. First, there was no effect of link format or screen area on either accuracy of hits or correct rejections. Second, there was an interaction between link and screen area, with accuracy of detecting bold links in the navigation area better than in the content area. Bold-underlined links had higher rates of accuracy than either plain or bold links in the content area. Third, link format had an effect on speed both in the navigation and content areas. In the content area, participants were quicker to locate links that were bold or bold-underlined, while in the navigation area, bold and plain formatted links were detected fastest. Plain and underlined links were also located more slowly in the content area than the navigation area. Fourth, there was an interaction between link format and screen location for reaction time for correct rejections, with link format affecting only the content area. Again bold and bold-underlined formatting led to faster reaction times than other formats in this area. As expected, reaction times were quicker for all formats in the navigation area than the content area.

There were significant differences between the levels of preference expressed for the different link formats. Bold and bold-underlined links were more highly rated than either plain or plain-underlined links, irrespective of screen location. Although there were no differences in participants' aesthetic evaluations of the different link formats in the navigation area, ratings did differ in the content area. In this location, participants gave higher ratings to the bold and bold-underlined formats than links presented in either plain or underlined formats.

In summary, these results are a consistent set of findings: the effect of link format is different for the navigation area from the content area. This shows that there is a clear difference in performance between the navigation and the content area depending upon the format of the links used.

Screen design had a significant impact on task performance, confirming the results of other researchers (e.g., Streveler and Wasserman 1984, Näsänen *et al.* 2001). This finding is important for all web sites—though these results have particular implications for commercial sites. Research has shown that commercial sites that are more difficult to use, have long download times, or make it difficult for users to locate required information are likely to be less successful (Nel *et al.* 1999). In the present study, poorly formatted links were more likely to be associated with longer reaction times and lower accuracy: if customers on a commercial site find this frustrating, they will be more likely to change their strategy in navigating the site as suggested by the results of Gray and Boehm-Davis (2000) or even abandon the site for a more usable competitor.

Tauscher and Greenberg (1997) found that 90% of browser actions were navigational. The present research therefore has important implications for the design of web pages as it focuses on an important navigational method, the use of hyperlinks. These implications are highlighted below.

First, the results show that it is insufficient to format hyperlinks in a different colour to normal text and expect that this will lead to optimal levels of performance. It was found that link format had a significant effect not only on the speed with which participants were able to find information, but also on whether they were able to discover specific information on a page at all. Although colour does have an impact upon users' interactions with web pages (Ling and van Schaik 2002), the present results are evidence that web designers also need to pay attention to other parameters involved in the presentation of textual information (Galitz 1997).

Second, the data further indicate that navigation and content areas need to be treated differently in terms of the way that links in these locations are presented. In the content area, links are distributed throughout the normal text of a page and therefore need to be made more salient so that they are easier to detect. In the navigation area there is no such need for links to stand out from a background of normal text as the only information in this location is that of other hyperlinks. In this area, therefore, the emphasis needs to be upon clarity of the link format, rather than on salience. This result demonstrates that the 'one size fits all' approach to hyperlink formats (e.g., Gee 2001) needs to be refined to take into account the context of presentation, where the surrounding information may have a significant impact upon the optimal link format.

The finding that measures of speed and in particular, preference were most sensitive to experimental manipulations leads to the recommendation that these measures be used in future research. The recommendation of speed measures is further supported by the impact of user interface design parameters on users' interaction strategies: 'Although milliseconds may seem too small to matter, milliseconds added to each low-level step of interactive behaviour quickly add up' (Gray and Boehm-Davis 2000: 334). Although test results for speed and preference were similar, the overall lack of correlation between performance and subjective measures highlights the need to use measures of both speed and preference.

Establishing the reliability of these results through replication is the first necessary stage in confirming the guidelines derived from these data. However, of equal importance is the need to examine whether the current default colours of blue links and black normal text is really the best combination of colours for both ease of reading and for detection of specific (hyperlink) information. Future research could employ cascading style sheets in web sites to discover whether particular colour and format combinations lead to better outcomes than others.

In conclusion, earlier research has demonstrated the importance of navigation within web pages. This study has focused on one element of navigation behaviour—visual search for hyperlink information—and has shown that link format is an important part of both success and speed of navigation tasks. This novel finding has important and clear design implications for web pages. Visual search is just one of the processes that influence information retrieval in web sites and thus these conclusions apply to the choice of design parameters that can improve visual search as part of the larger process of information retrieval. Future research should explore other processes that influence information retrieval from web sites within the context of realistic tasks.

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