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EFFECTS OF TARGET DENSITY AND GRAPHICS PRESENTATION STYLE ON SEARCH TIME AND REPORTS OF USABILITY AND PREFERENCE

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ABSTRACT

This experiment investigated the effects of target word density (i.e., high, medium, and low) and Web page presentation style (i.e., no graphics, static graphics, and animated graphics) on search time and user preferences. Nine Web pages were developed reflecting all combinations of target word density, determined by the number of targets embedded within a 200-word text display, and presentation style. Sixteen undergraduate students from a Systems Analysis and Design class participated. The task required the selection, using the mouse, of the embedded target words in each of the nine Web pages. A full-factorial within-subjects design was used, and the order of presentation of the nine pages was randomly determined for each student. The results showed a significant effect of target density on search time. Search time on low-density pages was significantly briefer than on high-density pages, an outcome that validated the experimental protocol. No significant effect was found for page presentation style, and the interaction between target density and presentation style was not significant. Self-report data showed that static graphics pages and animated graphics pages were sometimes perceived differently in terms of usability and aesthetics, and both styles were perceived as visually appealing to users.

INTRODUCTION

In a human-computer interaction (HCI), user interfaces displaying multimedia information may sometimes be perceived as more exciting, natural, enjoyable, and pleasant to use than text-only interfaces (Peterson, 1996). Nevertheless, adding more media can sometimes produce interfaces that are difficult to use, especially when concentrating on a particular item of information. Web pages displaying online advertising exemplify this problem, and users report annoyance when trying to read textual information on pages also containing such advertising (Zhang, 1999). Zhang (1999) also showed that graphics animations reduced users' attention when searching information displayed on Web pages. The initial aesthetic appeal of an interface, then, may sometimes be offset by undesirable changes in user performance.

There has obviously been an explosion of Web sites that intend to attract "surfers" to visit their pages by using highly animated graphics as advertisements or banners. However, many Web users experience difficulty when navigating through the Web and reading through pages to seek the information they want. This problem of "cognitive overload" occurs when users must perform several tasks simultaneously while navigating across Web sites to locate specific information, traversing many Web pages within a site, and reading a page to comprehend the information (Pilgrim & Leung, 1999). Accordingly, research on the impact of graphics elements in Web page design on user performance becomes increasingly important to designers. Not only user performance but also user perceptions toward the interface have been measured in evaluating interface design and effectiveness. Zhang (1999) has explored the impact of animation on searching for target words on Web pages that have animated graphics in relationship to task difficulty, animation color, animation content, and instructions to ignore animation. The results showed that animations degraded performance in searching for target words.

Related earlier work by Johnson and Nemetz (1998) defined multimedia design principles by analyzing Web pages in terms of text, diagrams, maps, photographs, hypermedia, and animation. They found that animation used in Web pages distracted the users' attention. Harrison (1995) conducted a comparative study of still, animated, and non-illustrated on-line help with written and spoken instructions in a graphical user interface. She found that subjects who used on-line help messages that had either static or animated graphics, both of which provided extra explanatory information about the messages, performed more tasks in less time and with fewer errors than did subjects who had text-only help. However, a significant difference between the subjects' performance in the still-graphics and animated-graphics conditions was not found. The interpretation of these various findings may benefit from consideration of theories of attention.

Attention is a human cognitive process that generally means selectivity of information processing (Eysenck & Keane, 1995), concentration effort on a stimulus, or the limited energy or resources available to the cognitive system (Ashcraft, 1998). Humans always encounter many information sources simultaneously, but they can not easily attend to more than one source of information at a time because of the limitation of their attention ability. When attempting to concentrate on one stimulus, humans ignore the surrounding stimuli or distractions. This process is called filtering or selecting (Ashcraft, 1998). Moreover, objects in our peripheral vision can sometimes capture our attention (Driver & Baylis, 1989). Understanding these attention processes may sug-

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gest approaches to the design and evaluation of web pages.

Two major study areas of attention include selective attention and divided attention. Selective attention, or focused attention, is the process of screening out the surrounding distractions and focusing only on one important event or stimulus (Ashcraft, 1998). Divided attention pertains to how well two tasks can be performed concurrently by presenting at least two stimuli simultaneously (Eysenck & Keane, 1995). The research on attention theory suggests experimental approaches to the assessment of Web page effectiveness, such as the search and retrieval paradigm used in the present study.

To measure how users perform and how they perceive or think about an information system is important to the formulation of interface guidelines that are empirically justified. Usability, a core concept of HCI, refers to interface characteristics that are easy to use, learn, and remember, and that are pleasant to use and generate the least errors (Nielsen, 1993). User evaluation toward interface design is necessary to discover ways to accommodate interface usability and preference perceptions. In addition to usability evaluations, "aesthetics evaluation" is also interesting to investigate. Generally, aesthetics can be defined as the visual appearance of a stimulus such as colors, sizes, shapes, density, and locations (Lynch & Horton, 1999). In fact, users look at the overall aesthetics of a Web page before they decide to navigate within the Web site. In other words, aesthetic designs can draw users' attention and also affect users' satisfaction and, perhaps, a company's brand image.

Usability and aesthetics are often debated whether which one is more important in designing an interface. Nielsen (1993) includes aesthetics as one characteristic of usability. From an interview with Aaron Marcus by Rhodes (1999), Marcus agrees that aesthetics is part of usability. However, few empirical studies have been conducted to explore the importance of aesthetics in interface design.

Against that background, the continued improvement of users' performance and the enhancement of users' perceptions of usability and aesthetics with respect to Web page interfaces are essential. There is a growing body of empirical research that addresses these factors from the perspectives of graphics, information density, and aesthetics. The purpose of the present experiment, then, is to integrate these classes of variables within a research paradigm that provides the opportunity to study the potentially interacting effects of several combinations of the variables. Furthermore, the study broadens the range of a density factor, in comparison to previous investigations. The intellectual context and theoretical framework are empirically and heuristically driven, rather than null-hypothesis driven, by aiming to show the generality and strength of the phenomena under a different set of observational conditions. The study aims to evaluate nine alternative Web page designs by investigating information searching performance as well as usability and aesthetic preferences in relationship to Web pages that vary in the density of target words, which are embedded within displayed text, and in the loading of graphics.

METHOD

Independent Variables

The two independent variables were page presentation style (i.e., text only, text with static graphics, and text with animated graphics) and target density (i.e., low, medium, and high). These variables will be explained below. Crossing the three levels of each of these two variables produced nine different Web pages.

Dependent Variables

The dependent variables were (1) total search time for the target words and (2) self-reports of usability and perceived aesthetics. Automatic recording of search time in seconds began when a Web page was displayed to the subject, and it ended when the subject finished searching for the target words. Perceived usability and aesthetics were assessed using a self-report questionnaire. Five statements were evaluated for both the static graphics and the animated graphics presentation style. The following statement was presented for static graphics, ending with each of the five factors to be rated: "When I visit a Web page, I find static graphics…" (1) annoying, (2) useful, (3) make Web pages more pleasant to use, (4) make Web pages more fun to use, and (5) make Web pages more visually appealing. The subject rated each factor by choosing one of the following seven options:

(1) Extremely disagree
(2) Quite disagree
(3) Slightly disagree
(4) Neither agree nor disagree
(5) Slightly agree
(6) Quite agree
(7) Extremely agree

The statement and choices were repeated for the animated graphics. The questionnaire was administered after the subject completed the experiment.

Experimental Materials

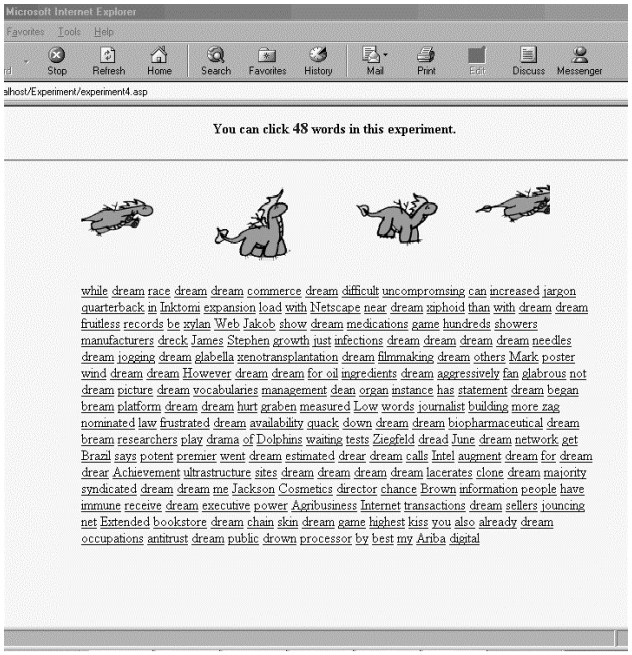
In this experiment, 200 words, including both target and non-target words, were displayed on each Web page. Non-target words were randomly selected from 500 words in a database. These 500 words were chosen from current Web sites in various areas such as healthcare, information technology, and education; the list of words is available on request. The word "dream" was used as the target word throughout the experiment with every subject.

The number of target words varied according to each density condition described below. In the study by Zhang (1999), target words used there were 8% of the total words displayed on a page. This figure was adopted in the present experiment for the low-density condition to allow for procedural comparability between the two studies. In summary, there were three target densities: (1) 16 target words (8% of total words) for low density; (2) 32 target words for medium density; and (3) 48 target words for high density.

The two types of graphics that were used in the Web pages were (1) static graphics and (2) animated graphics. Neither graphics presentation style conveyed any meaning regarding the 200 words displayed on the Web pages. The two types of graphics were located at the same position in the topmost center of the Web page. This position is most often used to position banners in Web sites. In summary, there were three graphics presentation styles: (1) no graphics, (2) static graphics, and (3) animated graphics.

All words in the Web page were selectable. Subjects searched for the target word "dream" in all nine Web pages that were evaluated, and the subject denoted finding the target word by clicking it with the mouse. **Figure 1** shows the screen for the high-density

Figure 1. High-density Web page with static graphics presentation style.



Web page with a static graphics. The static graphics displayed four small non-moving Dragons simultaneously. For the animated graphics, the four Dragons were displayed one at a time, from left to right in one-second intervals. Only one Dragon was displayed at a time in the animated presentation style. Whenever the subject clicked a target word, the animation was restarted with the first Dragon.

Subjects

Sixteen undergraduate student volunteers were recruited from the System Analysis and Design class in Information Systems, University of Maryland Baltimore County. They were given 5% course credit for participation. Subjects ranged in age from 21 to 30 years, nine males and seven females. Most of them were seniors in Information Systems. The majority indicated that they had used the Internet more than three years and spent 15 minutes to one hour each day navigating Web sites. The majority indicated that they were comfortable reading text from Web pages.

Apparatus

An IBM-based HP Pavilion computer (Model N3270 with a 14 in, 1024 x 768 TFT color display, a AMD K6-2 processor, 64 MB RAM, 6 GB disk drive, and an external mouse) was used. Web pages were written using Microsoft Active Server Pages and JavaScript. Microsoft Personal Web Server was running as a desktop server throughout the experiment. Search time, task sequences, and self-report results were recorded into Microsoft Access databases. A Microsoft IE 5.0 browser was used to access the Web pages.

Experimental Design

The experiment used a 3 (density) x 3 (presentation style) full factorial within-subjects design. The order of the nine Web pages presented to each subject was determined by a random number function.

Procedure

Each subject participated individually. The subject used a mouse to select target words and choices on the self-report questionnaire. The subject was told that the objective of the study was to evaluate several Web interface designs within the context of collecting search time and preferences.

Each subject was seated in front of the laptop computer. The experimenter informed the subject that (1) the task is to search for target words on a Web page as quickly and accurately as possible; (2) when the target word is found, click on it once; (3) the number of target words in each Web page may vary; (4) performance time and accuracy will be recorded; (5) when the number of words that have been clicked (either right or wrong) is equal to the number of target words displayed, the subject will be automatically taken to the next Web page; (6) there are nine Web pages to be searched for target words in this experiment; (7) after finishing each Web page, the subject should pause for 5 seconds; and (8) after a subject finishes the experiment, he/she will complete a questionnaire to obtain demographic data and preferences toward the graphics used in the experiment. The subject was also requested to observe the general appearance of each Web page before beginning the search task because the perception toward the page appearance will be asked in the questionnaire. Finally, the subject was told that each Web page will have different graphics, which are non-moving and moving, and some pages will have no graphics.

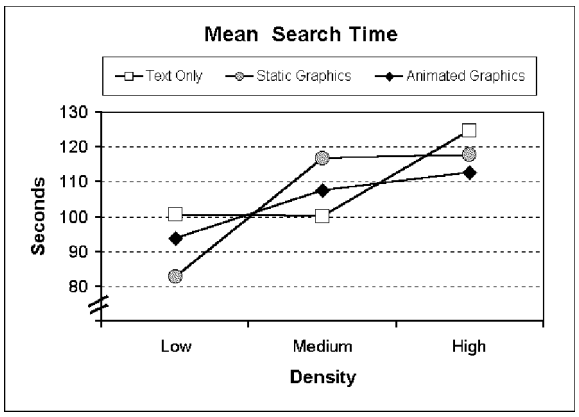
The subject then completed a practice session with a text-only, low density Web page with a different target word than the one used in the experiment. The experiment and the survey were completed in approximately 30 minutes.

RESULTS

The results below are based upon the 16 subjects who performed all tasks with no errors. The SPSS MANOVA software package was utilized to analyze the performance data because this approach does not require the sphericity assumption for repeated measures. The SAS software package was utilized to analyze the self-report data within the framework of a multivariate approach to ordinal data. These conservative analytic and interpretive approaches are taken from Maxwell and Delaney (1990).

Figure 2 presents mean search time for the three graphics presentation styles across low, medium, and high density target conditions. The categories are discrete, and points are connected for clarity of interpretation. MANOVA showed a significant effect of target density, $F(2,30) = 5.72$, $p < .01$, no significant effect of presentation style, $F(2,30) = 0.17$, $p > .05$, and no significant interaction between target density and presentation style, $F(4,60) = 1.30$, $p > .05$. **Figure 2** shows that regardless of Web page presentation style, average

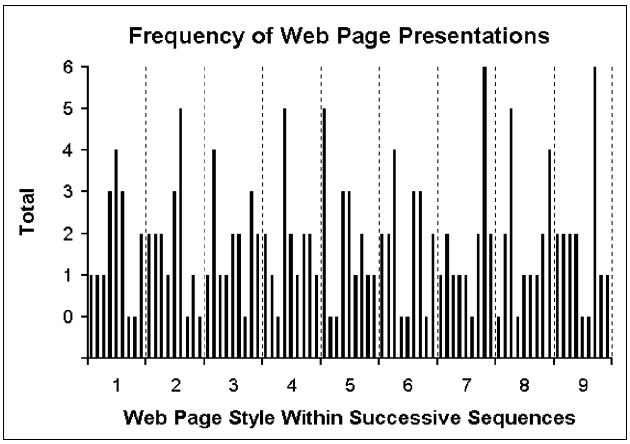
Figure 2. Mean search time for the three presentation styles across the three densityconditions.



search time was generally higher when the density of the target words was higher. Post-hoc pairwise comparisons showed a significant difference between the low density and high density target conditions for average search time ($p < .01$). However, the null hypothesis of no difference among the three presentation styles could not be rejected, and no further tests were conducted.

The frequency distribution of sequences in presenting each experimental Web page, which was completely randomized by a computer program, was problematic. **Figure 3**

Figure 3. The frequency distribution of the nine Web pages across successive sequence positions totaled for the 16 subjects.

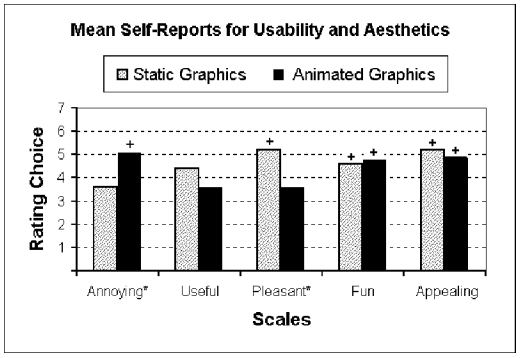


shows the total occasions that each of the nine Web pages appeared across successive sequence positions 1 - 9. The figure shows that the distribution was demonstrably irregular, although the individual components are not detectable given the volume of information displayed. Web pages with low target density and an animated graphics style tended to appear later in the sequence. Although all subjects received a practice session and the task was not difficult, these potential order effects do raise concerns about relying on computer-generated random sequences. Since there are 362,880 potential orderings of the experimental events, a variation of a blocked or Latin-square design is suggested for further research in this area of investigation. Finally, a test of linear trend over the nine successive sequence positions was not significant, $F(1,135) = 0.21$, $p > .05$.

Self-reports

Figure 4 presents mean self-reports for all subjects on each of the five scales.

*Figure 4. Perceptions on usability and aesthetics. * = significant difference between styles; + = significantly different from neutral choice.*



MANOVA showed a significant difference between static and animated graphics on mean ratings on the Annoyance scale, $F(1,15) = 4.87$, $p < .05$, and the Pleasant scale, $F(1,15) = 12.76$, $p < .002$. As shown in **Figure 4**, the animated graphics style was perceived as more annoying than the static graphics style. Moreover, the static graphics style was more pleasant to use than the animated graphics style. These comparisons indicate a potentially disruptive consequence of the use of animated graphics, at least with respect to subjects' reports of their preferences. The data for Useful, Fun, and Visually Appealing did not support a difference between the two presentation styles. However, a comparison of the observed ratings with a population of neutral scale values (i.e., 4) showed a significant difference for Annoyance/Animated Graphics, $F(1,15) = 18.06$, $p < .05$; Pleasant to Use/Static Graphics, $F(1,15) = 22.56$, $p < .05$; Fun to Use/Static Graphics, $F(1,15) = 5.06$, $p < .05$; Fun to Use/Animated Graphics, $F(1,15) = 10.56$, $p < .05$; Visually Appealing/Static Graphics, $F(1,15) = 22.56$, $p < .05$; and Visually Appealing/Animated Graphics, $F(1,15) = 14.06$, $p < .05$. These data show the tendency of the subjects, as a group, to give a favorable rating to the graphics presentation style.

DISCUSSION AND CONCLUSION

The results of this study show that search time reliably increases when the number of target words increases. Although intuitively obvious, perhaps, this finding validates the user interactions that were programmed in this research, and it leads to plausible interpretations about the effects of graphics on user performance and self-reports. Although no significant effect was found for Web page presentation style, this outcome might be attributable, at least in part, to the order in which the Web pages were presented across successive subjects. The high density animated pages tended to occur later in the sequence, and those positions may be sensitive to practice effects with the task. That is, user performance might be anticipated to improve over the nine successive trials without regard to the changes in the independent variables, but the test of trend was not significant. The density finding, however, suggests that the potential order effect was not robust in comparison to the strength or lack of strength of the independent variables. To clarify this potential issue requires systematic replication with a Latin square design variation that distributes the order of events over subjects with the objective of eliminating the potential role of position effects in the interpretation of the results. This issue also indicates the importance to researchers of verifying the sequences that are generated by so-called random number functions.

In terms of user perceptions toward the interfaces displayed in this study, static graphics pages and animated graphics pages were sometimes perceived differently in terms of usability and aesthetics. Self-reports of annoyance and pleasant factors showed that users reported animated graphics to be more annoying than static graphics and static graphics more pleasant to use than animated graphics. As shown in **Figure 4**, both of the higher mean rating choices differed from the neutral scale value in the positive direction. Moreover, self-reports of fun and visually appealing factors showed that all mean rating choices differed from the neutral scale value in the positive direction. Since the null hypothesis of no performance differences among the three presentation styles could not be rejected, these findings present a challenge for interpretation. Subjects reported animated graphics as annoying, but they also found them to be fun and visually appealing. This suggests the importance of separating the impact of text and graphics when the intent of the Web page differs between an initial visita-

tion to a page and the subsequent use of a Web page to search for designated information.

The design of this study can be improved in several aspects for future research. First, the order of the presentations of the tasks should be determined by a Latin square variation. Second, words used in the next experiment might be five letter words, which can be read with a single eye fixation and controlled for word familiarity. Third, the positions of target words and non-target words in the text display will not be totally randomized. It is necessary to find some methods to balance out the positions of target words and non-target words in each target density condition. With respect to future directions, additional studies on page presentation style to improve information presentation on the display screen would be useful. These include studies on attributes of animated graphics such as colors and positions. The ultimate goal is to produce a set of guidelines to show how to design usable and visually appealing Web pages that facilitate attention on interfaces that display multiple objects.

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