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Impact of placing icons next to hyperlinks on information-retrieval tasks on the web

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Abstract

Though several studies have demonstrated the usefulness of pictures in multimedia learning, memory, cognitive load and visual search, there have been very few attempts to study their impact in the web-navigation scenario. Also, cognitive models of web-navigation (like CoLiDeS, CoLiDeS+) ignore the information from visual modality and focus solely on the information from text. We conducted an experiment to study the extent to which providing icons next to hyperlinks facilitates information retrieval tasks on the web. Three different versions of navigation styles were created: Hyperlinks with Icons, Hyperlinks alone and Icons alone. Users took significantly less time, were significantly less disoriented and made fewer clicks to finish their tasks when icons were provided along with hyperlink text. These results suggest that it is important for a cognitive model on web-navigation to include information from pictures. An important practical implication is to provide meaningful icons next to hyperlinks for better navigation.

Keywords: Web-navigation, text, pictures, icons, web-usability, cognitive model

Introduction

With the advancement of web-technology, the World Wide Web (WWW) now has evolved into a complete hypermedia environment, i.e. information is spread across all modalities – text, picture, audio and video. This adds to the complexity and the *lost in hyperspace* phenomenon of the users (Conklin, 1987). Pirolli and Card (1999) found that a user always follows the path that gives highest *information scent*; i.e., a user estimates the cost and value of taking a particular action like clicking on a hyperlink, and comparing several such actions always picks the action that has the highest value or information scent (Chi *et al*., 2000, 2001).

Inspired by this information scent model, several cognitive models of web-navigation (CoLiDeS, CoLiDeS+, SNIF-ACT and MESA) have been developed. Comprehension based Linked model of Deliberate Search (CoLiDeS) developed by Kitajima, Blackmon and Polson (2000) divides the process of navigating a website into four steps – *parsing, focusing, comprehension and elaboration* and *selecting.* A user first parses the web page into 5-10 top-level schematic regions, focuses on one of the sub-regions, comprehends and generates an elaborated representation of each object in the sub-region based on his or her background knowledge and finally selects one object in that sub-region. This final step of selection is based on the computation of semantic similarity between the user's goals and the elaborated representations developed by the user.

CoLiDeS+ developed by Juvina and Oostendorp (2005, 2008) improved CoLiDeS by incorporating contextual information, i.e. information from previously visited web pages. It computes *path adequacy* as the semantic similarity between the user goal and the navigation path. CoLiDeS+ selects the incoming information only if it increases path adequacy. When the incoming hyperlink does not increase path adequacy, other hyperlinks with lower information scent are considered. Further, it considers backtracking to other regions in the same page and then to other pages.

Miller and Remington (2004) proposed a *Method for Evaluating Site Architectures* (MESA). This model focuses on the quality of link labels and the effectiveness of various link-selection strategies. By varying the link quality and using links that are not fully descriptive of the target goals, user behaviour is modelled. The common condition when the user is not sure of his goal or is not knowledgeable enough to assess the relevance of the link texts to the goal is also modelled.

SNIF-ACT (*Scent based Navigation and Information Foraging in the ACT Architecture*) developed by Pirolli and Fu (2003), predicts user-navigation behaviours when they perform unfamiliar information retrieval tasks. It also predicts that users would leave a site when the information scent falls below a threshold value. SNIF-ACT is based on an algorithm called Web User Flow by Information Scent

(WUFIS) developed by Chi *et al.* 2001. It combines both information retrieval and spreading activation techniques to arrive at the probabilities associated with each hyperlink that specify the proportion of users who will navigate through it.

All these models compute information scent by calculating the semantic similarity between the user goal and the hyperlink text. Although a web page contains much more information than just hyperlink text, the models ignore all of it. Actually, there has been very little research on the impact of such complex hypermedia environments on navigation in such web scenarios. However, extensive research from the fields of multimedia learning, memory, cognitive load and visual search give us an insight into the positive impact of multimodal representations, and potentially on web-navigation. We will present a study that examines the extent to which providing icons next to hyperlinks facilitate information retrieval.

Overview of research on impact of pictures

Mayer and Moreno (2003a, 2003b, 2004) demonstrated that meaningful learning that involves attending to important aspects of material, organizing it into a coherent structure, comprehending and understanding it and integrating with already known knowledge can happen better with content that has both visual and verbal format. Their theory is based on the dual-channel assumption of Paivio (1986), according to which humans possess separate channels for processing verbal and visual material, and the working memory theory of Baddeley (1998), which states that only a limited amount of processing can take place in any channel at any point of time. Of the seven principles that Mayer came up with, three are relevant to the web-scenario as well: coherence principle (present relevant pictures and avoid unnecessary information), spatial contiguity principle (present on-screen text nearer to the corresponding picture) and personalization principle (use words that are familiar to the user).

Larkin and Simon (1987) differentiate between diagrammatic and textual representations. They demonstrated that by preserving topological and spatial relations, diagrammatic representations make it easier to solve certain geometric problems. Scaife and Rogers (1996) proposed that graphical representations bring advantages for learning by reducing the amount of effort required to solve a problem and reducing ambiguity by limiting the range of inferences that can be drawn. It is known that students develop deeper understanding of material through self-explanations. Ainsworth and Loizou (2003) showed that this phenomenon is stronger when material with diagrams is presented. Sweller and Chandler (1994) showed that by physically integrating text and corresponding pictures, working memory load is reduced as it reduces redundancy and the effort in integrating information from various sources. Levie and Lentz (1982) have shown that information is remembered and retrieved better when accompanied by relevant pictures.

An eye tracking study by Namatame *et al.,* 2008 showed that for a directory-based search in a computer, fixation time and number of saccades are the least for labelled pictogram condition. This is also evident from the research on visual attention (Desimone and Duncan, 1995, Treisman and Galade, 1980), which demonstrated that any object significantly different from its surrounding objects along intensity, colour, orientation, and motion direction will be perceived by the human brain at very early stages of visual processing. Pictures, being the most salient objects on a web page, are thus attended to by the user before text. Although all this literature points to the positive influence pictures have on learning, memory and cognitive load, little effort has been put to study their impact in the domain of web-navigation.

Impact of graphics on web-navigation

Finding information on the web can at times be a daunting task given its vastness and non-linear nature. Further, recent research by Ruddle (2009) showed that even frequent visitors remember very little of the content and structure of a website. This further warrants the need to study factors affecting web-navigation behavior in detail. It has been found by Carnot *et al.,* (2001) that using a concept-map-based browser, which is a hierarchical organization of a set of concepts and relations between the concepts gives much more accurate search performance compared to a normal browser. The position of the navigation bar was found to significantly affect the mean time spent on a page (Petrie *et al.,* 2009).

Hinesley (2005) studied the impact of graphics in locating web page widgets by taking two versions of a page – one with original text intact and the other with all text replaced with character 'X' (greeked pages). She found that it was more difficult to find textual widgets on greeked pages than graphical widgets. Also, Hinesley and Blackmon (2008) investigated the interaction between location expectations and graphics with greeked pages. They found yet again that the performance detriment for graphical widgets was less when location expectations were violated. Hinesley thus claimed that it is graphics that play an important role in identifying web page widgets.

We scrutinized this claim in Karanam *et al.,* (2009) by examining the interaction of text and graphics completely. While Hinesley manipulated text with graphics intact in the first experiment, she manipulated graphics on greeked text in the second. We took four versions of each web page by systematically varying text and graphics. Our major result was that in the absence of graphics, having textual information was better than having no text. When there were no graphics, textual information significantly reduced the user's efforts in finding a widget. Thus, we argued that both text and graphics play an equally important role in a web page and it is important for cognitive models of web-navigation to take this into account.

Both Hinesley and Karanam restricted the tasks in their experiments to locating a widget on a web page. They did not involve any navigation or information retrieval. All that the user had to do was to locate the widget and click on it. What is the impact of graphics on navigation performance? Do graphics and text influence navigation for some information retrieval in the same way as they influence the task of locating a widget? Generally, we assume that users would visit a website with a predefined goal in mind. Thus, what would be the impact on their accuracy of finding the correct target page? This formed the starting point of our next study in which we wanted to investigate if providing meaningful icons next to hyperlinks would aid the user in navigating better. Would it help the user in finding their answers to their goals quicker? Van Oostendorp and Holzel (2005) for instance did find that presenting icons of the participants next to labels of messages on a bulletin board during collective problem solving had a positive effect on communication and performance. We will examine these questions by presenting participants with three different navigation structures – hyperlinks with icons, only hyperlinks and only icons. We will measure the influence of these three different structures on task completion times, number of clicks, task accuracy and user disorientation.

Method

Participants

Forty-five graduate and undergraduate students from Mahatma Gandhi Institute of Technology participated in this experiment. The mean age of the participants was 23. A pre-test was administered before the experiment on the content of the materials used. Three questions each on the country "Georgia" and "Musical Instruments" were given. Each question had four multiple choices, and the participants had to choose one of them as the answer. Correct answers were scored as 1 and wrong answers as 0. For each participant, total score was then calculated by taking the sum of individual scores of each question. All participants scored low on the final scores. (*M*=1.31, *SD*=1.05). It can be inferred that their prior knowledge of the subject was quite low.

Material and Apparatus

Website We used two topics for our websites: "Encyclopaedia of Georgia" (25 pages) and "Musical Instruments" (31 pages). Website on Georgia had content describing its geography, society, culture and religion. Website on Musical Instruments had content on different methods of classifying musical instruments – the Western System, the Hornbostel Sachs system and classification by Nationality.

Each website was 4 levels deep. Three versions of each website were created based on three different navigational styles: only hyperlink text (L), hyperlink text with icons (LI) and only icons (I), as shown in figure 1. For each hyperlink, at least five icons were collected, and two authors of this paper scored them for relevancy on a 7-point Likert scale. The icons with highest scores for relevancy were chosen as icons.

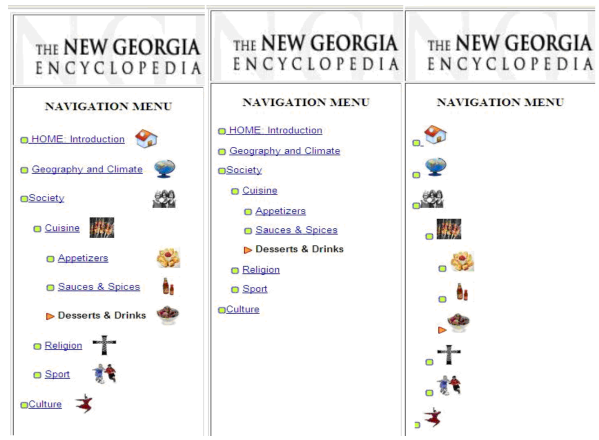

Figure 1: Three versions of a webpage with different navigational styles

Information Retrieval Tasks A total of eight user goals were generated: four for each website, one for each level.
An example user goal for Georgia website could be – *"A traditional Georgian confection made of caramelized nuts, usually walnuts, fried in honey, is served exclusively on New Year's Eve and Christmas. Name it"*.

Table1: Information Retrieval Tasks

"Georgia" Website	
Level	**Task**
1	The Georgian school system is divided into four stages, what are they?
2	Name two traditional Georgian feast songs.
3	A traditional Georgian confection made of caramelized nuts, usually walnuts, fried in honey, is served exclusively on New Year's Eve and Christmas. Name it.
4	Name three trees that cover the northern slope of Greater Caucasus Mountains?
"Musical Instruments Website	
Level	**Task**
1	According to Hornbostel Sachs system of Musical Instruments Classification, which mode of sound production do Idiophones use?
2	In the ancient system of musical instruments classification, xylophone belongs to which category of percussion instruments?
3	The Russian musical instrument – 'Ghusli' has similarities with other instruments in China, Japan and Baltic countries. What are they?

4	In Ancient system of classifying musical instruments, saxophone is categorized as woodwind instrument and not brass instrument. Why?

Measures Our dependent variables were mean task-completion time, number of clicks, task accuracy and disorientation.

Mean Task-Completion Time: The time taken by the user to finish the task was measured. There was a time limit of 5 minutes for each task.

Number of clicks: The number of clicks made by the user before reaching the target page.

Task Accuracy: Task accuracy was measured by scoring the answers given by users. A correct answer from correct page was scored 1. A wrong answer from correct page was scored 0.5. Wrong answers from wrong pages and answers beyond time limit were scored 0.

Disorientation: An objective measure of disorientation was used: It was computed using Smith (1996)'s L measure.

$$L = \sqrt{(N/S - 1)^2 + (R/N - 1)^2}$$

Where:
R = number of nodes required to finish the task successfully (thus, the number of nodes on the optimal path);
S = total number of nodes visited while searching;
N = number of different nodes visited while searching.

Design

We used a between-subjects design with fifteen participants in each group. Every participant answered all eight questions. The order of questions was randomized.

Figure 2: Layout presenting information retrieval tasks

Procedure

After the pre-test to check their prior knowledge about the domain, participants were presented with eight information retrieval tasks on the two different websites in random order. Their task was to locate the target page that contains the answer to these questions; type the answer in the box provided and proceed to the next task. Figure 2 shows the layout of the screen presenting information retrieval tasks. Participants first saw the task description on the screen and then the website was presented in a browser. The task description was always present in the top-left corner, in case the participant wished to read it again.

Results

We did not find a significant impact of condition on task accuracy (p>.05) and therefore we only report the results on other variables – task-completion time, clicks and disorientation.

We first did a mixed ANOVA analysis with our experimental condition as a between-subjects variable and Website as a within-subjects variable. We got a very strong main effect of website for all three of our measures but the interaction effect was not significant. We interpret that the website on musical instruments was relatively unfamiliar and new compared to the website on Georgia, to most of our participants and therefore they took more time, more clicks and were more disoriented in performing their tasks.

Task-Completion Time The number of time-outs in each of the three conditions was computed. The time-out percentages were: Hyperlinks with icons (7.5%), only hyperlinks (10%) and only icons (12.5%). We considered only the tasks for which participants gave correct answers for this analysis. A between-subjects one-way ANOVA with the three experimental conditions as independent variable and mean task completion time as dependent variable was conducted. Results show a main effect of condition ($F(2,36)$ =4.427, p<.05). Figure 3 shows the means plot.

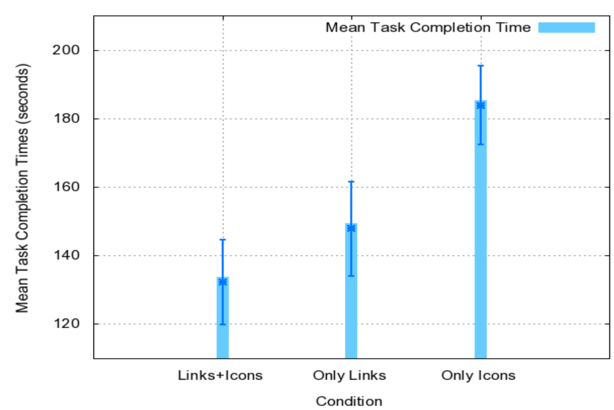

Figure 3: Mean Task-Completion Times

Post-hoc tests reveal significant differences between the groups – (LI)-(I) p<.01. That is, the task-completion times were significantly less when both links and icons were together when compared to only icons. The difference between (L) and (I) groups was not significant p>.05.

Number of Clicks A similar between-subjects one-way ANOVA with the three experimental conditions as independent variable and the number of clicks taken to find the target page with correct answer as dependent variable was conducted. The main effect of Condition is highly significant ($F(2,36) = 43.239$, $p < .001$). Figure 4 depicts this relationship for average number of clicks.

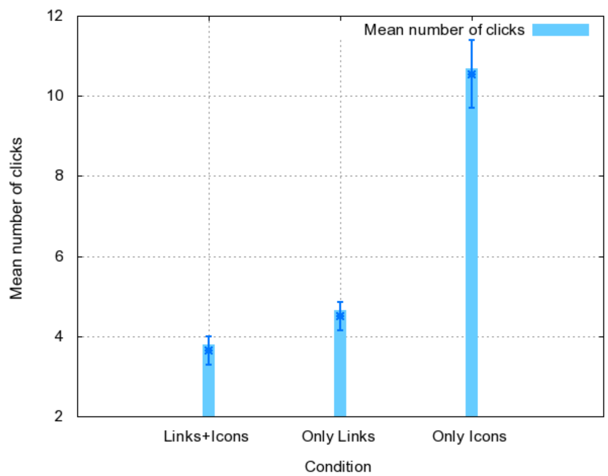

Figure 4: Mean number of clicks

Post-hoc tests reveal significant differences between (LI)-(I) $p < .05$ and (L)-(I) $p < .05$ groups. The number of clicks users took when there were both icons and hyperlink text was significantly less than when there were only icons. Similarly, the number of clicks users took to finish their tasks when there was only hyperlink text was also significantly less than when there were only icons. In other words, having only icons took the maximum number of clicks to finish the tasks, suggesting that only icon-based navigation might not be advisable. The difference in number of clicks between (LI) and (L) groups was not significant ($p > .05$).

Disorientation A between-subjects one-way ANOVA with the experimental condition as independent variable and mean objective disorientation measure as dependent variable was conducted. Results reveal a very significant main-effect of condition $F(2,36)=33.598$, $p < .001$.

Post-hoc tests reveal significant differences between the pairs – (LI)-(I) $p < .05$ and (L)-(I) $p < .05$. Having only icons induced the maximum disorientation in users. Users deviated from the optimum path the most under this condition. They took the maximum number of de-tours and returned to the same page visited earlier frequently. Their disorientation significantly reduced when icons were replaced with corresponding hyperlink text. Users could navigate much better compared to the condition when there were only icons. Further, when both hyperlink text and icons were provided, there was even more significant decrease in disorientation. Figure 5 shows the graph.

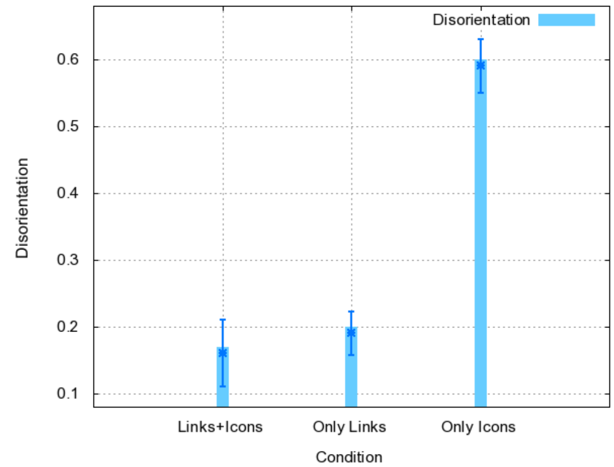

Figure 5: Disorientation

Discussion

In this research, we focused on the impact of providing icons next to hyperlink text in the main navigation menu of a page on user's search and information retrieval performance. Overall, we found that providing icons next to hyperlink text is very helpful for users in reducing the amount of time they take to finish their task, number of clicks they take to reach their target page and in optimizing the path they take to the target page.

It has been found that users take significantly less time when both hyperlink text and corresponding icons are provided compared to the conditions when only hyperlink text or only icons are present. Number of clicks also shows a similar pattern: Users take significantly less number of clicks to find their target pages with icons and hyperlink text present when compared with the pages with only hyperlinks or only icons. Users were disoriented the most when there were only icons present. It was hard to navigate with only icons. This phenomenon of disorientation decreased significantly when there was only hyperlink text and further decrease was effectuated by placing meaningful icons next to the text.

In general, our results support the positive impact of pictures found elsewhere in other domains like multimedia learning, cognitive load and visual search. We have shown that pictures / graphical information together with textual information play an important role in improving overall user-performance in not only locating their target on a web page but also navigating through a website and finding their target pages.

One practical implication of this study is to use meaningful icons next to hyperlink text to improve the overall usability of a website. Also, on basis of this study and our previous study (Karanam *et al.,* 2009), we argue strongly for inclusion of pictorial and graphical information in cognitive models of web-navigation. We have already shown that semantic information derived from pictures can be included into CoLiDeS (Karanam *et al.,* 2009). We also demonstrated that such a model would predict the correct hyperlink more frequently and more accurately.

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