A Comparative Experiment of the Effect of Visualization on User Performance of Information Systems

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ABSTRACT
This study investigated the effect of visualization on user performance of information systems by comparing an information visualization system with a textual based system. The results indicate that the difference is significant in terms of task completion time, user satisfaction, and total number of mouse clicks.

Keywords
User studies, searching, information visualization, user performance

INTRODUCTION
Visualization is an important information retrieval (IR) technique (Chen, 2004) in the field of IR and human-computer interaction. Researchers have investigated if and how visualization features can improve the effectiveness and usability of information systems (Yuan & Belkin, 2010), have studied the impact of users’ cognitive styles on user performance and usability of InfoVis systems (Yuan et al., 2011), and have tested the usability and the user interaction behavior of several information visualization (InfoVis) systems, including VIBE (Koshman, 2004), MetaCrystal (Spoerri, 2006), and CiteSpace (Allendoerfer et al, 2005). But we are not clear how users perform differently in different information visualization (InfoVis) systems, in comparison to generic text IR systems. This research hypothesized that a system with graphical network visualization results display will lead to better user performance in completing search tasks than one with textual retrieval results display. An InfoVis system called “CiteSpace” (CS) (Chen, 2004) (see Figure 1) and a generic text IR system called “ISI Web of Science” (WoS) (see Figure 2) were compared in the experiment. The CS system was originally created to identify intellectual turning points by constructing co-citation networks among highly cited articles. The visualization graph of the CS system (version 2.2.R1) is composed of nine nodes and lines connecting the nodes. Correspondingly, nine visualization graphs were designed to represent the patterns of scientific literatures. The WoS system provides researchers with quick and powerful access to the world’s leading citation databases. It displays the retrieved results in a ranked list.

Figure1. Resulting graph of the CiteSpace system: node type: Country

Figure 2. The search screen of the Web of Science system

METHODOLOGY
Experimental Design
We conducted a between-subjects user experiment, in which half of the subjects searched tasks using the CS system, while the other half used the WoS system. Subjects completed a cognitive test called Extended CSA-WA test (Peterson et al, 2003a) and then they were given a tutorial of the system (CS or WoS). After the tutorial, subjects did two training tasks of each task type. Before each task subjects filled out a pre-task questionnaire. Subjects were given up to 10 minutes to conduct each task. After completing each task, subjects completed a post-task questionnaire. After subjects finished all the tasks, they were asked to complete an exit questionnaire. Each subject performed eight tasks using the assigned system. The tasks were categorized into two groups: aspectual and analytical search tasks. Aspectual tasks required the subject to identify as many...
different aspects as possible for a given topic and save appropriate resources that cover all distinct aspects of that topic (Dumais & Belkin, 2005). For example, “List all the keywords that appear frequently with the word “life.”” Analytical search tasks were defined as tasks that need more goal-oriented and systematic analytical strategies (Marchionini, 1995). For instance, “find the author who has the most collaboration with Edwards HGM.” Tasks were randomly assigned using a Latin-Square design. Thirty-two graduate students from UAlbany participated in the experiment. The interaction between the subject and the system was recorded by TechSmith Morae 2.1.

**Dataset**

The dataset was constructed by searching the topic “life on Mars”, language “English”, document type “Articles”, and published between the years of “2000-2009” in the WoS system. In total, 857 records were retrieved from the WoS system. All of these documents were saved in a database, which was used in the experiment of this study.

**RESULTS**

The measures of user performance were the time taken to complete the task (collected from the logging software), the subjects’ satisfaction with their results (collected from the post-task questionnaire), the correctness of the results (determined by the investigator) (incorrect, correct), the total number of mouse clicks (collected from the logging software), and aspectual recall (the ratio of aspects of the search topic identified by the subject, to the total number of aspects of the topic (Dumais & Belkin, 2005)).

<table>
<thead>
<tr>
<th>Performance Measures</th>
<th>Systems:</th>
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<tbody>
<tr>
<td></td>
<td>CS</td>
<td>WoS</td>
</tr>
<tr>
<td>Time (mins)</td>
<td>3.70 (2.08)**</td>
<td>7.05 (3.89)</td>
</tr>
<tr>
<td>Result satisfaction (1-7)</td>
<td>5.16 (1.88)**</td>
<td>4.30 (2.10)</td>
</tr>
<tr>
<td>Result correctness (0-1) (analytical search task)</td>
<td>0.70 (0.46)</td>
<td>0.56 (0.50)</td>
</tr>
<tr>
<td>Number of mouse clicks</td>
<td>38.87 (24.71)**</td>
<td>58.64 (47.52)</td>
</tr>
<tr>
<td>Aspectual recall (aspectual task)</td>
<td>0.56 (0.37)</td>
<td>0.50 (0.41)</td>
</tr>
</tbody>
</table>

**Table 1. Performance Measure (*significant at <.01 level*)**

In Table 1, ANOVA results indicated that subjects using the CS system spent significantly less time ($M = 3.70$, $SD = 2.08$) than subjects using the WoS system ($M = 7.05$, $SD = 3.89$), $F(1,254)$ = 73.538, $p = 0.00$. Wilcoxon signed-rank test results showed that subjects felt significantly more satisfied with their results using the CS system than the WoS system, $Z = -3.731$, $p = 0.00$. ANOVA results indicated that subjects using the CS system had significantly fewer mouse clicks than those using the WoS system, $F(1,254) = 17.448$, $p = 0.00$.

**DISCUSSION AND CONCLUSIONS**

The results of the experiment demonstrated substantial and significant advantages to the InfoVis system named CiteSpace in terms of user performance.

Subjects using the CS system spent significantly less time in completing the tasks than those using the WoS system. Similar results were reported in (Osdin et al, 2002) that hierarchical clustering and summarization visualization techniques significantly helped the users to quickly find the relevant documents than the baseline textual system. Subjects using the CS system had significantly fewer mouse clicks than those using the WoS system. This indicates that graphical visualization can reduce the interaction between the user and the system, thus in turn improve users’ search performance. It further confirms the findings from (Yuan & Belkin, 2010) that a system relating different visualization techniques to tasks can improve user performance by reducing the interaction between the user and the system. Subjects using the CS system felt significantly more satisfied with the results than those using the WoS system. (Osdin et al, 2002) reported similar though not significant results in user satisfaction in favor of the visualization system.

The results provide implications for IR system design. For example, it may be helpful to organize the domain knowledge information or other general information in visualization graphs, which can show the pattern of such information and provide contextual information concerning such patterns.

**REFERENCES**


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3. This study has been approved by the IRB at the University at Albany.