Do flashy interfaces help? Comparing learning efficiency of different interface types based on cognitive load theory

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Abstract

The purpose of this study was to examine the efficiency of three different interface types on Web-based instruction: a text-based interface, a graphical interface and a metaphorical interface. In order to determine which interface type reduces cognitive load, learning efficiency scores formulated with performance scores and mental effort levels from 50 undergraduate students were compared. Results indicated there was no difference among the groups in terms of learning efficiency. Based on the results, implications for instructional designers are presented.

Introduction

In Web-based instruction, the user interface is a communication point between an instructional unit and a learner. While instructional designers are making efforts to develop effective and aesthetically pleasing interfaces, designing a usable and appealing interface, in fact, is still challenging for instructional designers (Metros & Hedberg, 2002; Chalmers, 2003). The importance of the user interface in Web-based instruction has been emphasized by many researchers: attracting learners’ attention (Hron, 1998; Szabo & Kanuka, 1998), facilitating communication between a learning domain and learners (Metros & Hedberg, 2002; Parizotto-Ribeiro & Hammond, 2005), and reducing cognitive load (Chalmers, 2003; Haag & Snetsigner, 1993; Hannafin & Hooper, 1989).

Cognitive load has been measured by a learner’s difficulty level or time to completion. In addition, a learning efficiency metric has been used to quantify the efficiency of instruction (e.g., Clark, Nguyen & Sweller, 2005; Tuovinen & Paas, 2004). The efficiency score is calculated by performance and mental effort, meaning a high efficiency condition occurs when performance is higher and effort is less (Tuovinen & Paas, 2004). Based on cognitive load theory, researchers and practitioners have proposed interface design guidelines (e.g., Norman, 1998; Shneiderman & Plaisant, 2005; Swan, 2004). The following guidelines have been proposed to reduce cognitive load: (a) provide informative system feedback (Norman, 1998; Shneiderman & Plaisant, 2005); (b) use intuitive elements (Norman, 1998); (c) provide directions (Swan, 2004); (d) avoid extraneous objects (Briswiss, 1998; Swan, 2004); (e) use organizational strategies (Chalmers, 2003; Norman, 1998); (f) provide visual elements (Swan, 2004); and (g) enhance learner’s autonomy (Shneiderman & Plaisant, 2005; Swan, 2004).

A cognitive load perspective is used to evaluate how well the user interface supports the cognitive processes involved in the task (Plass, 1998), and the goal of the approach is the interface should impose as minimal as possible a cognitive load on the learner (Stoney & Wild, 1998). In a graphical user interface, graphical elements have been used to make Web pages pleasing in order to get users’ attention. In addition, the elements use metaphors to assist users to intuitively navigate through a system (Lang, 2003). While menu buttons or images employ different metaphors to reflect each function in a graphical interface, metaphorical interface design has been proposed to connect whole-screen or system-environment to the instructional content (Haag & Snetsigner, 1993). A metaphorical interface design focuses on creating an interactive environment that reflects the learning content in order to provide learners with instructional cues. Metaphor plays a significant role in scaffolding the learner to intuitively interact with multimedia resources (Hron, 1998; Lang, 2003), because it helps the learner structure links between theme and content (Cates, 1996; Hron, 1998). Like graphical user interfaces, metaphorical interfaces can also decrease cognitive load and disorientation (Hron, 1998). However, there is little empirical evidence for the benefits of graphical or metaphorical interface regarding learning outcomes and cognitive load. Therefore, the purpose of this study was to examine if the interface of Web-based instruction affects learners’ performance and cognitive load with three different interface types: a text-based interface, a graphical interface and a metaphorical interface.
Methodology

Three different types of user interface were implemented with the same content on Cognitive Information Processing theory. The process of developing these three instructional units consisted of two layers: content layer and interface layer (Beriswill, 1998). First, in the content layer, learning materials, which were presented in the form of various media types, such as images and interactive sample experiments, were developed to provide the learners with cohesive learning. The same learning materials, including informational graphics and interactions, were used in all three instructional units. Next, in the interface layer, design guidelines based on various studies were applied to implement three different user interfaces as shown in Figures 1, 2 and 3. These instructional units provided different navigation designs, but the basic mechanism was same in that the units had both linear and user-controlled navigation.

**Figure 1.** Text-based interface implemented with typography and basic design guideline (Lee & Boling, 1999)

**Figure 2.** Graphical interface using five guidelines: unity, proportion, homogeneity, balance, rhythm (Parizotto-Ribeiro, Hammond, Mansano & Cziulik, 2004)
Figure 3. Metaphorical interface with primary and secondary metaphor (e.g., Cates, 1994; Lang, 2003; Hron, 1998)

Various data were collected from fifty undergraduate students: a pretest score, time to complete the instruction, a difficulty level of the instruction, a posttest score and responses for the attitude survey adapted from the studies of Ciavarelli (2003) and Moreno and Valdez (2005). The difficulty level, which can be called mental effort rating, was rated by the question adapted from Kalyuga and Sweller (2005): “Please indicate how difficult the test you just took was by clicking on the appropriate degree of difficulty.” The participants had to select one of the nine degrees ranging from extremely easy to extremely difficult. Cognitive load was measured with the time to completion, the mental effort for instruction, and the responses to the questions in the attitude survey. The mental effort and score difference between pretest and posttest were used to quantify learning efficiency.

Results

First, pretest scores and posttest scores were analyzed with one-between, one-within mixed analysis of variance (ANOVA). There was no difference of learning performance regarding interface types while all instructions were effective in increasing test scores ($F=2.356, p=.109$).

Second, three variables were used to compare cognitive load in the three interface groups: (a) mental effort for the instruction, (b) time to completion for the instruction and (c) attitude survey data. The mental effort scores were obtained when students rated the degree of difficulty on a scale of 1 to 9. The analysis of variable (ANOVA) revealed that there was no difference among groups in terms of mental efforts and time to completion (Time to completion: $F=.123, p=.884$; mental efforts: $F=.609, p=.549$).

Third, the performance score and mental effort for the instruction were used to quantify learning efficiency. This analysis followed Paas, Tuovinen, van Merrienboer and Darabi (2005) process for measuring efficiency. Regarding the performance score, differences between the pretest and posttest scores were used in the learning efficiency formula because the pretest scores among groups were different. The two data were standardized since they were scored with different scale, and learning efficiency score was computed by the formula as follows:

$$E = \frac{P - M_E}{\sqrt{2}} \quad (E = \text{efficiency}, \ P = \text{performance}, \ M_E = \text{mental effort})$$

The graphical interface had the highest efficiency score ($E=.1240$) as compared to the text-based interface ($E=-.0882$) and the metaphorical interface ($E=-.0052$, but the analysis of variance (ANOVA) revealed that there was no difference among groups in terms of efficiency scores ($F =.101, p=.904$).

Finally, the answers to the six questions in the attitude survey regarding cognitive load showed that there was no difference other than the question number 4 asking if the interface captured learners’ attention ($F=8.400, p=.001$). The mean scores and standard deviations presented in Table 1.
Table 1
The mean scores of the attitude survey questions

<table>
<thead>
<tr>
<th>Questions</th>
<th>Text-based</th>
<th>Graphical</th>
<th>Metaphorical</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. It took too long to complete.</td>
<td>3.62 (1.12)*</td>
<td>3.38 (1.39)*</td>
<td>3.63 (0.60)*</td>
</tr>
<tr>
<td>2. There is too much information on the pages.</td>
<td>3.69 (1.03)*</td>
<td>3.00 (1.41)*</td>
<td>3.42 (0.90)*</td>
</tr>
<tr>
<td>3. Graphics or other elements on the pages are distracting.</td>
<td>4.54 (0.52)*</td>
<td>4.38 (0.51)*</td>
<td>4.26 (0.45)*</td>
</tr>
<tr>
<td>4. Elements on the page, such as heading and graphics, focused my attention.</td>
<td>2.77 (1.01)</td>
<td>3.15 (0.90)</td>
<td>4.00 (0.75)</td>
</tr>
<tr>
<td>5. The information layout and locations are consistent throughout the instruction.</td>
<td>4.08 (0.95)</td>
<td>3.69 (0.75)</td>
<td>4.05 (0.78)</td>
</tr>
<tr>
<td>6. The menu is consistent throughout the instruction.</td>
<td>4.15 (0.99)</td>
<td>3.77 (0.84)</td>
<td>4.16 (0.38)</td>
</tr>
</tbody>
</table>

* Standard deviations are given in parentheses
* The three values of the question 1, 2 and 3 were recoded so that higher number represents positive perception.

Discussion and conclusion

This study was designed to explore the effects of interface on Web-based instruction. It should be noted that all interface types applied design guidelines based on the previous research and convention. The hypothesis was that a metaphorical interface would be the most effective and efficient interface, but the results revealed that there was no significant difference among groups in terms of performance or cognitive load. The implications of this research are informative to instructional designers as they develop Web-based instruction. First, this study revealed that interface did not exert any influence on learning performance, so instructional designers and developers should focus on creating meaningful instruction with interactions because the learners depend on these elements than on the interface. Second, interface did not affect learners’ cognitive load and learning efficiency. An aesthetically pleasing interface did not make any difference in cognitive load. It implies that time-consuming works of making attractive interface may not be worth the investment.

Even though the results indicated that both graphical interface and metaphorical interface were not beneficial to learning, the study requires further investigation with different assessment, domain and learning materials. For example, the assessment in this study was focused more on declarative knowledge, so a different assessment which includes more procedural or application knowledge might produce different results. A concrete domain instead of the abstract domain that was used in this study could be examined with different interface types. In addition, one type of interface with different types of learning materials could investigate to determine which combination of interface type and learning material is more effective.

References


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