A Comparison of Three Forms of Facilitation in Hypermedia Learning With Text and Diagrams

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Abstract. An ongoing experiment tests the effectiveness of three forms of facilitation in hypermedia learning with text and diagrams: 1) *signaling* key terms, 2) *prompted referencing* of diagrammatic representations, and 3) *integration scaffolding* (i.e., assistance in locating corresponding components within diagrams). Preliminary eye-tracking results indicate that the integration scaffolding condition led to more fixations on relevant components within the diagram and more overall time spent fixating on relevant components within the diagrams, compared to a control condition. Learning outcome measures suggest a beneficial impact of the integration scaffolding condition on participants' understanding of the human circulatory system. However, with the current sample of 34 participants, the difference between the integration scaffolding condition and the control condition on the learning measure has not yet reached statistical significance. Implications based upon the cognitive load theoretical framework and theoretical models of text-picture integration are discussed.

Keywords: Hypermedia; cognitive load theory; scaffolding; eye-tracking.

Introduction

According to Sweller, van Merrienboer, & Paas (1998), extraneous cognitive load is associated with processes which can be detrimental to the comprehension of text and graphics and germane load is associated with essential, or useful to learning, processing. Much research has been principally aimed at reducing extraneous cognitive load in order to free resources for germane processing.

One method intended to reduce extraneous load, prompting textual and graphical coordination (*prompted referencing*), has shown some promise (Bodemer & Faust, 2006). However, results from this set of experiments suggested that learners, especially those with low prior knowledge, demonstrated difficulty in successfully relating the two representations when prompted to do so. Some empirical research has demonstrated beneficial effects of attention guidance methods (referred to herein as *integration scaffolding*), such as color-coding corresponding elements within text and diagram, to overcome this difficulty (Kalyuga et al., 1999; Ozcelik et al., 2009; Witherspoon & Azevedo, 2008). However, other work indicates that similar methods can actually lead to increased subjective ratings of cognitive load and no differences in learning outcomes (Seufert & Brunken, 2006). Finally, Mayer and colleagues have supplied evidence for the beneficial impact of *signaling* learners to attend to particular information (Harp & Mayer, 1998)

Currently, it is unclear which particular instructional design manipulation would prove most effective in reducing extraneous load and facilitating learning with text and diagrams. Furthermore, none of the previous work exploring *prompted referencing*, *integration scaffolding*, or *signaling* effects on the comprehension of text and graphics has been applied within the context of hypermedia, rather than multimedia, learning (see Gerjets et al., 2009). The current experiment compared three forms of facilitation of hypermedia learning (prompted referencing, integration scaffolding, and signaling) against a control condition which provided no aids for coordinating text and diagram. The work employs a mixed-methodology approach, collecting product data in the form of pretest-posttest learning measures and capturing process data in the form of eye-gaze data. We hypothesized that the integration scaffolding condition would show highest learning outcomes and that eye-tracking measures from this condition would indicate reduced search time and elevated numbers of fixations and fixation time on relevant areas of the diagrams accompanying text (Ozcelik et al., 2009).

Method

Learning conditions

Participants were randomly assigned to one of four learning conditions: 1) the *Control* group learned about the human circulatory system using a hypermedia learning environment comprising 12 total pages of text and diagrams (12 unique texts and 3 unique diagrams); 2) the *Integration scaffolding* group used the same environment to learn, with the addition of integration scaffolding hyperlinks intended to encourage the visual inspection of diagrams at these points and to reduce search time within the diagrams for corresponding elements (see Witherspoon & Azevedo, 2008), 3) the *Signaling* group used the same environment to learn, with the addition of highlighted key terms within the textual representation, corresponding to the terms used for the integration scaffolding hyperlinks in the previous condition, intended to direct attention to especially central terms within the text; and 4) the *Prompted referencing* group used the same environment to learn as the control condition, with the addition of textual prompts to reference the diagram, at the same points where integration scaffolds and highlighted key terms were used in the two previous conditions, intended to encourage the visual inspection of diagrams at these points.

Procedure

Sixty-five college undergraduates (71% females, mean age 19.9) were first given five minutes to complete a diagram interpretation pretest, followed by 10 minutes to complete a 24-item, four foil multiple choice pretest. The learner was then given 20 minutes to learn about the circulatory system using the hypermedia environment associated with his or her condition. During the learning session, participants' eye-gaze information was recorded using the Tobii T60 eye-tracker and Tobii Studio software package. Finally, each participant was given 15 minutes to complete the posttest measures (identical to pretest).

Results

Learning outcomes

An ANCOVA was run on the current sample (N = 65) to determine the effect of condition on participants' post-task understanding, with pretest score as the covariate. Results indicated no significant difference among conditions, but the integration scaffolding condition did obtain the highest scores (See Table 1).

Eye-gaze data

Analyses of variance run on several measures of eye-tracking data indicated that learners in the integration scaffolding condition had significantly more fixations on relevant areas of the diagrams[1] compared to the control condition and spent proportionally more time fixating on relevant areas of the diagrams (vs. irrelevant areas) compared to the control condition (See Table 1).

Table 1: Mean Learning Outcomes and Eye-tracking Data, by Learning Condition.

Measure	Learning Condition					
	Control	Signalling	Prompted Referencing	Integration Scaffolding	F	p
Multiple choice posttest (adjusted)	62.7%	60.2%	60.0%	69.9%	1.775	.162
# Relevant diagram fixations	23.50 [b]	37.37 [a]	42.25 [a]	78.50	3.56	.027
% Relevant diagram fixation time	9.5% [b]	10.8% [b]	19.5%	21.2%	6.66	.002

[a] LSD Post-Hoc comparisons indicated significant difference from the integration scaffolding condition at the .05 level.
[b] LSD Post-Hoc comparisons indicated significant difference from the integration scaffolding condition at the .01 level.

[1] *Relevant* refers to areas in respective diagrams which are relevant to the particular page of content. *Irrelevant* refers to any other area within the diagram.

Discussion

According to Mayer (2005) and Schnotz (2005), the development of a coherent mental representation of multimedia information involves simultaneously processing verbal and pictorial information in working memory in order to integrate the verbal and pictorial information into a complete mental model. The integration scaffolding technique presumably facilitates this process through reducing search time for corresponding elements between text and diagrams. That is, as learners are reading the text and processing information concerning the function and behavior of described components, they are able to rapidly switch from the text to relevant areas of the diagrams to obtain structural (depictive) information about these same components. Preliminary results from this experiment, including product (learning outcomes) and process (eye-gaze) data support this hypothesis. The eye-tracking data indicated greater frequency of fixations on relevant elements within the diagrams and increased total fixation time on relevant components in the diagram, proportionate to fixation time on irrelevant areas. By using proportional time spent fixating on relevant areas, the reverse can also be said. Specifically, the integration scaffolding technique reduces fixation time on irrelevant areas of the diagrams. This indicates, as has been shown in previous research on the effect of color-coding (Ozcelik et al., 2009), that the integration scaffolding technique reduces search time, thereby reducing extraneous cognitive load. The reduction in extraneous load appears to be accompanied by an increase in germane processing, as suggested by the trend suggesting superior performance by the integration scaffolding condition on posttest measures of learning. With the addition of more data points and statistical power, we expect this trend favoring the integration scaffolding condition to reach statistical significance and more clear results concerning the remaining two experimental conditions to be brought to light.

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