The effects of lesson screen background color on declarative and structural knowledge

by

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Abstract

This experimental investigation replicates previous investigations of the effects of left margin screen background color hue to signal lesson sections on declarative knowledge and extends those investigations by adding a measure of structural knowledge. Participants (*N* = 80) were randomly assigned to receive one of four computer-based lesson treatments that consisted of color or no color lessons crossed with color or no color structural knowledge and declarative knowledge posttests. A disordinal interaction was observed, lesson color had a significant positive effect on the structural knowledge posttest (effect size *d* = 0.41) but had a non-significant effect on the declarative knowledge posttest (*d* = -0.17). A memory context effect was not observed. Designers of screen-based instructional materials should consider the commonsense notion that screen background color hues that signal lesson sections will tend to more strongly overlay the lesson organization onto the learner's memory organization.

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One common screen design convention is to use a navigation area, or panel, that is distinctly colored along the left column margin of the screen to set it apart from the rest of the screen (Nielsen, 2000). This navigation panel is commonly used on web sites, knowledge management systems, and web-based instructional modules to give the user a sense of where he/she is within the broader organizational framework. It can serve other useful functions as well, such as setting the tone of each section, improving the appearance and organization of the screen, and displaying the navigation hyperlinks. This investigation considers the effects on memory of using different *background* hues in the left margin area to signal lesson sections.

In this investigation, we make a distinction between foreground color that signals important lesson content and background color that provides context to situate that content. For example, the term "aorta" in a text passage on the human circulatory system can be highlighted with a red hue at every occurrence of the term and in accompanying diagrams. Using foreground color in this way signals this concept's multiple presences within a screen and across multiple screens. This type of foreground color coding may utilize an innate attentional ability of humans and other species to combine dispersed information instances at an implicit level into a single set (Halberda, Sires, & Feigenson, 2006).

Most research on screen color has considered the instructional effects of foreground color to direct attention to associated content instances or to highlight important content, but there is less research on the effects of background screen color.

Though results are mixed, foreground color in instructional texts and visuals yields small to moderate positive effects on recall and comprehension of the color-tagged item specific content (Dwyer & Moore, 1994, 2001; Lamberski & Dwyer, 1981, 1983; Misanchuk, 1992; Pett & Wilson, 1996). However there is likely to be a difference between the effects of foreground color-coding strategies that typically have item-specific effects (but could have relational effects if so designed), compared to background color-coding strategies that tend to have broader relational effects (Poindexter & Clariana, 2006; Smith, 1988).

In the memory literature, a background color band like this in a screen display is classified as an incidental context variable (Smith & Vela, 2001) that is *extra-item* since it is not a direct part of the to-be-remembered content, *local* on a continuum of local to global, and *nonverbal* (Mori & Graf, 1996). This screen design approach cuts across several related theoretical approaches regarding the effects of context on learning (e.g., Baddeley, 1999). Tulving and Thomson's (1973) *encoding specificity principle* would predict that background lesson color supports posttest retrieval of lesson content when the posttest color matches the lesson color. As a side note, over seventy years ago Dulsky (1935) reported that lesson-posttest color matching did have this effect and further, that intentionally mismatching lesson and posttest background colors actually suppressed recall of lesson content (recognition was not considered). Thus not only can matching lesson and posttest color support posttest retrieval; there is some evidence that mismatching color can hinder posttest performance.

When considering memory-context effects, it is also valuable to consider the nature of the memory task. Paired-associate learning investigations have shown that global context cues, such as a colored left margin, typically have a significant effect on *recall* tasks but that context cues have no substantive impact on *recognition* tasks (Godden & Baddeley, 1980; Jacoby, 1974, 1983; Kintsch, 1970; McCormack, 1972; Smith, Glenberg, & Bjork, 1978; Weiss & Margolius, 1954). The *outshining hypothesis* (Smith, 1994) proposes that lesson content and lesson context information are both encoded during the lesson task, but the context memory does not participate during posttest retrieval if the content memory 'outshines' the context memory activation level. Because a recognition posttest item contains more pertinent information than its complementary recall item (e.g., the item prompt *and* the correct response), a recognition posttest item would provide a stronger retrieval cue (e.g., more overlap between the item and the memory trace) so the content memory outshines the context memory (Smith, 1988). Thus the outshining hypothesis would predict that background color would more likely affect recall than recognition.

Several previous investigations have considered the effects of left margin background color hue on recognition and cued recall measures of declarative knowledge with mixed results (Clariana, 2004a, 2004b; Prestera, 2003; Prestera, Clariana, & Peck, 2005). Contrary to the outshining hypothesis, Clariana (2004a) found that lesson-test color matching had no effect on a cued recall posttest (e.g., using fill in the blank factual items) but significantly inhibited performance on a recognition posttest (i.e., using multiple choice factual items). Similarly, Prestera *et al.* (2005) reported that lesson-posttest color matching relative to intentional color mismatching had a non-significant (but negative) effect for both cued recall and recognition paraphrased items (d = -0.31 and d = -0.28, *ns*). These two studies suggest that lesson background color may have a *negative* rather than positive effect on declarative knowledge outcomes, especially for recognition posttests. Again, contrary to the outshining hypothesis, Prestera (2003) reported no significant differences for lesson color for cued recall posttest measures (i.e., fill in the blank factual and conceptual items), but posttest memory of the lesson color scheme was significantly better for females relative to males. Similarly, Clariana (2004b) reported that the lesson color scheme was significantly better remembered at posttest under recognition tasks relative to cued recall. These studies suggest that background color does not conform to the outshining hypothesis, at least as it relates to its effects on declarative knowledge.

So far, our working premise is that extra-item local nonverbal context elements, at least in this case with colored left margins, have an effect on the organization of participant's knowledge. Simply stated, when color is present on the screen, the resulting memory organization is different than when color is not present. In a review of context dependent memory, Smith (1988) states that previous studies have consistently shown that "environmental context information can act as an organization cue" (p. 26). Such organization or structure is the essence of knowledge (Anderson, 1984). Knowledge structure (also called structural knowledge) refers to how information elements are organized in memory and may be a facet of declarative knowledge (Mitchell & Chi, 1984) but Jonassen, Beissner, and Yacci (1993) go even further to hold that structural knowledge is a distinct type of knowledge. An individual's structural knowledge has an effect on other measures of learning that may be positive, neutral, or negative depending on how the memory organization relates to the other measures of learning. For example, more coherent knowledge structure is believed to be important for higher-order learning outcomes such as forming inferences, comprehension, and problem solving (Jonassen & Wang, 1992) but has unanticipated and sometimes negative effects on lower-order learning outcomes (Clariana & Marker, 2007).Thus, besides the possible effects of background color hues on declarative knowledge, we are even more interested in context effects on knowledge structure, specifically the organization of the lesson content in the participant's memory.

How can memory organization that might result from the lesson topic color scheme be measured? Clariana and Marker (2007) used a computer-based sorting task called *ALA-Mapper* to measure the effects of learner-generated lesson headings on knowledge structure. They proposed that memory of related lesson topics will be more often clustered together for participants who generate lesson headings relative to those who do not. Their results showed that the headings group outperformed the no headings control group on the structural knowledge sorting task, $d = 0.32$, but, unexpectedly, the headings group scored lower than the control group on the declarative knowledge cued recall fact-level posttest, $d = -0.35$, a disordinal interaction.

This present investigation replicates our previous research on the effects of lesson background color on recognition and cued recall declarative knowledge, and extends those studies by including the posttest measure of structural knowledge from Clariana and Marker (2007). In addition, color is included or not at posttest in order to consider a lesson-posttest color 'matching' alternate hypothesis. Based on the findings of our previous investigations of screen background color, we propose that a disordinal interaction like that observed by Clariana and Marker (2007) will occur. Specifically, color-associated lesson terms will be more often clustered together relative to the no color lesson as measured by the structural knowledge sorting task posttest and lesson color relative to no lesson color will have a small negative effect (or no effect) on a declarative knowledge posttest using recognition and cued recall formats. Effect sizes for the recognition and cued recall posttest will be provided to further account for any observed differences. Though declarative and structural knowledge outcomes are both of interest, we are especially interested in the effects of left margin background color on structural knowledge.

Method

Participants

The participants (*N* = 80) in this investigation were graduate student volunteers from the Instructional Design program at a northeastern university. Students in five sections of a course on assessing learning outcomes were randomly assigned to one of the study treatments as part of a required class project. All of the students agreed to allow their data from this project to be used in this investigation. About 55% of the participants are full time employees of local corporations and businesses and 44% are school teachers; most are female (75%) and all but one are in their mid-thirties.

Materials

The material to be learned consisted of a computer-based vocabulary review (the same lesson materials and posttest used by Clariana, 2004a) that covered 36 important instructional design terms. The terms were arranged in the lesson in a logical order based on the order of first occurrence in the introductory instructional design textbook that was used by these participants in a prerequisite course (Dick & Carey, 1996). The vocabulary terms were grouped into five sections each with a color hue including: *Overview* – items

1 through 7 (orange, hexadecimal RGB value #FF6531), *Instructional Analysis* – items 8 through 16 (yellow, #FFFF00), *Learner Analysis* – items 17 through 22 (blue, #0030FF), *Objectives and Tests* – items 23 through 27 (green, #00FF00), and *Development and Evaluation* – items 28 through 36 (purple, #9C0063). These color hues are not customarily associated with these terms or sections; the no color treatments used white (#FFFFFF) throughout in place of these hues.

Similar to the design of many web pages, each color was displayed on the screen as a solid column 3.5 cm wide along the left margin. Participants were not explicitly informed that the color hues signaled related groups of lesson concepts although it was probably obvious after the first section change of color hue. The remainder of the screen (the right side) was white and about 15 cm wide. This white area served as the main text display area.

This investigation used the same content and approach as Clariana (2004a). The lesson provided the 36 technical vocabulary terms with one item per screen. First, the definition was provided along with four possible terms. Participants were prompted to ‘click’ on one of the four terms provided. After a correct response, the learner was told "Right!!", and the correct alternative was highlighted in blue with the message “Here is the answer”. On error, the learner was told, "No, look above", as the correct answer was highlighted in blue with the message “Here is the answer”. Participants could not go back to redo previous screens. Though this lesson approach lacks pizzazz, it is instructionally effective and efficient for reviewing this type of factual lesson content (Clariana, 2004a).

Declarative Knowledge Posttest

Declarative knowledge (Anderson, 1995) is conceptual knowledge such as labels, names, facts, and lists often learned by rote that can be critically important in many situations. The declarative knowledge posttests consisted of the same 36 items as the lesson, with 18 cued recall items (fill in the blank by typing in the term) and 18 recognition items (multiple choice with four alternatives). To control for possible posttest item order effects, the declarative knowledge posttest was designed so that about half of the participants received posttest items that followed the lesson order and the others received posttest items that were randomized. Cronbach alpha reliability for this 36 item posttest is 0.78.

Structural Knowledge Sorting Task Posttest

The structural knowledge sorting task posttest was a computer-delivered program called *ALA-Mapper* (Clariana & Marker, 2007). The sorting task displayed the 36 vocabulary terms from the lesson randomly on the screen. Directions on the screen stated, "Drag related terms closer together and unrelated terms further apart. When done, click continue".

The final distances between the 36 terms were measured in screen pixels. To analyze this data, next the researchers used an excel spreadsheet to convert the *ALA-Mapper* coordinate data output into proximity array files. Each array (actually the lower triangle) contains 630 elements to represent every pair-wise distance between the 36 terms (e.g., $(36^2 - 36)/2 = 630$). Then, the proximity array files were analyzed by software called Knowledge Network and Orientation Tool for the Personal Computer, version 4.3 (*KNOT*, 1998). The *KNOT* software was used to reduce the raw proximity array data into a Pathfinder network representation (PFNet) using the following parameters:

Minkowski's *r* set to infinity, *q* set to 35 (i.e., 36 – 1), the maximum proximity value set to 1000 (pixels), and the minimum set to 0.

Participants' scores (referred to as 'common' scores in the literature) were calculated by the *KNOT* software by summing the number of links in the participants' PFNets that agree with a referent PFNet. The referent PFNet was established by creating a proximity file containing "0s" to indicate invalid links and "1s" to designate valid links between all lesson terms within a lesson section, in this case, 122 possible valid links of the 630 total possible links (for details on how referent PFNets are established, see Clariana & Marker, 2007, pp. 181-182).

Procedure

Participants logged in to the software program using a self-created pseudonym and were randomly assigned to one of the lesson conditions by the software based on a random number function. In order, the program consisted of the introduction, the lesson, the sorting task posttest, the constructed response posttest, the multiple choice posttest, and a final summary screen.

Results

Data for analysis consisted of the structural knowledge and the declarative knowledge posttest scores. The posttest data were analyzed by ANCOVA with three between subjects factors that included *Lesson* (color present or no color), *Posttest* (matches lesson color or no color) and *Posttest Item Order* (posttest item order matches or not the order of the lesson items), and the within subjects factor *Subtest* (structural knowledge consisting of the sorting task and declarative knowledge consisting of the combined recognition and cued recall scores). Both structural knowledge and declarative knowledge *Subtest* scores were converted to *Z*-scores to place these on the same scale of measurement. Lesson scores were used as a covariate to control for initial differences and increase power. Note that posttest item order is not of interest, but was included in the analysis to consider possible order effects. The means and standard deviations for the lesson and posttest scores are shown in Table 1.

Table 1. Lesson and Posttest Means.

		Lesson	Posttest	
Condition	*n*	Declarative Knowledge	Structural Knowledge	Declarative Knowledge
No color lesson				
No color posttest	19	29.7	11.8	25.8
		(3.0)	(4.1)	(5.0)
Color posttest	21	29.1	13.0	25.9
		(3.7)	(4.2)	(4.8)
Color lesson				
No color posttest	19	30.1	14.0	25.7
		(3.3)	(3.3)	(5.1)
Color posttest	21	28.4	14.1	24.4
		(3.9)	(4.1)	(4.5)

Note: Standard Deviations in Parentheses

No significant main effects were observed (see Table 2). The anticipated interaction of Subtest and Lesson Color was significant, $F(1, 71) = 5.008$, $MSe = 0.618$, $p = .028$, and $\eta = .066$. Inspection of the means indicates a disordinal interaction, with lesson color enhancing structural knowledge scores and inhibiting declarative knowledge scores (see Figure 1).

Table 2. Analysis of Variance of Posttest *Z*-scores.

Source	*df*	*F*		η	*p*
Intercept	1	48.19		0.40	0.00
Covariate (C)	1	48.82		0.41	0.00
Lesson Color (L)	1	1.12		0.02	0.29
Posttest Color (P)	1	1.49		0.02	0.23
Posttest Item Order (O)	1	0.45		0.01	0.51
L x P	1	0.11		0.00	0.74
L x O	1	0.23		0.00	0.63
P x O	1	0.55		0.01	0.46
L x P x O	1	1.08		0.02	0.30
error	71	(.85)			
Within subjects					
Subtests (S)	1	8.04	*	0.10	0.01
S x C	1	8.22	*	0.10	0.01
S x L	1	5.01	*	0.07	0.03
S x P	1	0.52		0.01	0.47
S x O	1	0.06		0.00	0.80
S x L x P	1	0.03		0.00	0.87
S x L x O	1	0.24		0.00	0.63
S x P x O	1	0.77		0.01	0.38
S x L x P x O	1	0.25		0.00	0.62
within group error	71	(.62)			

* *p< .05 level, mean square error shown in parentheses.*

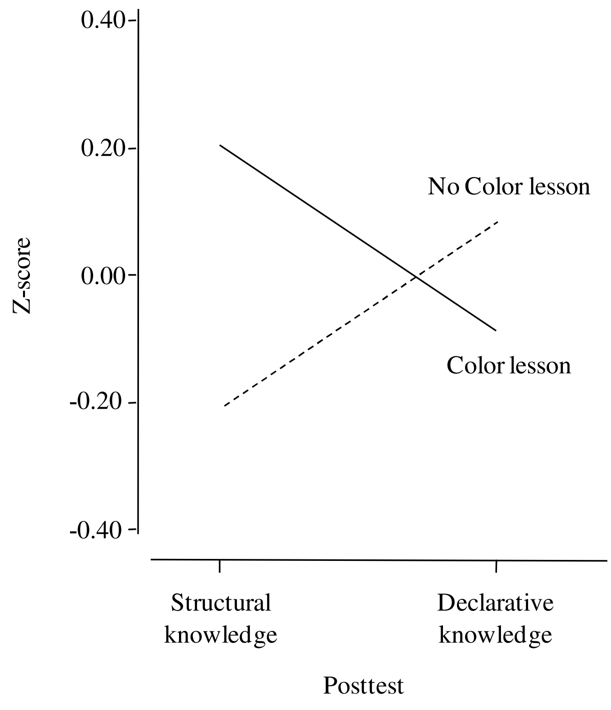

Figure 1. Subtest x Lesson color interaction.

Follow up analysis consisted of two separate one-way ANCOVAs of the lesson color factor (color present versus no lesson color) for the structural knowledge and the declarative knowledge posttest scores; lesson score served as a covariate. There was no difference on the *declarative knowledge posttest* between the color lesson treatment means compared to the no color treatment (M_{color} = 25.1 compared to M_{color} = 25.9, SD = 4.81; d = -.17). But there was a significant difference for the *structural knowledge posttest*; the color lesson treatment mean was significantly greater than the no color lesson treatment mean (M_{color} = 14.1 compared to M_{color} = 12.4, SD = 3.96; d = .41, $p <$ .05), indicating that lesson color did have a positive effect on structural knowledge posttest scores relative to the no color lesson control (see Figure 1). Specifically, the lesson items with the same color hue were more often clustered together on the structural knowledge posttest.

Separate *post hoc* analysis of declarative knowledge recognition and cued recall posttest scores indicates that lesson color relative to the no lesson color had a similar non-significant but negative effect on both recognition and cued recall (e.g., cued recall posttest $M_{color} = 10.1$ versus $M_{no\ color} = 10.4$; $SD = 3.4$; $d = -.12$; recognition posttest $M_{color} = 15.0$ versus $M_{no\ color} = 15.3$; $SD = 2.2$; $d = -.18$;). Further, in line with our past research, matching lesson and posttest color hue relative to the three non-matching treatments had a slightly negative effect (cued recall posttest $d = -0.14$ and recognition posttest $d = -0.35$); a memory context effect for lesson-posttest color matching was not observed for either cued recall or recognition posttests.

Discussion

This investigation considered the effects of left margin background color coding of lesson content sections on knowledge structure and on declarative knowledge, while controlling for lesson-posttest color matching and for posttest item order. Relative to no color, lesson color enhanced content clustering of associated lesson content as measured by a sorting task and had no effect on cued recall and recognition declarative knowledge. A memory context effect on declarative knowledge was not observed, matching lesson and posttest color hue had no significant effect on the declarative knowledge posttests relative to the three non-matching treatments, thus encoding specificity was not supported.

A limiting factor in this investigation is that the structural knowledge posttest was given before the declarative knowledge posttest. The declarative knowledge posttest in this investigation was likely influenced by the intervening structural knowledge sorting task. In a meta-analysis of incidental context-dependent memory effects, Smith and Vela (2001) noted that associative processing at input should diminish the observed effects of manipulations of incidental environmental contexts (p. 215). The associative processing effects of the sorting task in this investigation that occurred before the declarative knowledge posttest (e.g., an intervening test effect) may have diminished the effects of lesson color on the declarative knowledge posttests.

The lesson format used here provided recognition tasks with feedback while most screen-based lessons or informational web pages typically only allow reading. Thus the results observed here should not be generalized to all screen-based lesson approaches. Future research should consider the effects of screen background color on structural knowledge using more typical web pages.

Another possible limitation is that participants were not informed that color hue was used to signal lesson sections; color hue was an incidental context variable. Informing the participants to note the lesson topic color scheme mayly obtain stronger effects for lesson color.

We currently hold that left margin color contextual information is automatically encoded in the episodic memory trace, as evidenced by the greater sorting task posttest scores observed here. The implication is that left margin color will influence the organization of content in memory so that it is more like the organization of that content in the lesson, relative to no color lessons. This sort of memory organization is likely to have a positive effect on posttest measures that depend on organization, for example essays, concept maps, and some other higher-order measures. Actually, the sorting task used here contains relational aspects of concept maps. Thus future research should consider the effects of lesson color on higher-order learning outcomes.

In conclusion, the left margin screen color coding approach considered in this investigation is a very common design feature of instructional, personal, and commercial web sites. It seems critically important to determine the background context effects in screen-based media and especially to more fully establish a model to account for these experimental findings.

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