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Metaphorical graphics aid learning and memory

Robert W. Danielson [a,*], Neil H. Schwartz [b], Marie Lippmann [c]

[a] Rossier School of Education, University of Southern California, 3470 Trousdale Parkway, 600G Waite Phillips Hall, Los Angeles, CA 90089-4036, USA
[b] Department of Psychology, California State University Chico, 400 W 1st St, Chico, CA 95929, USA
[c] Department of Psychology, Dresden University of Technology, Zellescher Weg 17, 01069 Dresden, Germany

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ABSTRACT

The present investigation was designed to determine the effects of metaphorical graphics on learning from an expository text. The graphics were designed to function as metaphorical representations of the semantic elements inherent in the passage, with the level of correspondence between the graphics and text varied as weak or strong. In study 1, participants ($N = 168$) were randomly assigned to one of three graphic/text conditions (strong, weak, or none). Learning was measured immediately after the presentation of learning materials and again a week later. In study 2, participants ($N = 98$) followed the same procedure as study 1, but they were allowed to view the experimental materials online, rather than in a lab setting. Results from both studies revealed that, while decorative graphics may appear benign or detrimental to learning outcomes immediately after exposure under experimental lab conditions, further analysis indicated that graphics designed to metaphorically correspond to text content functioned to preserve learning across a one-week delay. In addition, when participants viewed the materials online, the decorative graphics improved learning, not just prevented decay. The online effect was mediated by the level of metaphorical correspondence between the passage and the graphic.

1. Introduction

It is well understood that when texts and graphics appear together, performance is consistently better than text alone (Carney & Levin, 2002; Mayer, 2001; Mayer, Hegarty, Mayer, & Campbell, 2005). Levin, Anglin, and Carney (1987); Schnotz, 2002 describe graphics paired with texts as "adjunct aids"—graphics that complement the text and increase perception, understanding, and learning. Across a number of fields, the pairing of graphics with texts has increased the: (a) effectiveness of health communications from doctors to patients (Houts, Doak, Doak, & Loscalzo, 2006), (b) processing speed and correctness of answers in tests of mathematics (Sab, Wittwer, Senkbeil, & Koller, 2011), (c) comprehension of difficult-to-learn concepts in science (Patrick, Carter, & Wiebe, 2005; Stroud & Schwartz, 2010), and (d) understanding of complex mechanical systems (Mayer, 2001; Moreno & Mayer, 1999).

In the present investigation, we outline three interconnected problems inherent in the assumptions that underlie much of the existing text-graphic research. Problem 1: the variety of graphical representations is nearly infinite, but the taxonomies used to categorize these graphics are defined by arbitrary and overlapping boundaries. Problem 2: researchers using current theories often fail to predict the degree to which learning outcomes are influenced by text-graphic pairings, rendering successful text-graphic pairing unpredictable. Problem 3: graphics are often paired with texts with the goal to increase learning; however, we suggest that the learning context and task demands in which these text-graphic pairs are presented contribute to this theoretical unpredictability. The present investigation was designed to explore these three problems by: a) creating graphics that illustrate the arbitrary boundaries of graphic classification, b) examining the ability of current theories to predict learning outcomes *a priori*, and c) conducting two studies — one in a psychology laboratory, and the other online — to explore how identical materials produce different outcomes in different settings.

1.1. Problems in graphical taxonomies

Carney and Levin (2002) identified five categories to which graphics can be assigned: representational, organizational, interpretational, transformational, and decorative. Representational graphics mirror part or all of a text's content; organizational

* Corresponding author.
E-mail address: Robert.Danielson@usc.edu (R.W. Danielson).

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graphics provide a framework for comprehending the content of a text; interpretational graphics clarify difficult to understand text; transformational graphics are mnemonic in nature; and decorative graphics simply decorate a page, purportedly bearing little to no relationship with text content. There are large variations in the forms graphical representations may take (Hegarty, 2011) and the forms are associated with a correspondingly large range of functionality (Fang, 1996; Marsh & White, 2003; Scaife & Rogers, 1996).

Graphics function in complex ways well beyond Carney and Levin's five-category taxonomy, with most graphics serving more than one function. Marsh and White (2003) identified 49 separate functions distributed across 3 major categories of assignment. One contains graphics having little to do with a text (such as functions of decoration or affect/mood); the second deals directly with the content of the text (restating or organizing text information); the third contains graphics that go beyond the text (elaborating, condensing, or having a learner draw inferences from text content). Lee and Nelson (2004) added two additional categorical domains: a) the instructional purpose of a graphic, and b) the graphical properties of a graphic— how a graphic's visual elements are organized and perceived.

When graphics are to be paired with texts, researchers should clearly specify the function the graphic is intended to serve. During our review of the literature, we found many researchers have omitted the specific properties that render graphics appropriate for these categorical assignments (Schwartz & Danielson, 2012). This is a problem – if authors fail to delineate the intended classification for the graphics used, it falls to others to infer these categorical assignments, which can lead to increased ambiguity and post-hoc classifications. In the present investigation, we sought to create graphics classified as “decorative” in Carney & Levin's taxonomy because this taxonomic category, more so than any other, shows the widest variation in predicting learning outcomes (Carney & Levin, 2002). The logic used to classify these graphics is as follows: these graphics “bear little to no relationship to text”, for example, (“a generic drawing of a pine tree next to a description of a hiking trail”, p. 7). Additionally, the graphics do not literally mirror any part of the text content; they fail to organize text content in any hierarchical way; they fail to interpret difficult text content (“e.g. representing blood pressure as a pump system”, p. 7); and, they fail to transform the text content into a mnemonic representation (concepts from the passage were not illustrated concretely as keywords, “e.g. a bell for (the fictitious city) Bellview”, p. 17). In sum, according to Carney & Levin's taxonomy, these graphics are decorative in nature, and fail to fit into the other four categories.

We agree with others (Carney & Levin, 2002; Lee & Nelson, 2004; Marsh & White, 2003) that all graphics—including decorative ones—can be defined according to the functional properties that describe them. However, we contend that these functional properties are not inherent within the graphic itself, but relative to the context in which the graphic is interpreted by the learner. From a purely descriptive perspective, graphics can be organized by type according to certain salient visual properties—iconic displays, relational displays, or complex displays, (c.f. Hegarty, 2011); however, the functionality of a graphic is bound to the context in which it appears — a context that we suggest is inductively reasoned by a learner. This inductive process is driven by the verbal-semantic context surrounding the graphic (Danielson, Schwartz, Falahi, & DeVries, 2011), suggesting that the functional properties of decorative graphics are relative and not absolute, and only specifiable in terms of the relative contextual relations in which they operate. That is, a graphic may be representational in one context, and decorative in another.

In text-graphic research, it is generally text that provides the relative contextual relations allowing graphics to be understood. However, while researchers have developed rich models to account, respectively, for the processing of texts (cf. Kintsch, 1992; McNamara, Kintsch, Songer, & Kintsch, 1996) and graphics (cf. Ainsworth, 2006; cf. Hegarty, 2011), models only of text and only of graphics fail to capture the effect of text-graphic integration. When viewed in isolation, learners infer very different meanings from both referents (Hagan, 2007) – with each referent having the ability to “clarify, contradict, or challenge the ordinary or associative meaning of the other” (Hagan, 2007, p.72). We contend that pairing texts and graphics together does not always provide an additive effect, and the addition of separate models of text and graphics processing is insufficient to predict the outcome of the combination of both referents. The spatial arrangement in which information is displayed can subtly communicate relationships *among* or *between* that information, (Hegarty, 2011; McCabe & Castel, 2008) and displays effective for one task may be ineffective for another (Hegarty, 2011; Liben, 2001; Schnotz, Bannert, & Seufert, 2002; Tversky, 2001; Tversky, Morrison, & Betrancourt, 2002). Thus, we propose that the synergistic effect resulting from combining texts and graphics cannot be satisfactorily predicted by merely adding a model of text-processing (Kintsch, 1992) to a model of graphic-processing (Hegarty, 2011). Rather, an integrated model of the two is required to predict learning outcomes.

1.2. Problems in predicting graphical efficacy

Researchers (c.f. Mayer, 1997; Schnotz, 2014) have attempted to explain how the respective processing of text and graphics overlap to create a unitary model of text-graphic understanding. Drawing on theories of working memory (Baddeley, 2001) and cognitive load (Chandler & Sweller, 1992; Sweller & Chandler, 1994), Mayer and Moreno provide evidence (cf. Mayer, 2001; Mayer & Moreno, 2002; Moreno & Mayer, 1999a, 1999b, 2000) that text comprehension is generally better when the text is accompanied with graphics. This finding—referred to as the Multimedia Principle—-states that verbal and pictorial information are actively processed in different cognitive subsystems, resulting in the parallel construction of two mental models, each mapped onto the other. Simply put, presenting information across two modalities (audio and visual, for example) should outperform presenting information in one modality (just audio, for example), resulting in greater learning.

However, not all representations will be equally understood (Pozzer-Ardenghi & Roth, 2005), and some combinations can impede learning (Mayer, 2001; Segers, Verhoeven, & Hulstijn-Hendrikse, 2008). Even when illustrations are intended to entertain, promote interest and motivation, or simply decorate, learning has not always been shown to improve (Cook, 2011; Elia, Gagatsis, & Demetriou, 2007; Harp & Mayer, 1997, 1998; Norman, 2010; Park & Lim, 2007; Sung & Mayer, 2012). This finding – referred to as the Coherence Principle – states that pairing texts with extraneous graphics leads to compromised learning outcomes (Mayer & Moreno, 2002). Briefly, if a learner spends a significant amount of effort: locating the graphic while keeping the text content in mind (finding the figure/table on another page), processing the graphic instead of the text (a picture of celebrity engaged in something interesting but possibly unrelated), or attempting to understand how the graphic and text go together (incoherent), learning is expected to suffer. While the first two examples are fairly easy to remedy, it is the third example we wish to focus on in this manuscript. We suspect it is impossible to determine, *a priori*, which principle – the Multimedia Principle or the Coherence Principle – will accurately predict learning outcomes when pairing decorative graphics with text. The question is: how does one decide whether a