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Navigational spatial displays: The role of metacognition as cognitive load[☆]

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Abstract

One hundred and six undergraduates searched a hypermedia environment under three navigational conditions, wrote an essay measuring their comprehension, and completed a test of metacognition. The map conditions were spatial/semantic, spatial only, and none. Analyses revealed that a navigational map capable of incurring an integrative cognitive model of the meaningful relationships underlying website content incurs significantly more metacognitive load and higher levels of comprehension. When the map was incapable of revealing these relationships, metacognitive skills were of no value and compromised learning performance. The results demonstrate that a navigational map can create significantly more cognitive load; however, the nature of the load—whether germane or extraneous—is based on the degree to which the map permits integrative model construction during processing.
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Learners who navigate Internet websites spend much of their cognitive effort orienting to the content and structure of the site. This orientation generally occurs at the expense of the elaborative and evaluative processing necessary for deriving deep levels of comprehension and achieving instructional goals (Eveland & Dunwoody, 2000). The condition appears with surprising regularity across a broad spectrum of learning outcomes, patterns of navigational behavior and a variety of hypermedia environments (Baylor, 2001; McDonald & Stevenson, 1998; Nilsson & Mayer, 2002). McDonald and Stevenson (1998), for example, showed that the learning outcomes of learners navigating a hypermedia environment are decreased when the navigational structure of the environment is unavailable because the learners need to simultaneously attend to the task at hand while trying to orient themselves to the spatial configuration of the site. Even forcing learners to think about the structure of the hypermedia environment is not a certainty for better navigation (Nilsson & Mayer, 2002). That is, learners, when afforded information about the navigational structure of content within a website, fail to show performance increases in content comprehension relative to learners without

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it—although decreasing the effort required to comprehend the structure of a website improves learners' navigation performance over time.

Other researchers have found similar results. Tripp and Roby (1990), for example, found that the absence of either a graphical advanced organizer or a spatial metaphor for the organization of a website hindered the amount learners acquired from the site. Finally, Chen and Rada (1996) and Simpson and McKnight (1990) in general found that learners given the opportunity to derive structural knowledge of a site were more efficient in their navigational behavior, visited fewer extraneous pages, and yielded more efficient achievement of specific instructional goals. In short, the problem with hypermedia learning is that learners must be able to (a) comprehend the information available in the site, (b) keep the structure of the site in mind, and (c) integrate the information into a cognitive model that allows them to achieve their instructional goals. The investigation reported here was designed to address this problem.

The problems learners experience in balancing content comprehension with orientation to navigational structure is typically explained via the concept of cognitive load—the amount of space consumed in a limited working memory incurred by the cognitive demands necessary for orienting to a website's navigational structure, navigating the site and deriving a cognitive model for comprehending its contents (Paas, Renkl, & Sweller, 2003). Sweller's (1988) Cognitive Load Theory is based upon Baddeley's (1986) Working Memory Model—a tripartite system of working memory comprised of a central executive and its two slave subsystems: the phonological loop and the visuospatial sketchpad.

One of the ways to reduce cognitive load in hypermedia navigation is to provide learners with a navigational map. Site maps presumably reduce learners' cognitive load because they reduce the disorientation learners experience by making explicit the navigational structure of the site (Danielson, 2002; Eveland & Dunwoody, 2000; Nielson, 2000; Zizi & Beaudouin-Lafon, 1995). Danielson (2002) contended that a map depicting the nodes and links between locations in a website is all that is necessary to decrease the level of disorientation learners experience when they navigate a site. Park and Kim (2000) agreed, finding that the provision of a navigational map assists learners in orienting themselves, finding relevant textual information, and decreasing cognitive load because the map leaves more space in working memory for processing information.

However, we believe that it is unclear why a navigational map should reduce a learner's cognitive load during hypermedia navigation. While navigational maps presumably orient learners to their present location within a website, there is no clear evidence as to what underlying cognitive activities are incurred by the presence of the maps. Navigational maps provide more, not less, information when websites are searched. Maps also convey a myriad of different types of information, which can cause an increase in cognitive load instead of reducing it. It is also unclear as to whether the reduction of cognitive load by using a navigational map for discerning a website's structure allows learners to derive deeper comprehension of the information contained within the site. Thus, we believe that it is unclear which factors of a map are responsible for the reduction of cognitive load, and what cognitive variables are involved in learners' performance as a function of the load reduction. Finally, we are not convinced that the provision of a website map reduces learners' cognitive load. The investigation reported here addressed these issues directly.

1. Cognitive processing of maps

A number of researchers have attempted to explain the way maps and other graphic adjuncts are processed together with text (cf. Robinson, Katayama, & Fan, 1996; Schnotz, Bannert, & Seufert, 2002; Shah & Carpenter, 1995; Shah, Hegarty, & Mayer, 1999; Verdi & Kulhavy, 2002; Winn, 1994). In the main, the role of the displays is explained in terms of the limitations of working memory and their role in either increasing or reducing cognitive load.

According to Kulhavy's Conjoint Retention Model (Kulhavy & Stock, 1996) a map is encoded as a single chunk of information in working memory and acts as an organizer for the semantic and spatial relations it represents. There has been a great deal of research on maps with adjunct text (Kulhavy, Stock, & Kealy, 1993; Kulhavy, Stock, Peterson, Pridemore, & Klein, 1992; Schwartz, 1997; Schwartz & Kulhavy, 1988; Verdi, Johnson, Stock, Kulhavy, & Whitman-Ahern, 1997). The results of this research reveal that maps reliably facilitate the long-term retention of adjunct text and suggest that maps free up working memory for processing, leading to deeper comprehension of text. Kulhavy and his colleagues, employing Paivio's (1986) dual coding model, explain that maps, as graphic adjuncts to text, are processed in the visual store, while text is processed in the verbal store. The referential links between the two allow the propositions of text held in the verbal store to be placed at specific locations on the map in the visual store. Once placed there, the map image is used by learners to "unpack" the verbal propositions of text during the retrieval process. Thus,