



Internet exploration behaviours and recovery from unsuccessful actions differ between learners with high and low levels of attention[☆]



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ABSTRACT

Sustained attention (i.e., focusing attention on an activity for a prolonged amount of time) has important implications for learning and memory. However, little is known regarding the behavioural factors that contribute to sustained attention during Internet learning. The primary purpose of the current study was to explore differences in navigational choices and recovery from unsuccessful actions of learners with high and low levels of sustained attention. Undergraduate students searched the Internet for information corresponding to an assigned low domain knowledge topic for 20 min while their eye-gaze was recorded. High- and low-attending learners differed in the selection of links, level of linearity used to navigate the Internet, Web reading strategies, and frequency of deploying unsuccessful actions. These results indicate that sustained attention may be impacted by the monitoring of one's progress towards the learning goal, and have implications for scaffolding provided by teachers and adaptive hypermedia systems.

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1. Introduction

People frequently navigate the Internet with the goal of comprehending information and learning from multiple sources (Jones, 2002; Madrid, VanOostendorp, & Melguizo, 2009; Pew Internet & American Life Project, 2001). As a type of hypermedia the Internet combines graphics, audio, video, text and hyperlinks in an interactive and nonlinear environment. Users must decide how to find information, what information to read, which hyperlinks to follow, and when to modify behaviours. Consequently, for the Internet to be a valuable resource, individuals typically must be autonomous and active in their learning (Ally, 2004). Researchers have identified that learners with low domain knowledge, on average, have exhibited little or no learning gains after studying from hypermedia environments, including the Internet (Dillon & Gabbard, 1998; Lawless, Brown, Mills, & Mayall, 2003; Shapiro & Niederhauser, 2004; Willoughby, Anderson, Wood, Mueller, & Ross, 2009). However, these studies do report great variability for the outcome measures, suggesting that some learners fair well when learning from hypermedia and domain knowledge is low. The next step then is to explore variation in how low-domain-knowledge navigators direct their learning when using the Internet.

In general, attention has been regarded as a major influence on the information that is remembered; affecting entry, maintenance and retrieval of information (Craig & Lockhart, 1972). Differences in attention to relevant information may account for variation in low-domain-knowledge learners' knowledge acquisition when studying from hypermedia. Although evidence for the facilitative effect of attention for knowledge acquisition during Internet learning will advance the current understanding of sustained attention, the primary goal of the current study was to describe the factors that distinguished low-domain-knowledge learners with high levels of attention from peers with low attention levels when learning from the Internet. Results from studies that compare hypermedia navigations of high- and low-domain-knowledge learners suggest that exploration behaviours may contribute to time spent attending to relevant information (e.g., Lawless et al., 2003). Therefore, the current study explored differences in the navigation choices of learners with high and low levels of sustained attention (referred to as high- and low-attending learners, respectively), when navigating the Internet for 20 min to learn about an assigned low domain knowledge topic.

Understanding the individual differences among the navigations of low-domain-knowledge learners has practical implications for the development of supports. Various supports have been shown to be effective for increasing learning gains during hypermedia learning, usually in comparison to a control group. Researchers have examined the benefits associated with supports that involve assistance from others, including self-regulatory training (Azevedo & Cromley, 2004), providing learners with a list of appropriate websites (Kafai & Bates, 1997), teaching learners basic

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information related to the topic to increase domain knowledge prior to navigations (Lawless, Schrader & Mayall, 2007; Mayer, Mathias, & Wetzell, 2002), and working with peers (Lazonder, 2005; Winters, Azevedo, & Levin, 2004). Other supports have involved computer programs with features that promote the use of learning strategies (Lumpe & Butler, 2002; Winne et al., 2006). However, if differences in exploration behaviours are observed between high- and low-attending learners, then teachers and users may consider providing/using supports that specifically promote on-task attention.

1.1. Theoretical background

According to information-processing frameworks, learners first actively select and attend to information. The information then enters working memory where it is held for active processing and integration with prior domain knowledge to form a coherent mental model. The mental model is then permanently stored in long-term memory within interrelated networks or schemas for later recall (Anderson & Pearson, 1984; Atkinson & Shiffrin, 1968; Schneider & Shiffrin, 1977). Information processing is not always considered a serial process as outlined above, as processes that happen rather quickly may occur in parallel (Rumelhart, Smolensky, McClelland, & Hinton, 1986). When domain knowledge is low, information processing is an effortful, active and controlled process; in effect, less knowledgeable learners typically exhibit poor recall of novel information (Schneider, Körkel, & Weinert, 1990; Spilich, Vesonder, Chiesi, & Voss, 1979; Voss, Vesonder, & Spilich, 1980). Retention failures associated with low domain knowledge may be attributed to any stage within the information processing model, including but not limited to: a failure to distinguish between relevant and irrelevant information (Broadbent, 1952; Symons & Pressley, 1993), cognitive demands associated with executive control may be too high (Chandler & Sweller, 1996), use of ineffective cognitive strategies and metacognitive monitoring (Azevedo & Cromley, 2004; Azevedo, Cromley, & Seibert, 2004; Hill & Hannafin, 1997), or the information may not be retrieved from long-term memory due to insufficiently developed schemas (Rumelhart, Hinton, & McClelland, 1986). Bearing in mind that attention to relevant information underlies the success of effective processing, encoding and retrieval, it is important to identify the factors that influence the time low-domain-knowledge learners spend attending to relevant information in order to understand Internet learning.

There are three categories of effortful attention (Sarter, Givens, & Bruno, 2001; Schmeichel & Baumeister, 2010). Selective attention involves attending to one stimulus while avoiding other competing stimuli, and divided attention involves attending to different stimuli simultaneously. Although instances of selective and divided attention may arise during learning from the Internet, the amount of time usually have to study the information would likely provide them with an opportunity to recover before effects to knowledge acquisition became detrimental. Navigation times within studies have typically ranged from 20 min (e.g., Willoughby et al., 2009) to 60 min (e.g., Desjarlais & Willoughby, 2007). On the other hand, learning may be noticeably impacted by the third category, sustained attention, which involves focusing one's attention on an activity for an extended period of time, while ignoring irrelevant information.

Sustained attention performance has typically been assessed using situations in which a participant watches for and responds to unpredictable signals on a computer screen over prolonged periods of time (Sarter et al., 2001). The attentional process can involve the activation of top-down (knowledge-driven mechanisms) or bottom-up (driven by characteristics of stimuli) processes. Until the beginning of the 2000s, there was limited investigation regard-

ing the significance of sustained attention for higher cognitive functions including learning and memory. Since then, sustained attention has been found to be a predictor of higher performance in school (Steinmayr, Ziegler, & Träuble, 2010), and experimental settings involving either text-based resources (Rawson, Dunlosky, & Thiede, 2000; Tsai, Hou, Lai, Liu, & Yang, 2012; Wei, Wang, & Klausner, 2012) or hypermedia environments (Last, O'Donnell, & Kelly, 2001; Lawless et al., 2003; McDonald & Stevenson, 1996; McDonald & Stevenson, 1998). In addition, eye-tracking studies have demonstrated that fixations tend to be longer for more important information (Hyönä, 2010; Rayner, 1998), and that individuals who show longer fixations on goal-relevant information in comparison to irrelevant recall relevant information better (Kaakinen, Hyönä, & Keenan, 2002; Tsai et al., 2012). The next logical step then is to identify the variables that distinguish high- and low-attending learners.

1.2. Comparing the exploration behaviours of high- and low-attending navigators

The capability to sustain one's attention is influenced by numerous factors, including for example, context-related variables (e.g., working memory demands, stress, or uncertainty regarding presentation of stimuli; Hancock, 1989; Parasuraman, 1979; Sarter et al., 2001) and personal characteristics (e.g., ADHD; Barkley, 1997). In order to contribute to this body of knowledge, the current study investigated the differences in exploration behaviours among high- and low-attending learners when domain knowledge is low. This study is timely, when considering that, within the hypermedia research, there is limited investigation regarding navigators' attention to information on a particular webpage, which may be due to a lack of opportunity track learners' eye-gaze. In addition, researchers have not thoroughly examined the variation in exploration behaviours and their efficiency among only low-domain-knowledge learners.

Researchers who have at least considered domain knowledge when examining learners' exploration behaviours typically compared behavioural differences between learners with high and low domain knowledge (Balcytiene, 1999; Calisir & Gurel, 2003; Chen & Ford, 1998; Eveland & Dunwoody, 1998; Last, O'Donnell, & Kelly, 2001; Lawless & Kulikowich, 1996; Lawless et al., 2007; Lawless et al., 2003; Marchionini, Dwiggins, Katz, & Lin, 1993; McDonald & Stevenson, 1998; Willoughby et al., 2009). Such research used log files to record learners' actions during navigations (Calisir & Gurel, 2003; Lawless & Kulikowich, 1996; Lawless et al., 2003; Lawless et al., 2007; McDonald & Stevenson, 1998; Willoughby et al., 2009), and interviews to gain insight into their reasons underlying certain navigational choices (Balcytiene, 1999; Last, O'Donnell, & Kelly, 2001). A log file records mouse and keyboard clicks and thus is limited to identifying the total number of pages accessed, the sequence of pages accessed and the time spent per page. According to research using log files, learners with low domain knowledge were more likely to stop navigating before accessing the whole hypermedia program, exhibit difficulty executing direct routes to desired information by taking longer paths to access desired information, and take longer to search for information in comparison to high-domain-knowledge learners. Qualitative analyses of the interviews indicated that low-domain-knowledge learners typically report feelings of not knowing where they had been in the hypermedia or where they should have gone.

The literature, however, does indicate that there is variability in the exploration behaviours used by low-domain-knowledge learners. For example, Lawless and colleagues (2003) had undergraduate students study information from an online instructional hypermedia designed for the study. The hypermedia consisted of 60 screens setup in a nonlinear fashion connected by hyperlinks.

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