Individuals with ADHD and the Cognitive Processing of Multimedia

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Abstract: Individuals with attention deficit disorder experience dysfunction within two working memory subsystems: the phonological loop and the visuospatial sketchpad. With phonological memory functioning better than visuospatial memory, the redundancy of visual and audio information presented in multimedia could increase their cognitive load when using multimedia in instructional situations. This study will examine those effects. Understanding how individuals with ADHD process multimedia information will assist in the design of instruction for these individuals.

Introduction

Sweller (2003) proposed instructional designers must develop instruction with methods that take into account the limitations of the human cognitive architecture. This cognitive architecture has one dominate structure "working memory," but also includes long term memory and all the sensory systems associated with the human nervous system. Those individuals with attention deficit hyperactivity disorder (ADHD) may process multimedia differently, than those without the disorder. The symptoms of impulsivity and hyperactivity seem to effect the phonological and the visuospatial subsystems within the working memory of individuals with ADHD (Alderson, Rapport, Hudec, Sarver, & Kofler, 2010; Sowerby, Seal, & Tripp, 2011). Evidence of increased cognitive load upon both types of memory, impacts an individual with ADHD or rather their ability to process information through both modalities (Cutting, Koth, Mahone, & Denckla, 2003; Shalev & Tsal, 2003; Weiler, Bernstein, Bellinger, & Waber, 2002; Borkowska & Zawadzka, 2008; Barnett, Maruff, Luk, Costin, Wood, & Pantelis, 2001). Identified deficits in the phonological and visuospatial memory may also impact the cognitive processing of multimedia-based instruction. The "cognitive theory of multimedia learning" (Mayer, 1997; Mayer, 2009; Mayer & Moreno, 1998) provides a framework to explain how ADHD learners process multimedia instruction. Because of their working memory deficits, learners with ADHD may process multimedia instruction differently than other learners. Thus this study compares the processing of multimedia of those with and without ADHD.

Working Memory

The key to processing multimedia material is the ability to process information that is presented in different modalities. The current theory of working memory identifies four components that work together to allow the identification of relevant stimuli, process that information, utilize it and/or store it into long term memory (Baddeley, 2001). Stimuli appear to be subdivided into the phonological loop which processes and stores auditory stimuli; while, the visuospatial sketchpad processes and stores visual and spatial information. The central executive component is the attentional controller responsible for the oversight and coordination of the information processed through the phonological loop and visuospatial memory. Finally, a recent addition to the original model (Baddeley & Hitch 1974), the episodic buffer, integrates the information processed through the phonological loop and visuospatial memory using sequencing of events (Baddeley, 2001).

Evidence of a dysfunction within the working memory in individuals with ADHD can be observed in exercises designed to test phonological and visuospatial memory components. This inability to process information, however, is more pronounced in the visuospatial memory for individuals with ADHD (Alderson, Rapport, Hudec, Sarver, & Kolfler, 2010; Sowerby, Seal, & Tripp, 2011). Because the deficits are noted in both portions of the modality subsystems, complex executive functions within the central executive component seem be attribute to those deficits rather than the storage system (Alderson, et al., 2010).

Cognitive load

Sweller (1988) synthesized several aspects of cognitive psychology and instructional design, to derive cognitive load theory (Sweller, 1988) a theory of human performance, given the information processing requirements of instructional materials. According to this theory, a learner’s ability to efficiently encode instructional materials is dependent upon their ability to process new information. Therefore, instructional materials must be streamlined to remove extraneous information. This is because a learner’s working memory is limited only allowing him/her to process so much information simultaneously. If the complexity of those materials is not properly managed, a learner’s working memory may become overloaded, preventing schema acquisition, later resulting in poorer performance.

Extraneous information imposes what Sweller and his associates describe as extraneous cognitive load (Sweller & Chandler, 1991; Chandler & Sweller, 1992) inducing extraneous processing (Mayer & Clark, 2010). Chi, Feltovich and Glaser (1981) were probably the first to describe novices as being distracted by problem features. Sweller and Chandler later generalized this idea, to describe any irrelevant problem feature as extraneous, be it the problem presentation mode or irrelevant data contain within a problem (Chandler & Sweller, 1991; Sweller & Chandler, 1991). Later, Pollock, Chandler, and Sweller (2002) described extraneous cognitive load as that load which is controlled by an instructional designer as they present, structure and sequence instructional materials. Extraneous load imposes additional cognitive processing which is not inherent within the instructional activity, or does not support the goal of the instruction being presented (Mayer & Clark, 2010).

Learners with ADHD are particularly susceptible to distraction by extraneous stimuli (APA, 2000; Brown, 2009). For example, they appear to be unable to sustain attention over time. When a delay in response, or a change in the response patterns are introduced, performance accuracy decreases (Cutting et al., 2003). Individuals with ADHD are unable to narrow their attention to a specific spatial region or able to locate targeted stimuli within high density displays (Shalev & Tsal, 2003). When the cognitive load increases with the addition of distracters, to retain multiple elements of information concurrently, or asked to perform multiple operations to complete a task, these individuals perform with slower response times and lower accuracy rates (Borkowski & Zawadzka, 2008; Barnett et al., 2001; Weiler et al., 2002). For these reasons, identifying the best way to support these individuals in the processing or removal of extraneous information/stimuli as they interact with multimedia instructional material will improve their educational outcomes.

The Cognitive Theory of Multimedia learning

Mayer and his colleagues proposed the “Cognitive theory of multimedia learning” (Mayer, 1997; Mayer, 2009; Mayer & Moreno, 1998) which relies on cognitive load theory, but also draws from dual-coding theory (Mayer & Moreno, 2002; Paivio, 1978). While cognitive load theory is more generalized because it considers the information processing requirements of all instructional materials, Mayer's theory specifically focuses on the processing requirements of multimedia instruction. According to Mayer’s theory, humans process visual and auditory information via separate channels during multimedia instruction; have a limited working memory; and learn by selecting, organizing and integrating information from the multimedia environment into their long term memories (Mayer, 2009).

The learner's visual and audio channels are what were described as the visuospatial sketchpad and phonological loop in Baddeley's description of working memory. According to cognitive load researchers, learners are able to process and effectively and simultaneously distribute the load across these two modalities, when processing multimedia (Mousavi, Low, & Sweller, 1995). Both Mayer and Sweller have documented a number of learning effects associated with multimedia. In particular Mayer and his associates have built on dual coding theory and cognitive load theory, to document the “modality effect” or “modality principle” (Mayer, 2005; Mayer, 2009; Mayer &Anderson, 1991; Moreno & Mayer, 1999; Mayer & Sims, 1994).

Modality Effect

Mayer takes a sensory-modality approach toward learning and instruction (Mayer, 2009). In this view, learners interpret information from their environment and must relate that information to previous learned material (knowledge construction) in which “multimedia learning is a sense-making activity in which the learner seeks to build a coherent mental representation from the presented material” (Mayer, 2009, p.17).

Mayer and his colleagues have conducted several empirical studies of the modality effect within multimedia. For instance, Mayer and Moreno (2002) used animation to find strong and consistent evidence for the use of animation and narration, over narration alone, and described this as the “multimedia principle.” Over four experiments, they found the addition of animation to narration, resulting in enhanced problem-solving transfer performance, with a media effect size of 1.74 (Mayer & Moreno, 2002). A common theme among these studies is that the instructional materials revolved around the learner’s application of principles portrayed in animated multimedia instruction of causal systems.

For the modality effect to work, both the phonological and the visuospatial subsystems must work together. For individuals with ADHD, the two processes within working memory work differently. First, the visuospatial memory appears to be less effective in processing information than the phonological system (Alderson et al., 2010). Deficits noted in younger children in the phonological system appear to improve with maturity, as a result, differences in performance on verbal tasks are less acute in over time (Sowerby, Seal, & Tripp, 2011). However, it is unclear as to whether the addition of visual elements to audio information would act as supporting or extraneous information altering the benefit of the modality effect for individuals with ADHD.

Given the processing of information for the visuospatial subsystem is not as well developed in individuals with ADHD, the modality effect may be function differently. There are two processes that have been identified as challenges in processing visual information in individuals with ADHD. One is the inability to limit visual searches a specific spatial region on the screen (Shalev & Tsal, 2003). Even though the diagrams are integrated into the instruction, the individual with ADHD may not be able to differentiate the information quickly enough to benefit from the diagrams and labels. The addition of the diagrams to the screen also increases the density of objects on the screen. Individuals with ADHD struggle with the identification of locating targeted images that are densely populated screen (Shalev & Tsal, 2003); therefore, unable to benefit from the close integration of the visual with the text on the screen.

Redundancy Effect

The redundancy effect as it relates to multimedia was first described in the 1990s by Sweller and his associates (Chandler & Sweller, 1991; Sweller & Chandler, 1991). In essence, this is duplicate or redundant information that is provided as a part of instruction. This redundant induces an unnecessary extraneous cognitive load upon the learner. If the redundant components can be understood in isolation, then learners must process this extraneous information, while trying to acquire the underlying schema or understand the instruction as it is being provided.

The redundancy effect may not have the same impact for individuals with ADHD. There is conflicting evidence from the literature concerning redundant text and learners with disabilities. Montali and Lewandowski (1996) found evidence that simultaneous narration and redundant text (bimodal presentation) would improve the reading comprehension of less skilled readers. However Montali and Lewandowski did not include visuals with their narration (multimedia). Bimodal presentation of verbal messages may make the processing of the multimedia learning materials more difficult (Moreno & Mayer, 2002). The dual processing of visual and audio is complicated by the slower response to visual information by individuals with ADHD as compared to audio information (Weiler, Bernstein, Bellinger, & Waber, 2002). Increasing the complexity of the task has also led to inaccurate responses and slowing down of processing for individuals with ADHD (Martinussen & Major, 2011; Shalev & Tsal, 2003; & Alderson et al., 2010). Given the dual processing challenges experienced by individuals with ADHD, redundancy could have an opposite effect.

Method

All interested participants will be directed toward a web site. After reading and acknowledging their informed consent, participants will begin the study by being randomly assigned (by a JavaScript) into one of two instructional conditions: audio with text or audio without text. The subject matter of the multimedia presentation is hurricane development. This narrated presentation will include animations, movies and a variety of visual elements. This is what Mayer (2009) describes as a narrated animation. The narration will also have redundant text elements (subtitles) presented on screen for those learners in the audio with text condition. So in short we are considering the effect of subtitles (redundant text) on learning by ADHD learners.

After interacting and viewing the multimedia, participants will answer a self-assessment questionnaire (Likert scale, multiple choice questions, and open ended questions). Responses to each of these questions will be collected via a web-based form. Based upon their scores in the ADHD Current Symptoms Scale Self Report Form (18 questions within the self-assessment) participants will be categorized as having symptoms associated with ADHD or not. The data will then be examined as four separate groups. Individuals will be divided into the following four groups: audio & text (Individuals without ADHD), audio & text (individuals with ADHD), audio only (individuals without ADHD), audio only (individuals with ADHD).

Audio & Text (Individuals without ADHD)	Audio & Text (Individuals with ADHD)
Audio Only (Individuals without ADHD)	Audio Only (Individuals with ADHD)

In addition the questionnaire contains questions about: the perceived difficulty of the lesson, difficulty of the instruction, their ability to attend to the lesson, perception of what they remembered, and demographic questions.

Analysis

An ADHD survey (18 questions) will be given to all participants. Depending on their responses they then will be randomly assigned to an instructional condition. Finally learners will also be given a series of quiz questions based on the instruction. The survey score will be used to categorize participants as either normal, or having symptoms consistent with ADHD. We will be considering two sub-categories of ADHD ("impulsivity" or "inattentive/hyperactivity"). Survey responses will be scored with a range of 9-36. A score of 24 (or higher) will be necessary, to be categorized as having symptoms associated with ADHD. To analyze the data received we will develop a regression model based on the severity of the symptoms (survey score) and this model will be used to predict learner performance on the quiz. All learner performance will be measured given redundant text and split-attention during multimedia instruction. It is hoped that this research will provide support for Multimedia development guidelines for those with and without ADHD.

Results

Preliminary results will be added to this paper and presented at the conference.

Conclusions

Individuals with ADHD experience interference with their cognitive processing of multimedia (Solomonidou, Areou, & Zafiropoulou, 2004) because of the deficits in the phonological and the visuospatial subsystems of their working memory (Alderson et al., 2010; Sowerby, Seal, & Tripp, 2011). However little research has documented how well these learners are able to retain and transfer what they have learned given multimedia. Several studies have documented how learners without ADHD retain and transfer what they have learned in multimedia learning (Mayer, 2009). This study intends to replicate some of Mayer's work to determine how individuals with ADHD process information given multimedia learning. It is hoped that this research will help Instructional designers develop materials that aid learners with symptoms related to this common disorder.

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