THE REDUNDANCY EFFECT ON RETENTION AND TRANSFER FOR INDIVIDUALS WITH HIGH SYMPTOMS OF ADHD

Victoria Brown, Ed. D.
Florida Atlantic University

David Lewis, Ph. D.
Miami University

Mario Toussaint
Florida Atlantic University

Abstract

The multimedia elements need to be carefully integrated together to maximize the impact of the multimedia elements on learning. Redundancy information presented through audio and visual channels can inhibit learning for individuals diagnosed with ADHD who may experience challenges in the processing of information through visuospatial and phonological loop channels in the memory system. This study explores how redundancy affects the individuals' with self-reported higher levels of ADHD symptoms ability to process information presented using multimedia presentations. Individuals with higher-reported ADHD symptoms had lower performance levels when using the multimedia presentation with redundancy.

Prevalence and Diagnoses

Prevalence rates of individuals who have been diagnosed with attention deficit/ hyperactivity disorder (ADHD), have not varied significantly over the past 3 decades (Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014) with parents reporting that approximately 11% of their school-age children had a diagnosis of ADHD by a health care provider (Visser et al., 2014). ADHD was once considered a childhood disorder because of the difficulty in determining the prevalence in the adult population. However, one third of the participants with a childhood diagnosis of ADHD retained symptoms into adulthood (Barbaresi et al., 2013). Diagnostic tools for ADHD evaluate the disorder along a continuum based on severity of the symptoms (Lubke, Hudziak, Derks, van Bijsterveldt, & Boomsma, 2009). Understanding the disorder can be beneficial for many who may experience challenges in attention and hyperactivity but may not present with severe symptoms for a diagnosis.

As with any disorder, ADHD symptoms may be experienced by anyone. Although the symptoms may not be severe enough to create a situation where the individual is unable to function, many experience difficulty in listening to a speech, presentation, or lecture or sitting for extended length of time. Because of this continuum of experiences from exceptional ability to unable to attend, the application of the principles of universal design is applicable. The principles advocate the creation of instruction that supports individuals with an ADHD disability also assist others with lesser symptoms along the continuum providing effective instructional for all learners (CAST, 2012).

Individuals with ADHD can experience a range of symptoms from three different subtypes as described by the *Diagnostic and Statistical Manual of Mental Disorders 5th Ed*. The subtypes provided are primarily inattention, primarily hyperactivity-impulsivity, and a combination of both. The symptoms for the inattention type include:

> (a) inability to pay attention to details; (b) difficulty sustaining attention to tasks; (c) inability to listen; (d) failure to follow through on instructions; (e) failure to finish schoolwork, chores, or workplace duties; (f) difficulty in organizing tasks; (g) avoidance of tasks requiring sustained mental effort; (h) easily distracted by extraneous stimuli; and (i) forgetfulness in daily activities.
>
> Individuals with hyperactivity-impulsivity type can exhibit (a) fidgeting with hands and feet, (b) leaving a seat when sitting is expected, (c) running about or climbing excessively, (d) blurting out responses before the question is completed, (e) difficulty waiting one's turn, and (f) interrupting or intruding on others (American Psychiatric Association, 2013, pp. 59).

Neurobiological Challenges

Although not easily identifiable, individuals with ADHD appear to have neurobiological deficits within working memory. Specifically brain networks associated with executive control have been implicated in those with ADHD (Curatolo, D'Agati, & Moavero, 2010; Sergeant, Geurts, Huijbregts, Scheres, Oosterlaan, 2003). Working memory consists of four different functions (Baddeley, 2007). First, the central executive function is an attentional control system responsible for the oversight and coordination of three subsidiary systems. Second, the phonological loop is responsible for temporary storage and rehearsal of auditory information. Third, the visuospatial short-term memory is used when the learner stores and rehearses visual information. The last system is the episodic buffer, which provides the context for the information to enhance memory. Although the neurological basis for these systems was found in the 1990s (D'Esposito et al., 1995; D'Esposito et al., 1998; Jonides, et al., 1993; Paulesu, Frith, & Frackowiak, 1993), it is unclear how the systems interact and within which system deficits occur, but deficits in the phonological loop and the visuospatial systems impact the ability to process multimedia information.

The modality effect occurs when the information is presented through both auditory and visual material in multimedia presentations. In most cases, the modality effect allows learners to process stimuli simultaneously via separate subsystems to perform better than those who learn through a single mode of instruction (Kalyuga & Sweller, 2014; Mayer & Anderson 1991; Mayer & Anderson, 1992; Moreno & Mayer, 1999; Penney, 1989). However, combinations of multimedia elements within instruction should be carefully designed to ensure the modality effect occurs during learning (Mousavi, Low, & Sweller, 1995). Depending on the mode of instruction, different combinations of multimedia elements may create distractions. As distractions are introduced into a multimedia presentation, extraneous cognitive load increases, leading to decreased learner performance (Moreno & Mayer, 2002). These distractions have the potential to create an overload on a learner's working memory limiting their ability to learn (Sweller, 1988).

The redundancy effect was first described in the 1990s by Sweller and his associates (Sweller & Chandler, 1991). This learning effect occurs when duplicate or redundant information is provided as a part of instructional materials. Redundant information is a distraction which may induce memory overload, by increasing extraneous cognitive load and subsequently decreasing learner performance (Kalyuga & Sweller, 2014; Mayer, 2009). If the instructional components may be understood in isolation, then providing the same information through multiple working memory systems creates redundancy within the instruction (Kalyuga, & Sweller, 2014). Under these instructional conditions learners must process extraneous information simultaneously while trying to acquire the underlying schema or the instruction being provided. Because the redundant instructional components may be understood in isolation, the processing of the same information through the phonological loop and the visuospatial short-term memory creates an unnecessary load (Kalyuga, & Sweller, 2014; Sweller & Chandler, 1994). For a typical learner, redundancy negatively impacts learning when the visual material is not presented concurrently with the audio (Chandler, Kalyuga, & Sweller, 2004; Kalyuga, & Sweller, 2014).

Individuals with ADHD appear to have deficits that impact the ability to process information through the different systems in the working memory (Curatolo, D'Agati, & Moavero, 2010; Sergeant, Geurts, Huijbregts, Scheres, Oosterlaan, 2003). Learners with ADHD are particularly susceptible to distraction by extraneous stimuli (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 is introduced, performance accuracy decreases (Cutting, Koth, Mahone, & Denckla, 2003). Individuals with ADHD are unable to narrow their focus to a specific spatial region or to locate targeted stimuli within high-density displays (Shalev & Tsal, 2003). Increasing task complexity causes individuals with ADHD to have slower response times and lower accuracy rates. Examples of increased complexity may be: (a) the addition of distracters, (b) retention of multiple pieces of information concurrently, or (c) the performance of multiple operations simultaneously (Barnett et al., 2001; Borkowska, Zawadzka, 2008; Weiler, Bernstein, Bellinger, & Waber, 2002).

Studies have indicated that deficits in both the phonological loop and the visuospatial memory appeared to be directly linked to the deficits in working memory rather than in behavior inhibition or the storage systems of memory for individuals with ADHD (Alderson, Rapport, Hudec, Sarver, & Kofler, 2010). In the Alderson et al. (2010) study, a regression analysis was used to determine specific factors that contributed to the working memory deficits. The researchers determined that the phonological loop and central executive functions were contributing underlying factors (Alderson, Hudec, Patros, & Kasper, 2013). When cognitive load was introduced to a task, either through increasing the complexity of the task or sustaining attention over a period of time, the likelihood of identifying deficits in the phonology loop and the visuospatial memory increased (Borkowska & Zawadzka, 2008). Furthermore, the deficits in visuospatial channel appear to be more pronounced than in the phonological loop (Alderson et al., 2010). The deficits in the phonological loop appeared to improve as individuals with ADHD became adults (Sowerby, Seal, & Tripp, 2011). However, the visuospatial memory deficits remained stable into adulthood and appeared across all age levels (Sowerby et al., 2011; van Ewijk et al., 2014). A concern is the ability of the learners to transfer the knowledge presented in multimedia instructional material (Kalyuga, & Sweller, 2014; Mayer & Johnson, 2008). Transfer is most often described as the ability to use information learned in one situation, or problem, and apply that learning to another novel situation (Broudy, 1977). The cognitive perspective is that transfer occurs when the learner is able to abstract the underlying structure of the problem; then apply that schema to a similar problem (Gick & Holyoak, 1983). Broudy (1977) notes that people have difficulty applying their knowledge and describes this as "transfer failure." Bransford and Schwartz (1999) proposed for transfer to occur to a new problem, assumes original learning has occurred. For individuals with ADHD, working memory training did not improve transference which indicated that the neural plasticity of the brain does not improve the efficiency of the neuronal responses with working memory training (Gathercole, 2014) With the training not improving the transference performance of individuals with ADHD, how would multimedia presentations using dual modality presentation impact transference of knowledge from one situation or problem to another situation?

Rationale

Individuals diagnosed with ADHD may process information with reduced accuracy as compared to individuals without ADHD. (Barnett et al., 2001; Ortega, López, Carroscco, Anllo-Vento, & Aboitiz, 2013; Weiler et al, 2002). Given this information, it is hypothesized that redundant information in a multimedia lesson will increase the cognitive load encountered by learners with ADHD, resulting in slower and less accurate performance on retention and transfer tasks.

Method

A between-groups design analysis was used to compare individuals with self-reported high frequency of ADHD symptoms to those with lower self-reported frequency levels. The primary instructional variable was the presence or absence of redundant subtitles (redundancy) within the instruction. Groups were further subdivided based upon their performance on the ADHD questionnaire into groups with or without ADHD. This process resulted in four groups: (a) control group of non-ADHD without redundancy, (b) ADHD without redundancy, (c) non-ADHD with redundancy, and (d) ADHD with redundancy.

The participants for this study were College of Education students (across all levels from undergraduate to doctoral) from two universities in south Florida. Individuals with ADHD were solicited across all levels to ensure maximum participation; therefore, the results cannot be applied to a specific age group or educational level. After two attempts to recruit participants, 34 education students were recruited for the study, of which 6 students self-reported symptoms with high frequencies in 6 of the 9 categories necessary to be placed in the group with high levels of ADHD symptoms on the ADHD Current Symptoms Scale Self Report Form for this study (Barkley & Murphy, 1998). One inference should be made based upon the participant pool. The participants, who reported high-levels of ADHD symptoms, would have developed coping skills allowing them to overcome barriers the symptoms can pose in acquiring information as reflected in their ability to progress through a postsecondary education.

Procedure

An email invitation was sent out to the students asking for participation. Embedded within the email was a link to the multimedia instruction. As the students agreed to participate, they were randomly assigned to one of two presentations with or without subtitles. Twelve students were randomly assigned to the presentation without redundancy (audio and not subtitles) of which two self-reported symptoms frequently enough to be placed into the high symptoms of ADHD category. Twenty-two students were randomly assigned to the presentation with redundancy (audio and subtitles) of which four were placed in the high reported symptoms of ADHD group. This process resulted in four groups: (a) without redundancy with lower symptoms of ADHD, (b) without redundancy with high symptoms of ADHD, (c) with redundancy with lower symptoms of ADHD, and (d) with redundancy with high symptoms of ADHD. The uneven group sizes were the result of the random assignment by the computer program into the different treatments by the program. After being randomly assigned to one of the two presentations, the participants viewed the instructional material.

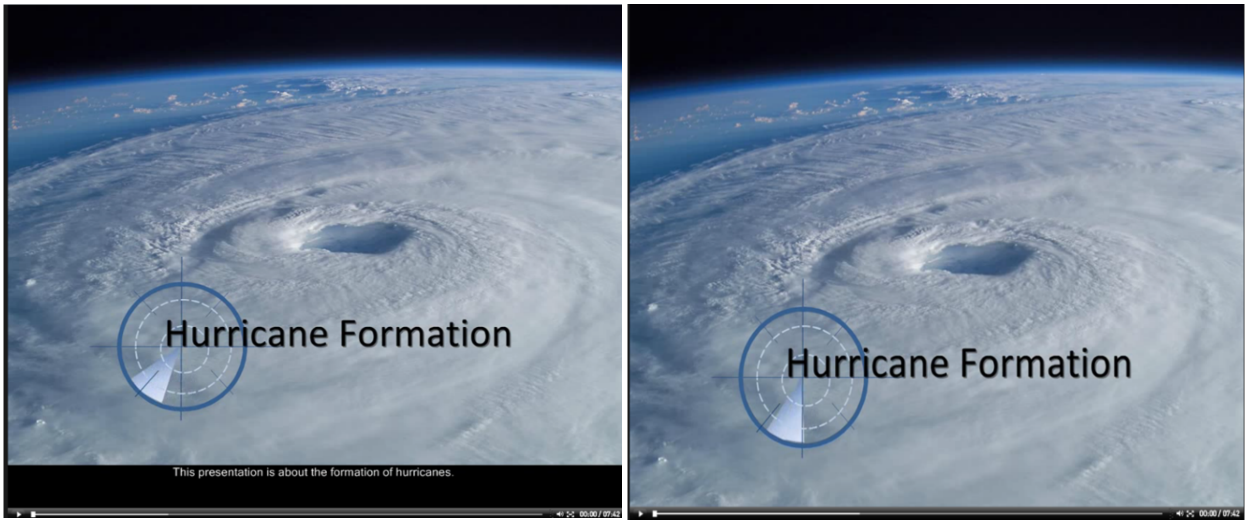
After viewing the narrated presentation, participants were directed to a web-based questionnaire which included demographic, multiple-choice, open-ended transfer, and Likert scale questions. Responses to these questions were collected via a web-based form using the survey system Opinio 6.5.1 (Opinio, 2014). Once learners finished the questionnaire, they were thanked for their participation.

This study replicated many multimedia studies (Mayer, 2001; Mayer, 2009; Mayer & Johnson, 2008) to consider retention and transfer as dependent variables. Nine multiple-choice questions based upon the narrated presentation were used to measure retention (scored 0 to 9). Three open-ended questions were presented to measure transfer, and learner responses were scored as correct or incorrect (scored 0 or 1). In addition to the instructional variables (retention and transfer), the questionnaire considered a Likert scale mental effort question (Paas & van Merriënboer, 1993) and a subscale of 18 ADHD questions for a total of 36 questions. The questionnaire included a single mental effort question as in prior cognitive load studies (Chandler & Sweller, 1996; Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Paas & van Merriënboer, 1993; Paas, Tuovinen, Tabbers, & van Gerven, 2003).

The ADHD subscale questions were identical to the ADHD Current Symptoms Scale Self Report Form (Barkley & Murphy, 1998). These questions are often used as a diagnostic tool to document ADHD symptoms. This tool was used as a means of further categorizing learners as either having symptoms consistent with ADHD or as non-ADHD learners. We considered two subcategories of ADHD ("impulsivity" or "inattentive/hyperactivity"). If learners scored a 2 or 3 on 6 of the 9 questions (within a category) that indicated that the individual experienced symptoms of impulsivity or inattentive/hyperactivity severe enough to impact their daily lives.

Multimedia Instruction

The multimedia presentation was developed with two purposes. First, the topic was expected to be of interest to the participants because they lived in south Florida, which occasionally experienced hurricanes. Many of the participants may have a cursory knowledge of hurricanes; however, the presentation described the storm development, a topic in which students may not have had prior knowledge. The presentation also used a combination of still pictures and animation to demonstrate concepts and principle-based information within what Mayer (1997) described as a scientific explanation. The content was then added to the presentation with a voiceover. The presentation with narration became the control presentation. The second presentation for the experimental group was identical but included subtitles that matched the narration. See an example of the presentation in Figure 1.



Group with Redundancy | Group without Redundancy

Figure 1. Screen shots of instructional conditions

Results

The overall mean score was calculated for both categories of ADHD, inattention and hyperactive/impulsive (see Table 1). ADHD scores are presented for participants who received instruction with and without redundancy. In the low symptoms of ADHD category, the group with redundant subtitles and the group without subtitles had almost identical scores with .26 and .27 in the hyperactivity subcategory; however, in the inattention category, they had scores of .22 and .38 respectively. Mean scores for the participants in the high symptoms of ADHD category were also very similar with .62 and .61 in the inattention subcategory and .64 for both groups for the hyperactivity subcategory.

Table 1
Self-Reported Average Scores for ADHD Categories

	Inattention		Hyperactivity	
	LS ADHD	HS ADHD	LS ADHD	HS ADHD
With redundant subtitles	0.22	0.62	0.26	0.64
Without redundant subtitles	0.38	0.61	0.27	0.64

*LS = low levels of report symptoms and HS = high levels of report symptoms

Retention

The retention questions were multiple-choice questions evaluating the understanding of the content within the multimedia presentation. On the retention questions, the students in the low symptoms of ADHD groups had similar scores in both redundancy and non-redundancy presentations (0.74 and 0.73). The participants with high symptoms of ADHD using the redundancy material scored lower than the other groups on retention at 0.61. Individuals in the lower symptoms of ADHD groups scored higher in answering the retention questions than those in the high symptoms of ADHD groups. The performance gap on retention of the participants in the high symptoms of ADHD category between the redundancy (0.61) and no redundancy (0.67) presentations were more pronounced. Further, one hundredth of a point difference was noted between the lower symptoms of ADHD groups on the retention questions (see Table 2).

Table 2
Scores across Groups

n	GROUPS	Effort	Retention	Transfer
	Without redundancy			
10	LS ADHD	3.20	0.74	.50
2	HS ADHD	4.50	0.67	.33
	With redundancy			
18	LS ADHD	3.61	0.73	.79
4	HS ADHD	2.00	0.61	.25

Transference
More pronounced differences in the groups emerged in the transference questions. The transference questions introduced complexity to the task by requiring participants to apply their factual knowledge. The transference questions required the participants to explain how the factors impacted the strength of a hurricane and the damage as a hurricane moved inland. Participants with lower symptoms of ADHD performed better with redundancy (0.79) as compared with those (with low symptoms) using the presentation without redundancy (0.50). In both groups, one individual chose not to provide a response to the transference questions. Both groups which had self-identified high rates of ADHD symptoms struggled with the transference questions. The group with high symptoms of ADHD using the presentation without redundancy scored 0.33 as compared with the other groups with high symptoms of ADHD using the redundant presentation at 0.25.

Two of the six individuals with high frequency of ADHD symptoms did not provide responses to the transference questions, one from each group. As expected, the accuracy of the answers to the transference questions were lower for both high frequency ADHD groups as compared with those in the lower symptoms of ADHD group as the complexity of the task increased. Complexity was increased in two ways. One was that the questions were not multiple choice and required the individuals to compose an answer. Second, the answers required the application of the knowledge presented in the presentation rather than recital of facts. The group with higher rates of ADHD symptoms using the redundant presentation scored lower than all other groups for transfer.

Mental Effort
Perceived mental effort was measured and analyzed across the different groups, by the participants (see Table 2). For this question, the participants were asked to evaluate the level of effort they invested on a scale of 1 to 9 with 1 referred to very, very low mental effort to very, very high mental effort at 9. Participants with high-symptoms of ADHD using the presentation

with redundant information scored lower on both retention and transference and also exerted the least amount of effort (2.00). The participants with higher levels of ADHD symptoms using the multimedia presentation, without redundancy reported the highest level of mental effort or cognitive load (4.50) of all the groups. This group scored slightly better on the retention and the transference questions than the group with high-symptoms of ADHD using the redundant presentation but did not result in scores higher than the groups that reported lower levels of ADHD symptoms. The group with high ADHD symptoms reported higher levels of mental effort (4.50) while using the without redundant presentation and also scored the highest on the transference questions (See figure I).

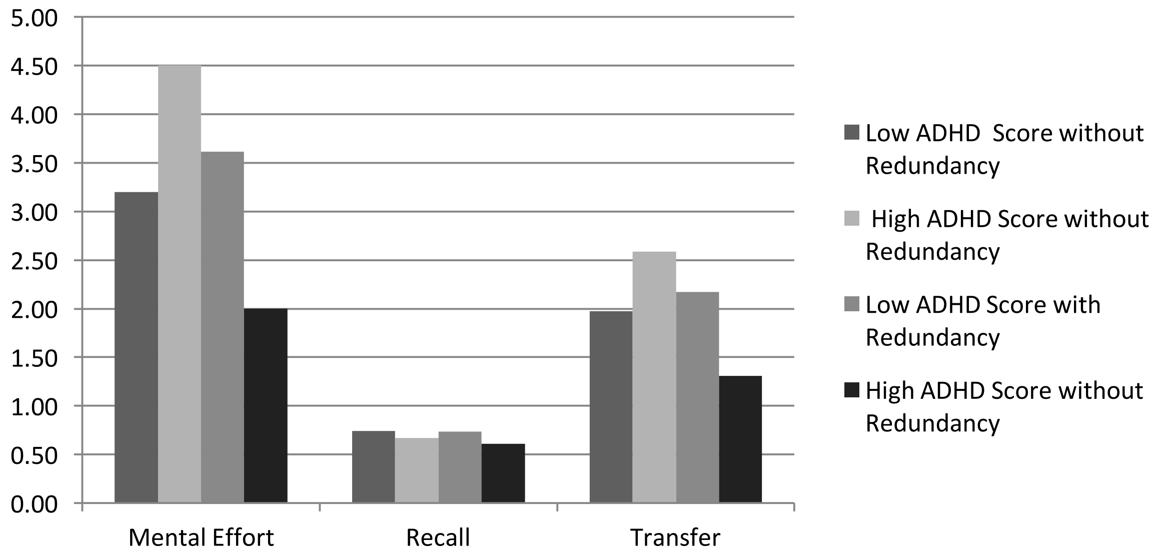


Figure 1. Visual representation of the mean scores of mental effort, recall and transfer for comparison across the different groups and measures.

One of the participants, using the redundancy presentation self-reported high rates of hyperactive symptoms and low rates of the inattention symptoms, was nonresponsive to the transference questions. Rather than respond with an answer to the questions, this individual chose to express her challenges in using the presentation for learning. She indicated an inability to pay attention to more than one slide at a time if there were no interactive elements on the slide. In a real instructional situation, she would have taken notes on the slide to keep herself engaged. Because she clicked through the slides, she used her prior knowledge to answer the multiple-choice questions. We assumed rather than providing inaccurate answers on the transference questions, the participant decided to describe her experience. This individual's description was repeatedly pasted into the textboxes for all transference questions on her submission.

Discussion

Redundant presentations, the merging of visual and auditory information, are frequently created by instructors to convey large amounts of information (Fenesi, Heisz, Savage, Shore, & Kim, 2014). Since typical learners struggle with these types of presentations, it is possible that the effect would be accentuated in individuals with higher ratings of ADHD symptoms. In this study, individuals with higher ratings of ADHD symptoms scored slightly lower than individuals with lower ratings of ADHD symptoms on the retention questions. The individuals with high-symptoms of ADHD scored the lowest of all of the groups when using the redundant presentation.

Individuals with high-symptoms of ADHD displayed a delay in response and accuracy to changes in patterns and when the complexity increased with the addition of distracters (Barnett et al., 2001; Borkowska, & Zawadzka, 2008; Cutting et al., 2003; Weiler et al., 2002). The transference questions enhanced the complexity of the task by requiring the students to apply the information in the presentation. While typical students were able to score better on the transference questions; the participants with higher reported symptoms of ADHD scored much lower with both types of presentations. Furthermore, students with higher reported symptoms of ADHD using the redundant presentation scored the lowest across all groups in transfer with an average score of .25.

Interesting patterns emerged in the perceived mental effort question. The participants with higher reported symptoms of ADHD using the non-redundant presentation scored better on the inference questions indicating some effort was used to answer the questions. A non-significant trend was noted when the non-redundant presentation appears to promote better mental effort scores for individuals with higher reported ADHD symptoms on both the retention and transfer measures. The group of individuals with higher reported symptoms of ADHD using the redundant presentation scored lower on effort, retention, and transfer (figure I). It may be possible that the participants perceived that the redundant presentation as easier because of their familiarity with that format. This study replicates the "false perceived understanding" (Fenesi et al., 2014, p.259) of content in this format with typical learners.

Implications for Future Study

This study raises questions about the redundancy effect upon the learning outcomes of students with high symptoms of ADHD. Furthermore, this study indicated that the understanding how the integration of the two subsystems (visuospatial and phonology loop) can provide important links to deficits within the memory systems for individuals with ADHD. Clues to that process can be found in the reported higher level of reported mental effort by participants with higher self-identified symptoms of ADHD, than those with lower levels of symptoms in the use of the without-redundant presentation. Future research should consider other multimedia, instructional conditions on the mental effort and accuracy in the transfer of knowledge to other situations. Would comprehension improve as it does for individuals without ADHD, if the text used in the presentations was abridged rather than full word-for-word presentation when combined with the audio? Finally, are animations combined with the audio distracting or beneficial for individuals with ADHD?

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About the Authors

Victoria S. Brown, Ed. D.

Victoria is the Assistant Provost for eLearning at Florida Atlantic University. Prior to that appointment, she taught instructional technology and instructional design in the Department of Teaching and Learning. She also has 10 years of experience in K12 special education.

David Lewis, PhD

David has served as a professional Instructional Designer, Instructional Technology Manager, and Professor of Instructional Technology. Since the mid 1990s, he helped faculty design and develop fully online, hybrid, and blended degree courses and programs at USF, FIU, UWF, and now the University of Miami.

Mario Toussaint