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The Interplay of Recall, Transfer, and Perceive Mental Effort with Attention Deficit Symptoms on Multimedia Learning

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Abstract

Section 508 of the Rehabilitation Act (1998) has mandated that subtitles be provided in multimedia presentation as an accommodation for individuals with disabilities (Section 508, 2014). However, learners with ADHD are unable to narrow their attention to a specific spatial region nor locate targeted stimuli within high-density displays (Shalev & Tsal, 2003). Designers need to understand how individuals with ADHD differ from the general population and how their disability impacts recall, transfer, and mental effort in multimedia learning environments. This study aims to discern how information presented in a multimedia lesson affects ADHD learners' in either retention, transfer, or their reported levels of mental effort.

Participants were asked to view a presentation with narrated animation or a narrated animation with subtitles, then answer questions for recall, transfer of knowledge, and mental effort. Independent samples t-tests were conducted on the data obtained to test the hypothesis that when the information is presented without redundancy transfer and recall scores are higher, and mental effort is lower. The mean score for recall was higher for the non-redundancy group even though that group reported higher levels of ADHD symptoms. In addition, the results of a regression analysis supported the hypothesis that an increase in ADHD symptoms will result in an increase in mental effort and a decrease in recall and transfer. Thus, it is suggested that all learners have control of redundant subtitles and be able to turn them off to accommodate differences in the processing of information through visuospatial and phonological memory.

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Keywords: ADHD; cognitive load; redundancy

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1. Introduction

With the rapid expansion of distance learning in both the education and business training, an understanding of how the brain processes the information presented in an asynchronous learning environment is important. Online learning is able to integrate multiple modalities into a single presentation form to support learning. Early research suggested that learners who used multimodal instruction performed significantly better on learning tasks than their peers who used single-mode instruction (Mayer & Anderson, 1991; Mayer & Anderson, 1992; Mousavi, Low, & Sweller, 1995). This research was based upon dual-coding and working memory theories (Baddeley & Hitch, 1974; Clark & Paivio, 1991). These theories now serve as foundational framework for today's most important theories of cognitive processing during learning: Cognitive Load Theory (Sweller, 1988) and the Cognitive Theory of Multimedia Learning (Mayer, 1997). However learner performance may decrease when using multimedia if the content presented splits the learner's attention, or if the information presented is redundant (Austin, 2009; Ayres & Sweller, 2005; Chandler & Sweller, 1991; Craig, Gholson, & Driscoll, 2002; Jamet & Le Bohec, 2007; Kalyuga, Chandler, & Sweller, 1999: Kalyuga & Sweller, 2014; Mayer et al., 2001; Miller, 1937; Mousavi et al., 1995; Reder & Anderson, 1980).

These cognitive theories explore how using multimedia to present information through visual and auditory channels impacts learning on two dimensions (retention and transfer) (Mayer et al., 2001). Mayer's first dimension (retention) is the recall of factual information immediately after a presentation. The use of multiple choice questions are used to stimulate the brain to retrieve the facts. His second dimension is the transfer of the learning to new tasks which demonstrates a higher level of knowledge, as the learner must apply what they have learned. Further research into multimedia presentation, reveal that students exert differing amounts of effort based upon the way information or tasks were presented to the learner (Sweller, van Merriënboer, & Paas, 1998). Cognitive load theory describes the learner's performance during learning, and usually pairs a performance measure, with a self-report measure mental effort rating (Sweller, 1988; Paas, & Van Merriënboer, 1993).

Another branch of research in the attention and hyperactivity deficit disorders (ADHD) field suggests the cognitive processing in the dual-coding and working memory is somewhat different for individuals with ADHD (Alderson et al., 2010). Individuals with ADHD appear to experience deficits in the visuospatial channel and the phonological loop with the visuospatial deficits remaining into adulthood (Alderson et al., 2010; Sowerby, Seal, & Tripp, 2011; van Ewijk et al., 2013; Sowerby et al., 2011). Working memory deficits may be apparent with observations of poor verbal or visuospatial short-term memory during a performance (Chiang, Huang, Gau, & Shang, 2013; Tillman, Eninger, Forssman, & Bohlin, 2011).

2. Development of the Multimedia Instructional Frameworks

The memory models of the 1960s and 1970s are often described as being based upon multiple memory stores: sensory, working, and long-term memory. This multi-store model of working memory was later described as the human cognitive architecture (Sweller, 2003). In the early 1990s, researchers found neurological structures, which correlated with Baddeley and Hitch's (1974) visual-spatial sketchpad (Jonides, et al., 1993) and articulatory loop (Paulesu, Frith, & Frackowiak, 1993), giving further credence and neurological evidence of channels within working memory. Of the subcomponents of working memory identified by Baddeley and Hitch (1974), the phonological loop and the visual-spatial scratchpad are the most relevant to this study.

In Dual-Coding theory, Paivio (1978) explained how multimedia may be interpreted in working memory as either verbal or nonverbal symbols. In short, Paivio described the processing of sensory information as it is organized into working memory and later encoded into long-term memory (Paivio, 1971; Paivio, 1978). Paivio's insight was that humans encode modality-specific representations of stimuli into long-term memory, as they make referential connections to other modal information.

Mayer and Anderson (1991; 1992) built on Paivio's Dual-Coding theory to propose that when both modalities are presented simultaneously, learners use those referential connections, allowing students to subsequently perform significantly better on problem-solving and transfer tests. This theoretical explanation was later found to be the case given learner performance following multimedia instruction, and subsequently described as the modality effect (Mayer & Anderson, 1991; Mayer & Anderson, 1992). Sweller and his colleagues explained this modality effect from a cognitive load perspective, describing learners who use multiple modalities as being more efficient during learning. These researchers proposed learners use working memory more effectively to share the load of that incoming information across multiple channels, avoiding overload (Low & Sweller, 2014; Mousavi, Low, & Sweller, 1995).

Universal design, a model for development of adaptive instruction, recognizes the modality effect through the establishment of principles to address three learning networks (a) recognition networks, (b) strategic networks, and (c) affective networks (Rose, Meyer, & Hitchcock, 2005). Through the networks, multimedia becomes the tool to provide multiple means of presentation, action and expression, and engagement. (CAST, 1999-2013). The recognition network uses the senses to identify information and make connections. The strategic network consists of the cognitive strategies used to retain the information acquired through the recognition network. The affective network acknowledges the importance of motivation in the individual's ability to retain the information. These principles provide developers of instruction with a framework to develop adaptive systems in the design of instruction. By using multiple means of representation, instructor can ensure that they are reaching students in whatever modalities is their strengths. Multiple means of action and expression allow the learners to engage their strategic network. Finally, multiple means of engagement activate the affective networks by providing different motivational approaches. The challenge is to understand the neurobiological processes of individuals with disabilities and ensure that instruction compensates for their cognitive processing deficits. All students are then able to interact with and to learn from the instructional materials as described by the universal design principles.

An important principle of universal design is that instruction designed for an individual with a disability ultimately assists everyone. Disabilities occur along a continuum with each individual having strengths or weaknesses in these areas (Rose, Meyer & Hitchcock, 2005; Silver, Bourke, & Strehorn, 1998). A weakness within a disability area occurs when that weakness results in the inability to function in daily life. Identification of the exact number of adult individuals who cope daily with symptoms of attention deficit hyperactivity disorder (ADHD) is difficult to identify. However, it is known that approximately 11% of school-age children, as reported by parents, have a diagnosis of ADHD by a health care provider (Visser et al., 2014b). Prevalence rates appear to be stable, with no significant variance over the past 3 decades (Polanczyk, Willcutt, Salum, Kieling, & Rohde, 2014).

Variability exists in how the symptoms of ADHD change from childhood to adulthood. In 2000, Resnick's study approximated the prevalence of ADHD in adults at 2% to 10% with as many as 2 out of 3 children continue to exhibit symptoms into adulthood. In a prospective cohort study, only one-third of adults retained the diagnoses into adulthood (Barbaresi et al., 2013). Upon examination of the symptoms, anyone can identify themselves as experiencing these challenges in many different situations, lending support to the basic premise of universal design that designing instruction to support any disability benefits everyone.

Individuals with ADHD can experience a range of symptoms from three different categories as described by the Diagnostic and Statistical Manual of Mental Disorders: *DSM-V* (American Psychiatric Association, 2013). The categories are inattention type, hyperactivity-impulsivity type, and combination type. 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. Those 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. Those diagnosed with the combination type exhibit symptoms from both types. Diagnosis is not simple. Severity is critical because anyone can experience a range of these symptoms; therefore, the tools used for diagnosis indicate the severity along the continuum within the combination of the six symptoms across the three types of ADHD (Lubke, Hudziak, Derks, van Bijsterveldt, & Boomsma, 2009).

The behavioral symptoms of ADHD listed are observable in individuals with ADHD. However, they also experience unobservable challenges in the neurobiological processes within their working memory. Working memory, as defined by Baddeley (2007), consisted of several interdependent components. The central executive component functions as the attentional controller which oversees and coordinates the three subsidiary systems. The phonological loop provides temporary storage and rehearsal of auditory information. The visuospatial channel replicates the phonological loop by providing temporary storage and rehearsal of visual information. While, the episodic buffer holds information which surrounds events by adding context and emotions to the memories. Individuals with ADHD experience deficits in working memory which results in difficulty in performing novel and complex tasks, maintaining an alert state to sustain responses, difficulty with response inhibition, and delay in aversion responses (Gupta & Kar, 2010; Martinussen & Major, 2011).

Within the universal design model, accommodations to address the recognition network are provided through multiple means of presentation (Rose et al., 2005). The different methods of presentation in a multimedia environment are typically through visual and auditory modalities which use two different channels in working memory of visuospatial and phonological loop. Studies have indicated that deficits in both the phonological loop and visuospatial memory identified in individuals with ADHD appear to be more directly linked to the deficits in working memory rather than behavior inhibition or the storage systems of memory (Alderson, Rapport, Hudec, Sarver, & Kofler, 2010). In another study, through a regression analysis the phonological loop and central executive functions were determined to be the specific factors that contributed to the working memory deficits of individuals with ADHD (Alderson, Hudec, Patros, & Kasper, 2013). As cognitive load was introduced to tasks either by increasing the complexity of the task or sustain attention over a period of time, the more likely deficits in the phonological loop, or visuospatial memory would impact the task performance by individuals with ADHD (Borkowska & Zawadzka, 2008). For individuals with ADHD, deficits in the visuospatial channel appear to be more pronounced than in the phonological loop (Alderson et al., 2010). Deficits in the phonological loop appear to improve as these individuals become adults (Sowerby, Seal, & Tripp, 2011), while the visuospatial deficits remain into adulthood and appear to cross all age levels (van Ewijk et al., 2013; Sowerby et al., 2011).

Of the different types of symptoms associated with ADHD, inattention appears to be more closely linked to the deficits of working memory than hyperactivity-impulsivity. Tillman, Eninger, Forssman, & Bohlin, (2011) observed that poor verbal short-term memory, central executive functioning, and visuospatial short-term memory were associated with higher levels of inattention symptoms. These observations were supported in a later study (Chiang, Huang, Gau, & Shang, 2013) in which the symptoms of impulsivity, hyperactivity, and inattention were considered independent variables in the evaluation of visuospatial planning activities. These researchers found the inattention variable independently predicted poorer visuospatial planning performance.

3. The Phonological Loop, Visuospatial Memory, and Learning

As researchers began to examine the modality effects with typical learners, they discovered several learning effects given multimedia. Working memory is limited in its capacity and duration (Baddeley, 1992; Miller, 1956; Sweller, 2003). Unfortunately, due to the limitations of their ability to perceive and store information, individuals with ADHD may experience increased cognitive load during multimedia learning. It has been determined that these individuals have an inability to integrate the two systems effectively to process the information (Alderson et al., 2013). Therefore, it is suggested that those designing instruction consider how the deficits within an ADHD learner's working memory may be accommodated (Martinussen & Major, 2011). This issue is a concern in designing multimedia to meet the needs of a variety of students. In Mayer's (2009) later research, he identified conditions in which multimedia supported learning and when it had limited support for typical learners. For example, the use of animation and simultaneous narration promoted learning, as opposed to animation and on-screen text (Mayer, 2001). Well-designed multimedia directs the learner's attention to visual stimuli which is complemented with an auditory message. It does not split the learner's attention between competing simultaneous stimuli (Ayres & Sweller, 2005; Kalyuga, Chandler, & Sweller, 1999).

Redundant information hinders, rather than facilitates learning (Kalyuga & Sweller, 2014). Chandler and Sweller (1991) were among the first to describe this learning effect, given instructional materials. This redundancy effect occurs when redundant instructional elements are presented simultaneously, even though the material may be understood in isolation. Learners must simultaneously process both instructional elements, the verbal narration and the redundant subtitles, trying to acquire an underlying schema. In this case, presenting more instructional material results in lower learner performance and less learning. This may seem counterintuitive. A behaviorist, for instance, would expect the second stimuli to reinforce the initial instructional message. However, many studies have shown just the opposite (Austin, 2009; Chandler & Sweller, 1991; Craig, Gholson, & Driscoll, 2002; Jamet & Le Bohec, 2007; Mayer et al., 2001; Miller, 1937; Mousavi et al., 1995; Reder & Anderson, 1980). In each case they found positive learning gains when redundant elements were removed. Unfortunately, redundancy complicates the learning environment, potentially overwhelming learners with extraneous cognitive load.

Processing redundant elements in either the phonological loop or visuospatial sketchpad creates cognitive load limits working memory capacity, decreasing subsequent performance. Although increased cognitive load may support some learning, at some point additional stimuli overwhelm the learner with extraneous cognitive load (Sweller, et al., 1998). Cognitive Load Theory stresses the need for just the right amount of information to be presented to learners in order for them to process the materials and learn (Sweller, 1988; Sweller et al., 1998). Chandler and Sweller (1991) first described this as the “redundancy effect,” and it was later described as “the redundancy principle” by Mayer and Johnson (2008).

Kalyuga et al., (1999) considered redundancy when they investigated computer-based instructional materials that consisted of diagrams and text. They found learners, who were presented with audio rather than text, performed significantly better than their peers who received redundant text in their multimedia. Later, Chandler, Kalyuga, and Sweller (2004) conducted a series of experiments to test the redundancy effect, and found that learners who were provided audio-only narration performed significantly better, than those who were provided with simultaneous auditory and visual versions of the text. Weaknesses in working memory have been identified in learners with ADHD, with larger deficits in the visuospatial channel (Barnett, Maruff, & Vance, 2005). Therefore, it is possible that the learners with ADHD may experience redundancy effects as they interact with multimedia.

When evaluating the mental effort of learners as they interact with multimedia presentations, an interesting pattern appears to be emerging. Learners may prefer full text matching in an animated presentation over the abridged text, even though their performance was better with abridged text (Yue, Bjork, & Bjork, 2013). This pattern also was noted when using more of a natural setting to test redundancy, with students reporting a preference for redundant instruction, versus an audio-only condition, even when there were no significant differences noted in performance. Thus student preference is not a guide toward improved performance. Furthermore, this pattern has been attributed to the familiarity to redundant instructional methods in face-to-face presentations where the instructor commonly creates redundant presentations to convey abundant information (Fenesi, Heisz, Shore, & Kim, 2014). With a difficulty in processing visuospatial memory, the question arises as to whether learners with ADHD would also indicate a preference for redundant instructional presentations that may not be supportive of learning.

4. Rationale

The cognitive load literature has made an evidence-based argument that redundancy negatively impacts learning when redundant instructional elements are presented simultaneously (Chandler et al., 2004; Kalyuga & Sweller, 2014). Even though redundancy was found to be detrimental for many populations, it is not certain how those with ADHD may react when provided with redundant subtitles. Support for presenting short text statements as an additional support for typical learners has been identified (Mayer & Johnson, 2008; Moreno & Mayer, 2002). ADHD learners are particularly susceptible to distraction by extraneous stimuli because they are unable to sustain attention over time (Brown, 2009). Given the above arguments, the possibility exists that learners with higher ADHD symptoms ratings, will perform poorly when given redundant subtitles.

However, Section 508 of The Rehabilitation Act (1998) has mandated that subtitles be provided for individuals with disabilities (Section 508, 2014). Subtitles also are considered an application of universal design principles because the subtitles provide a means of multiple presentation modes which should improve learning outcomes for a broad range of individuals. However, individuals with ADHD were unable to narrow their attention to a specific spatial region nor locate targeted stimuli within high-density displays (Shalev & Tsal, 2003). When the cognitive load increased with the addition of distracters, retaining multiple pieces of information concurrently or attempt to perform multiple operations to complete a task, individuals with ADHD performed with slower response times and lower accuracy rates (Barnett et al., 2001; Borkowski & Zawadzka, 2008; Weiler, Bernstein, Bellinger, & Waber, 2002).

Research has shown that neurobiological processes used by individuals with ADHD are different from those individuals without ADHD symptoms (Alderson et al., 2010; Sowerby, Seal, & Tripp, 2011; van Ewijk et al., 2013). Designers need to understand how individuals with ADHD differ from the population and how their disability impacts recall, transfer, and mental effort in multimedia learning environments. The examination of the literature on cognitive load and working memory deficits experienced by individuals with ADHD leads to the following research question: Would the differences in their ability to process information affect their ability to process redundant information presented in a multimedia lesson in both the recall and transfer of the information and affect their perceptions of the level of mental effort they experience? From this question, the following three hypothesis were developed:

- Hypothesis 1: Individuals with higher self-rated scores of ADHD symptoms, will have lower recall scores using the multimedia presentation with redundancy than those that used the multimedia presentation without redundancy.
- Hypothesis 2: Individuals with higher self-rated scores of ADHD symptoms will have lower transfer scores using the multimedia presentation with redundancy, than those that used the multimedia presentation without redundancy.
- Hypothesis 3: Individuals with higher self-rated scores of ADHD symptoms will report higher levels of mental effort when using the multimedia presentation with redundancy than those that used the multimedia presentation without redundancy.

5. Methods

5.1. Participants

The number of respondents in this study was relatively low (*n* = 34) and predominantly female. Barkley and Murphy (1998) reported no gender differences given the ADHD subscale. Some (*n* = 6) scored high enough on the subscale to be considered as having symptoms consistent with ADHD. The remaining participants were considered non-ADHD learners (*n* = 28) because they did not score high enough for placement within the ADHD groups. The participants consisted of pre-service teachers and graduate education students from two large southeastern universities. They were solicited through their university email. Upon clicking a link within their email, they were taken to a website with the relevant materials. The participants were randomly assigned to two different presentations using different multimedia design. One presentation used narrated animation and the other one used narrated animation with subtitles.

5.2. Instruments

After viewing the narrated presentation, the participants were automatically redirected to a web-based questionnaire, which included demographic, multiple-choice, open-ended transfer, and Likert questions. These questions were based upon the research hypotheses. The responses to these questions were collected via a form, using the web-based survey system Opiono 6.5.1 (Objectplanet, 2014). Once learners finished the questionnaire they were thanked for their participation.

Nine multiple-choice questions were developed based upon the narrated presentation and were used to measure recall (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 (recall and transfer) the study considered a Likert mental effort question (Paas & van Merriënboer, 1993) and, finally, a subscale of 18 ADHD questions (Barkley & Murphy, 1998) for a total of 35 questions. The self-reporting instrument did not require the participants to self-identify with a disability, but this method allowed them to be placed into groups based upon their responses. This approach provided four groups: (a) non-ADHD without redundancy

(NADHD-WOR), (b) non-ADHD with redundancy (NADHD-WR), (c) ADHD with redundancy (ADHD-WR), and (c) ADHD without redundancy (ADHD-WOR).

To differentiate the individuals with ADHD from those who did not report these symptoms, the ADHD Current Symptoms Scale Self-Report Form (Barkley & Murphy, 1998) was embedded into the questionnaire that followed the instructional material. Barkley and Murphy's (1998) questions are often used as a diagnostic tool to document ADHD symptoms. This scale consists of 18 Likert questions of which the odd-numbered items (1, 3, 5, 7…) are considered inattention and the even numbered items (2, 4, 6, 8…) are considered hyperactivity-impulsivity. Participants scored questions as 1 (*never or rarely*), 2 (*sometimes*), 3 (*often*), 4 (*very often*). If learners scored a 3 or 4 on 6 of the 9 items (within a category), that indicated that the individuals experience symptoms of impulsivity or inattentive/hyperactivity severe enough to impact their daily lives (Barkley & Murphy, 1998) and were categorized into an ADHD group.

5.3. Instructional Materials

The subject matter of the instructional presentation was hurricane formation. This 7.5 minute presentation discussed the formation of clouds, storm formation from atmospheric convection currents, and the characteristics of hurricanes and tropical storms according to the Saffir-Simpson Hurricane scale (Saffir, 1973; Simpson, 1974). A web-based presentation was developed using Microsoft PowerPoint 2007, narrated with Articulate Presenter, and recorded with Techsmith Camtasia Studio producing a web-based, narrated animation sequence that provided the base presentation. Subtitles were then applied to the recorded presentation with Camtasia. Subtitles served as redundant text (See Fig. 1). These subtitles were transcribed and were identical to the narration (Group WR). The base presentation without subtitles provided a web-based, narrated animation (Group WOR). Each was posted on the web. Figure 1 is a graphic depicting the difference between the two presentations.

Instruction with redundant subtitles (WR) Instruction without redundant subtitles (WOR)

Figure 1. Screen shots of instruction

5.4. Statistical Analysis

Independent samples t-tests were conducted to analyze the quantitative data obtained. To address the first hypothesis and ascertain whether individuals with higher self-rated scores of ADHD symptoms will have lower recall scores using the multimedia presentation with redundancy than those that used the multimedia presentation without redundancy, a t-test of the mean recall score between the groups with redundancy (WR) and without redundancy (WOR). Similarly, to address hypothesis 2, a t-test was applied to determine whether the transfer scores for individuals using the multimedia presentation with redundancy is statistically significantly lower than those individuals who used the multimedia presentation without redundancy. For hypothesis 3, a t-test was also conducted to ascertain whether the redundancy group self-reported higher levels of mental effort.

The initial number of respondents in this study was n = 34 (redundancy group WR = 22 and the group without redundancy WOR = 12). After careful inspection, the known outliers consisting of respondents who had not completed the survey created unlikely patterns in the dataset. So, 3 data points from the group with redundancy (WR) and 2 data points from the group without redundancy (WOR) were removed (Triola, 2004). As a result the final sample size consisted of 29 subjects (n = 29); the group with redundancy (WR) consisted of 19 participants and the group without redundancy (WOR) consisted of 10 individuals.

Since the sample size was relatively low, the bootstrapping approach illustrated in Preacher and Hayes (2008) was utilized before conducting the statistical analyses. Bootstrapping consists of repeatedly sampling the data set (Efron, 1982). One of the main characteristics of this procedure is that it is not necessary to assume that the sampling distribution is normal. Bootstrapping offers several advantages over other methods (e.g, causal steps approach, Sobel test) as it yields higher power, better confidence interval placement, and a more precise Type I error (Preacher & Hayes, 2008; Williams & MacKinnon, 2008).

6. Results

The following results are described in terms of the three research hypotheses:

Table 1. Group Mean Scores Original Sample

		Recall	Transfer	ME*	ADHD-SR*
	n	*M*	*M*	*M*	*M*
WOR**	10	6.7	1.7	3.8	18.9
WR**	19	6.61	2.21	3.58	16.26

*ME= Mental Effort; ADHD-SR = Attention Deficit Hyperactivity Symptoms Rating
** With redundant subtitles (WR), without redundant subtitles (WOR).

Table 2. Group Mean Scores Bootstrapped Sample

		Recall	Transfer	ME*	ADHD-SR*
	n	*M*	*M*	*M*	*M*
WOR**	1000	6.73	1.69	3.78	18.9
WR**	1000	6.25	2.20	3.58	16.4

*ME= Mental Effort; ADHD-SR = Attention Deficit Hyperactivity Symptoms Rating
** With redundant subtitles (WR), without redundant subtitles (WOR).

Within the two table of group means, it can be observed that the mean for the bootstrapped sample is almost equal to the mean of the original sample in the non-redundancy group suggesting that the bootstrapped sample is similar to the original sample (Efron & Tibshirani, 1994). The mean transfer score for the redundancy group (WR) was higher than that of the non-redundancy group (WOR). The mean recall score for the redundancy group (WR) was lower than that of the non-redundancy group (WOR). The mean score for mental effort (ME) was lower for the redundancy group (WR) than for the non- redundancy group (WOR). The non-redundancy group was associated with a mean ADHD symptom rating M = 19.15 (SD = 3.76); compared to a numerically lesser ADHD symptom rating for the redundancy group M= 16.25 (SD = 2.40). An independent samples t-test was conducted to test the hypothesis that the non-redundancy group and the redundancy group had statistically significantly different mean ADHD symptoms ratings. In addition, the variances were assumed to be equal; Levene's F test yielded: F(1998) = 187.24, $p < 0.05$. A statistically significant difference between the two groups was obtained, t(1998) = 20.53, ($p < 0.05$). .

6.1. Recall

Hypothesis one considered recall, which was measured by scoring a series of multiple-choice questions. The recall variable was based upon a total possible score of 9 points on content-based multiple-choice questions. Given the findings of Chandler and Sweller (1991), it was hypothesized that recall would be negatively impacted given redundant subtitles. The results revealed that hypothesis 1 could not be rejected as the mean recall score for the redundancy group (WR) was statistically significantly lower than that of the non-redundancy group WOR ($p < 0.05$). With the assumption of equal variances; Levene's F test yielded: F(1998) = .208, p = 0.648. A statistically significant effect was obtained, t(1998) = 16.44 ($p < 0.05$). As a result, it was concluded that the non-redundancy group had statistically significantly greater recall than the redundancy group even though the non-redundancy group self-reported higher symptoms of ADHD. Further, the effect size was moderate as Cohen's d was estimated to be 0.74.

6.2. Transfer

Hypothesis two considered transfer which was based upon three open-ended transfer questions with three possible points. Given the findings of Mayer and Anderson (1991), it was hypothesized that transfer scores for the redundancy group (WR) would be negatively impacted given multimedia instructional materials. The results revealed that the mean transfer score for the redundancy group (WR) was statistically significantly higher that of the non-redundancy group (WOR). Therefore, the null hypothesis of no significant difference between the two populations was rejected, ($p < 0.05$). The results contradicted the hypothesis that transfer is negatively impacted by the addition of redundant subtitles. These results are explained by the non-redundancy (WOR) group reporting higher levels of ADHD symptoms. Levene's F test yielded: F(1998) = 362.63, ($p < 0.05$). Assuming equal variances, the results show a statistically significant difference between the means of the two groups, t(1998) = -40.11, ($p < 0.05$). The results revealed that the non-redundancy group had a lower mean transfer score than the redundancy group; the effect size was large as Cohen's d was estimated to be 1.79.

Hypothesis three referred to mental effort (ME); an independent samples t- test was conducted between the redundancy (WR) and non-redundancy (WOR) group. Based on the findings of Moreno (2004), it was hypothesized that removing redundant subtitles would decrease the level of mental effort (ME). However, this was not the case since the results showed that the mean score for mental effort was statistically significantly lower for the redundancy group (WR), ($p < 0.05$). Levene's F test yielded: F(1998) = 77.73, $p < 0.05$. A statistically significant difference between the means of the two groups was obtained, t(1998) = 11.25, ($p < 0.05$). As a result, it was concluded that the non-redundancy group reported statistically significantly higher levels of mental effort. It was expected that those receiving non-redundant subtitles would report lower levels of mental effort (ME). These results can be explained by higher levels of ADHD symptoms reported in the non-redundancy group. The effect size was moderate as Cohen's d was estimated to be 0.50.

The questionnaire included a 9-point Likert-scale mental effort rating, which was first described by Paas and van Merriënboer (1993). As in prior cognitive load studies (Chandler & Sweller, 1996; Kalyuga, Chandler, Tuovinen, & Sweller, 2001; Paas & van Merriënboer, 1993; Paas, Tuovinen, Tabbers, & van Gerven, 2003) this question was included to measure the learners' perceived mental effort (ME) of their instructional condition.

In light of the results obtained, a regression analysis was performed on each group separately to discern the effects of the level of ADHD symptoms on recall, transfer, and mental effort. The results indicated that ADHD symptoms ratings had a statistically significant effect on recall for both groups. For the redundancy group (WR), ADHD symptoms ratings account for l0.3 % of recall (R^2 = 0.1033); and for the non-redundancy group ADHD symptoms ratings accounted for 9.4 % of recall (R^2 = 0.094).

Similarly, the results of the regression analysis conducted on the original data revealed that higher ratings of ADHD symptoms resulted in lower transfer scores. For the redundancy group (WR) ADHD symptoms accounted for 1.75 % of transfer (R^2 = 0.0175); and for the non-redundancy group (WOR), ADHD symptoms ratings accounted for 9.43% of recall. The negative impact of ADHD symptoms on transfer was higher for the non-redundancy group since they reported higher levels of ADHD symptoms.

Further, the results of the regression analysis supported the hypothesis that mental effort Increased as the level of ADHD symptoms increased (R^2 = 0.0686) suggesting that ADHD symptoms account for almost 7 % of mental effort. For the redundancy group (WR) ADHD symptoms had virtually no effect on mental (R^2 = 0.0002). However, for the non-redundancy group (WOR) ADHD symptoms ratings explained 52.5% of mental effort (R^2 = 0.5252) suggesting that mental effort increases significantly with higher ratings of ADHD symptoms.

7. General Discussion

Universal design principles suggest that providing multiple means of accessing presentations increase access to the instruction by individuals with a wide variety of disabilities. Individuals with ADHD are thought to benefit from the various forms of presentation because they process visual and audio information slower than those individuals without ADHD due to deficits in the phonology and visuospatial memory (Alderson, Hudec, Patros, Kasper, 2013). Visuospatial memory deficits appear to be more stable and persist into young adulthood (Alderson, et al., 2010; Ewijk, et al, 2013).

Multimedia instruction relies on the ability to simultaneously process information through the visuospatial sketchpad and phonological loop. The results show that individuals with higher ratings of ADHD symptoms struggle with the processing of information. The results also reveal that redundant subtitles within animation may affect an ADHD learner's ability to process the instruction as both mental effort and transfer are negatively impacted.

The current study replicated several historically important multimedia learning and redundancy studies (Mousavi et al., 1995; Mayer & Johnson, 2008; Moreno & Mayer, 2002). The current study evaluated the impact of ADHD symptoms on recall, transfer, and mental effort in a multimedia learning environment. A relatively small group of individuals (*n* = 4) or about 14% scored high enough on the ADHD subscale to have symptoms consistent with ADHD. From a survey response perspective, this was a relatively good response given an estimated 11% of the population within the United States has been reported as having ADHD (Visser et al., 2014).

The results show that mental effort increases as symptoms of ADHD increase and transfer decreases as ADHD symptoms ratings increase. Further, recall scores were negatively affected by the presence of redundant subtitles within the multimedia environment. The outcomes of the quantitative analyses revealed that the effects of ADHD on mental effort and transfer are more severe for the non-redundancy group as they reported higher levels of ADHD symptoms. However, the results of the regression analysis within both the redundancy and nonredundancy groups as well as the results of the independent samples t-test for the recall variable support the redundancy principle. Contrary to hypotheses 2 and 3, participants using redundant subtitles had lower scores on mental effort than the non-redundancy group, and their average transfer score was higher. Transfer questions introduced an additional complexity by requiring learners to apply information. However, participants who received redundant subtitles did very well on average relative to their peers and were able to retain the information and transfer that knowledge when they needed to apply that information. This seems to indicate that the non-redundancy group had slower processing of the visuospatial and phonological memory. This impacted their ability to process and transfer information.

Overall, those who received redundant subtitles performed better than those who did not. Given each of the variables measured in this study (recall, transfer, and mental effort) we recommend the removal of or the ability to turn off redundant subtitles, since the regression analysis within the redundancy group show that transfer and mental effort are affected by the level of ADHD symptoms. Strategies should be developed to balance the need for including subtitles as recommended in 508 compliance for instructional presentations with the needs of typical learners and those with ADHD who do not necessarily benefit from the inclusion of subtitles (Section 508, 2014).

For typical learners, Sweller and others have noted that “the best instructional design is one that eliminates redundancy or at the very least, allows learners to ignore the redundant material because it is separated from more relevant information” (Sweller et al., 1998, p. 284). Based upon these results, of the application of the universal design principle of multiple means of representation, it is suggested that all learners have control of redundant subtitles and be able to turn them off to accommodate differences in the processing of information through visuospatial and phonological memory.

This study has some limitations because of the small number of participants within the ADHD subgroups. Results should not be generalized to learners with or without ADHD. The study only indicates a pattern that should be explored further through replications of this study. In future studies, efforts should be undertaken to ensure a balance in ADHD symptoms ratings between the redundancy and non-redundancy group. Further, other patterns also could be explored by analyzing the data based upon the different subtypes of ADHD of hyperactivity and impulsivity to determine if the neurobiological process of the subtypes interact differently with the multimedia instructional presentation.

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