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UNIVERSITY OF NORTHERN COLORADO

Greeley, Colorado

The Graduate School

SEDUCTIVE DETAILS IN EDUCATIONAL
MATERIALS: EXPLORING ATTENTION
DISTRACTION USING
EYE-TRACKING

A Dissertation Submitted in Partial Fulfillment
of the Requirements for the Degree of
Doctor of Philosophy

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College of Educational and Behavioral Sciences
School of Psychological Sciences
Educational Psychology

August 2019

This Dissertation by: Matthew A. Swaffer

Entitled: *Seductive Details in Educational Materials: Exploring Attention Distraction Using Eye-Tracking*

has been approved as meeting the requirements for the Degree of Doctor of Philosophy in the College of Education and Behavioral Sciences in the School of Psychological Sciences, Program of Educational Psychology.

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ABSTRACT

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Current advances in technology allow for a great deal of learning intervention materials to be designed by teachers. An active body of research is being conducted on how information is processed from these materials which are often created using electronic media. The design of these materials often includes interesting but irrelevant details which may detract from learning. These are termed “seductive details” and the impact of these inclusions in learning materials is not yet fully understood. Developing a better understanding of what factors play a role in the damaging effects of seductive details can help in the design of learning materials. The primary cognitive explanations to date for the impact of seductive details include working memory capacity (WMC) and distracted attention. These elements do not fully explain the variation in results from prior studies. A primary goal of this study was to explore if the emotional salience of seductive details could help explain whether and how seductive details detract from learning. This experimental study was conducted with 39 undergraduate university students. The design accounted for WMC and directly measured visual attention using eye-tracking. Eye-tracking devices allow for empirical measures of how much time a learner spends attending to seductive details versus pertinent learning materials. The study provided little evidence to suggest the seductive details used in the materials

detracted from learning. The evidence suggests learners visually attend to seductive details when they are present, and they are more likely to attend to emotionally salient seductive details than neutrally valenced details.

TABLE OF CONTENTS

CHAPTER

I. INTRODUCTION	1
Background	1
Research Focus	3
Value of Research	4
Research Questions	4
Chapter Summary	5
II. REVIEW OF LITERATURE	7
Working Memory	7
Multi-Store Memory Model: Atkinson and Shiffrin	8
Multiple Component Working Memory Model: Baddeley and Hitch	11
Activation, Attention and Expertise Working Memory Model: Cowen ...	14
Working Memory Capacity	16
Attention	18
Feature Integration Theory: Treisman and Gelade	20
Guided Search Theory: Wolfe	23
Attentional Engagement Theory: Duncan and Humphreys	24
Biased Competition Theory: Desimone and Duncan	25
Active Vision Attention Model: Findlay and Gilchrist	26
Flaws in the Visual Search Paradigm	27
Seductive Details	28
Background	28
Impact of Seductive Details on Learning	28
Seductive Details and Visual Attention	30
Seductive Details and Working Memory Capacity	32
Emotional Salience	34
Background	34
Emotion and Attention	35
Emotion and Working Memory	38
Eye Tracking: Measuring Attention	40
Chapter Summary	40
III. METHODOLOGY	42
Participants	42
Measures	43

Measurement of Emotion in Seductive Details	43
Working Memory Capacity.....	44
Prior Knowledge	45
Demographic Information.....	45
Research Design.....	46
Sample Size.....	47
Materials	47
Intervention	47
Reading Span and Operation Span	49
Recall and Transfer Assessments	50
Procedure	51
IV. RESULTS	53
Research Question One.....	53
Research Question Two	56
Research Question Three	56
Research Question Four.....	61
Research Question Five	63
Chapter Summary	65
V. DISCUSSION.....	67
Review of Purpose and Method.....	67
Research Questions	68
Research Questions 1 & 2.....	68
Research Question 3	69
Research Question 4	70
Research Question 5	70
General Discussion	71
Future Directions	72
Conclusion	73
REFERENCES	74
APPENDIX	
A. EXAMPLE STUDY MATERIALS	89
B. EXAMPLE EMOTIONAL MATERIALS USED	95
C. EXAMPLE ASSESSMENT ITEMS.....	100
D. INSTITUTIONAL REVIEW BOARD APPROVAL AND INFORMED CONSENT	104

LIST OF FIGURES

Figure 1. Boxplot of AOI hit rate by treatment.....	58
Figure 2. Mixed GLMM model.	58
Figure 3. Histogram of random effects from GLMM.....	59
Figure 4. Q-Q plot of effects from GLMM.....	59
Figure 5. DHARMA model fit output Q3.....	60
Figure 6. Mixed GLMM model with WMC.	61
Figure 7. WMC histogram, boxplot, and cumulative frequency	61
Figure 8. DHARMA model fit output Q4.....	62
Figure 9. Multiple linear regression model.....	63
Figure 10. Scatterplots between IVs and DV for multiple linear regression	64
Figure 11. Scatterplot of fitted values against standardized residuals	65
Figure 12. No seductive details sample image from “How Lightning Forms”.	90
Figure 13. Neutral seductive details sample image from “How Lightning Forms”.	90
Figure 14. Emotional seductive details sample image from “How Lightning Forms”.....	91
Figure 15. No seductive details sample image from “Causes of Ice Ages”.....	92
Figure 16. Neutral seductive details sample image from “Causes of Ice Ages”.....	93
Figure 17. Emotional seductive details sample image from “Causes of Ice Ages”.....	94
Figure 18. Negatively valenced image.....	96
Figure 19. Negatively valenced image.....	96
Figure 20. Negatively valenced image.....	96
Figure 21. Negatively valenced image.....	97
Figure 22. Positively valenced image.	97
Figure 23. Positively valenced image.	97
Figure 24. Image subset density curves for arousal.....	98
Figure 25. Image subset density curves for valence.	98
Figure 26. ANEW word subset density curves for arousal and valence.	99
Figure 27. Sample of questions from Qualtrics for “How Lightning Forms”.	101
Figure 28. Sample of questions from Qualtrics for “Causes of Ice Ages”.	102
Figure 29. Sample of questions from Qualtrics related to prior	103

LIST OF TABLES

Table 1. Valence and Arousal Scores from the ANEW Database	99
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CHAPTER I

INTRODUCTION

Children entering educational institutions today have increasing access to computing devices. According to the nonprofit organization Project Tomorrow (2013) 61% of 3rd grade students have a personal laptop, 27% have access to a school-provided laptop and this group is more likely to have a personal tablet device (44%) than 12th graders (40%). The proliferation of computers and tablet devices in educational contexts provides new and different forms of information presentation that were not readily accessible in the past. Educators can easily design rich visual representations both for classroom presentations as well as online interventions. Research providing insights into the best methods for designing these visual aids has been ongoing for decades but is perhaps more important now in this age of proliferation than ever. Research in this area addresses a variety of topics including modality selection, information design principles, interactivity, and the seductive details effect.

Background

The area of research the current study addresses is the seductive details effect. This describe the condition of adding non-relevant but interesting details to text or visual learning interventions. Writers and teachers strive to make content more stimulating by including intriguing tidbits of information loosely related or even unrelated to the core concept of the lesson. The hope is to increase learning through heightened interest;

however, these details often “seduce” the learner’s attention away from the main topic. Early research into the seductive details effect intuitively demonstrated a positive effect on learning when non-salient, thought-provoking details were added. This early research focused on interestedness of content and found higher levels of comprehension and free recall when learners reported higher levels of interest (Hidi, 1990). More recent research has focused on negative impacts to learning. These studies more narrowly focused on asking specific questions of the learner so rather than asking questions of the form “what do you remember?” questions are of the form “do you remember the main point of the content?” Under these conditions, seductive details have been found to inhibit learning to varying degrees. Rey (2012) conducted a meta-analysis of seductive details research which suggested the proposed explanations for inhibited learning do not account for enough of the variation in the results. Understanding the mechanisms by which seductive details can impair learning provides a potential source of influences on seductive details. The relevant mechanisms of seductive details are visual attention and working memory capacity.

The role of visual attention in harmful seductive details has been the subject of numerous studies. Harp and Mayer (1998) introduced the distraction hypothesis by which seductive details are damaging to learning because they gain and hold a student’s selective attention. Lehman, Schraw, McCrudden, and Hartley (2007) refined and extended this line of research by taking into account the amount of time spent reading both the base text (non-seductive material) and the seductive details material in order to account for variations in selective attention. Rey (2014) conducted an eye tracking study incorporating a measure of selective attention to address the addition of seductive details

in images as well as text. The above research represents details learners attended to visually. Working memory capacity presents another perspective of attention as it relates to details learners attend to through cognitive processing.

The role working memory capacity (WMC) plays in how seductive details damage learning is seen as two-pronged: limited information processing capacity and limited attention control. Related to limited information processing capacity, measures of WMC have correlated with reading comprehension and various components of the reading process (Daneman & Carpenter, 1980; Just & Carpenter, 1992; Turner & Engle, 1989; Waters & Caplan, 1996). The limited attention control perspective presents WMC as the ability to delineate between relevant and irrelevant information (ignoring the latter) by controlling attention (Conway & Engle, 1994). In this view, the resource of working memory is not governed by a limit on the amount of information processed but rather ability to control which information is attended to while processing.

The emotional salience of seductive details is a possible moderator to explain some of the range of results of the evidence, specifically as an inhibitor of working memory and attention. Attention and emotion interact during information processing and learning as evidenced by reaction time studies. Working memory and emotion have been shown to interact using brain imaging studies. Both attention and working memory are key cognitive processes in understanding the role of seductive details as they relate to learning outcomes.

Research Focus

Rey (2012) identified four main theories researchers have put forward to explain the negative impact of seductive details on learning: overloading working memory

(Garner, Gillingham, & White, 1989; Mayer, 2009); attention distraction (Harp & Mayer, 1998); schema interference (Harp & Mayer, 1998; Lehman et al., 2007); and inhibiting main idea transition (Harp & Mayer, 1998; Mayer, Griffith, Jurkowitz, & Rothman, 2008). In addition to identifying these theoretical models, Rey suggested future studies should consider distinguishing features of the seductive details themselves as potential explanatory factors and he indicated a need for more eye-tracking studies to be included in future research. The current study analyzed the impact of the emotional salience of seductive details on attention and learning outcomes using an eye-tracking methodology, controlling for working memory capacity.

Value of Research

Since Rey's (2012) meta-analysis, a handful of studies related to seductive details have utilized eye-tracking. Few studies have been conducted relating emotion to seductive details. Lehman et al. (2007) included emotional interest on the part of the participant as a variable but did not consider the emotional content of the seductive details in their eye-tracking study. Educators, instructional designers, and textbook editors designing materials and selecting images and words for inclusion will benefit from understanding the potential impacts of emotional salience on learning outcomes if the inclusions are in the form of non-relevant but interesting, seductive details.

Research Questions

The following research questions are addressed in the current study:

- Q1 Does the presence of seductive details in materials have a negative effect on recall and transfer learning? (replication of previous studies)
- Q2 Does the presence of emotionally salient details in materials influence the level of the negative effect on recall and transfer learning more than non-emotionally salient details?

- Q3 Do learners attend more to emotionally salient seductive details than non-emotional?
- Q4 Does WMC predict the level of attention given to emotionally salient seductive details?
- Q5 Does WMC interact with the amount of time spent viewing seductive details to explain performance on the outcomes of recall and transfer learning?

Chapter Summary

The current study addressed the stated research questions which in turn fill gaps in the literature as suggested by Rey (2012). Specifically, the study utilized the theoretical foundations identified in the literature as outlined by Rey to address the distinguishing features of seductive details that may explain impacts on learning. Further this study utilized eye-tracking as suggested to gather empirical evidence of visual attention. This research will help educators and instructional designers understand better how to design and create educational interventions with the greatest potential for learning.

Children, university students, and educators today have increasing access to computers and tablets. This presents opportunities to create educational interventions including seductive details which are interesting but non-relevant text or images. Seductive details are known to reduce learning to some degree, but the specific mechanism is not well understood. Understanding this better can help educators create better educational interventions which may include interesting details that may not be harmful to learning. The role that working memory and visual attention play in seductive details and learning is evidenced in previous studies. Understanding elements that interact with these constructs may uncover further evidence to help explain how seductive details interfere with learning. Emotional valence was included for the current study as a

potential construct that interacts with both working memory and visual attention. The current study utilized eye-tracking to measure visual attending to emotional details as well as measures of working memory capacity to understand the role of seductive details in learning outcome differences.

CHAPTER II

REVIEW OF LITERATURE

The theoretical foundations of seductive details are working memory and visual attention. This chapter outlines the essential literature related to the working memory models specifically as they relate to attention, namely: multi-store memory model; multiple component working memory model; and the activation, attention and expertise working memory model. In addition, a short review of working memory capacity will cover how this construct is related to the current study. Next, visual attention theories are explored including: feature integration theory, guided search theory, attentional engagement theory, biased-competition theory, and the active vision attention model. A short review of the criticisms of the visual search paradigm is also included. In the following sections, a review of seductive details, emotional salience, and eye-tracking are surveyed.

Working Memory

In his review of working memory, Logie (1996) outlined seven distinct “ages,” or models, of working memory in the cognitivist tradition, with working memory viewed: as contemplation (Locke, 1690); as primary memory (James, 1890); as short-term memory (Atkinson & Shiffrin, 1968); as processor (Craik & Lockhart, 1972); as constraint on language comprehension (Daneman & Carpenter, 1980; Just & Carpenter, 1992); as activation, attention, and expertise (single, flexible model) (e.g., Cowan, 1995; Ericsson

& Pennington, 1993); and as having multiple components (Baddeley, 1992; Baddeley & Hitch, 1974). The various models are useful in explaining different aspects of human cognition; however, for the present purpose of understanding how potentially distracting images and words are processed, the short-term memory model, the activation, attention, and expertise model, and the multiple components model are the most relevant.

Two of these models focus on the structural elements of memory and recall with implications on how the brain stores and retrieves verbal information and visual images. Atkinson and Shiffrin's (1968) multi-store memory model and Baddeley and Hitch's (Baddeley, 1998; Baddeley & Hitch, 1974) working memory model explore and explain how knowledge is stored after perception and before long-term storage. The activation, attention, and expertise model of working memory focuses on the aspects of visual and verbal information that activate and capture attention. Each of these models has important implications for working memory capacity and the study of visual and verbal learning from multi-media interventions with seductive details.

**Multi-Store Memory Model:
Atkinson and Shiffrin**

Not all models of memory include multiple, separate storage mechanisms (e.g., Melton, 1963) but the framework proposed by Atkinson and Shiffrin (1968) was among the first to identify and operationally define the sensory register, short-term store (STS), and long-term store (LTS). The STS was thought to consist of a single, flexible structure, albeit separate and distinct from the LTS. Atkinson and Shiffrin's multi-store model complemented the long-standing terms in psychological literature of short-term memory (STM) and long-term memory (LTM), terms that Atkinson and Shiffrin considered important constructs, yet separate and distinct from their formulation of STS and LTS.

STM and LTM were generally used to describe the length of retention intervals and broadly defined limits of memory. STS and LTS on the other hand were defined as theoretical storage structures with specific capacity limits and decay rates. Thus, STM and LTM were constructs used to identify varying strength levels of recall whereas STS and LTS were constructs used to identify different storage mechanisms. The essence of the multi-store memory model lies in the transfer of information from sensory register to STS then to LTS. The transfer of information from one store to the next was explained as a probabilistic function of time; thus for example, the longer information is present in STS, the greater the probability it will be transferred to LTS. Empirical studies showed both STS and LTS were utilized during measures of LTM and confirmed that control processes such as rehearsal hold information in STS longer leading to greater probability of transfer to LTS (e.g., Phillips, Shiffrin, & Atkinson, 1967). Transfer of information in this model does not imply movement of information but rather the copying of information from one store to the next as demonstrated in the early experiments in support of the model (Atkinson & Shiffrin, 1968).

The initial experiments demonstrating the separate nature of STS and LTS, as well as the proposal that time spent in STS increased the likelihood of being transferred to LTS, were conducted by Phillips, Shiffrin, and Atkinson (1967). Participants were presented with a series of between three and seven color-coded cards of varying colors in sequence. After each card was presented, it was placed face down on the table in the order of presentation. Once all the cards had been placed face down, the researcher pointed to one of the cards in the sequence and the participant would report the color they thought was on the face down side of the card. The researchers tested participants over

different positions in the card sequence over several trials, so they could detect the probability of a correct response as a function of position or, more importantly, time elapsed between the presentation of the card and the response. The probability of a correct response on the most recent card was 1: every participant responded correctly. However, the probability of correct recall rapidly decreased as the cards were older in time sequence. For the oldest cards however, the probability of correct recall rose slightly, creating a bow-shaped curve in the distribution. Overall the most recent cards had the highest probability of correct recall and the older cards had a much lower probability of correct recall, except for the oldest cards presented that had a slightly higher probability of correct recall than the cards presented just after. The authors believed these data fit their model for STS and LTS because the probability of information transferring from STS to LTS increases as a function of time. Thus, the increased probability of correct recall for the oldest card in the sequence was a result of this information being retrieved from LTS rather than STS. Other responses were retrieved from STS with the older cards retrieved from STS having lower probability of correct response and the most recent card having the highest probability of a correct response. These results appropriately modeled the predicted STS decay rate as well as the expected probabilistic transfer of information from STS to LTS (Phillips et al., 1967).

The framework as proposed focused almost exclusively on what the authors termed the auditory-verbal-linguistic stores as opposed to visual stores. Even so, when the initial model of STS and LTS was extended to include a sensory register that held information in modality-specific format for very short periods of time, visual images were observed to only remain for several hundred milliseconds (Shiffrin & Atkinson,

1969; Sperling, 1960). Early experiments focused on modality of information found information perceived through imagery resulted in enhanced recall from LTS in cued recall tests (Schnorr & Atkinson, 1969). Despite these findings, researchers using the STS / LTS model continued to focus on auditory-verbal-linguistic stores. Other researchers noticed a division between auditory and visual abilities in both sensory register and STS under dual task conditions (Kahneman, 1973; Treisman & Davies, 1973) but it was Baddeley and Hitch (1974) who extended the short-term memory model to explicitly separate verbal and visual processing.

Multiple Component Working Memory Model: Baddeley and Hitch

Where Atkinson and Shiffrin (Atkinson & Shiffrin, 1968) identified only a single short-term memory store in which information was stored with an auditory-verbal-linguistic format, Baddeley and Hitch (Baddeley, 1998; Baddeley & Hitch, 1974) expanded the model to include separate, modality-specific stores to account for empirical studies utilizing the dual-task paradigm. Dual-task techniques involve requiring a participant to perform a task that absorbs most of the capacity of their working memory while at the same time performing a second task that incorporates learning, reasoning, or comprehending, tasks that are all crucially dependent on working memory. If working memory consists of a unitary short-term store with a single representational (verbal/auditory) format then a task that absorbs most of the capacity of the store should inhibit performance of any other secondary task performed concurrently, regardless of secondary task modality. Empirical evidence suggested that the single short-term store model was inadequate to explain some findings from dual-task studies (Baddeley & Hitch, 1974; Salamé & Baddeley, 1982, 1989, 1990). The updated short-term memory

model, known as working memory, included a central executive that controls both a visuo-spatial sketch pad and a phonological loop, each separately enhancing STM (Baddeley, 1998). Traces in the STS mechanism fade rather quickly (one to two seconds); however, an articulatory control in the phonological loop continually refreshes phonological information and a separate visuo-spatial process acts similarly for both *what* (visual) and *where* (spatial) information relating to visual imagery. This model allows for separate storage and processing of visual images and verbal information in STS. Thus, Baddeley and Hitch's model predicted that if the primary and secondary tasks in a dual-task paradigm involve different modalities such as verbal and visual, then performance on the secondary task should not be inhibited.

Researchers conducted a number of experimental studies based on these predictions but Baddeley (1998) conceded the phonological loop was the most studied and most complete aspect of the proposed working memory model, likely because it was the simplest and built on several decades of verbal memory testing. For the study of seductive details, however, the experimental evidence surrounding the visuo-spatial sketch pad is relevant. The pioneering research regarding the use of visual imagery for learning was conducted by Brooks (1967), who devised a working memory task based on a grid that allowed for spatial memory performance. This initial study did not involve a dual-task component but rather focused on the verbal-visual nature of memory. The 4x4 grid had a path of sequential numbers that could be defined by sentences similar to the following:

In the starting space put a 1
In the next square to the right put a 2
In the next square beneath put a 3
...

The grid could also be filled in using nonsensical statements by replacing the spatial referent words *right*, *left*, *beneath*, and *above*, with *good*, *bad*, *quick* and *slow* resulting in sentences like:

In the starting space put a 1
In the next square to the good put a 2
In the next square quick put a 3
...

Participants were given several practice trials before the test trial to eliminate practice effects and then were tested to determine how many of the sentences could be remembered after presentation. Nearly all participants reported using visual imagery to complete the spatial task while resorting to rote memorization for the nonsense task. Both errors and performance times were lower in the spatial condition than in the nonsense verbal condition. In addition to the spatial and nonsense verbal conditions, researchers also varied the presentation of the sentences between visual (reading from cards) and auditory (being read to from cards). The interaction showed that in the spatial condition, auditory presentation elicited the best performance while in the nonsense verbal condition, visual presentation worked best. Brooks hypothesized the reading-spatial interference was due to reading using the same processing apparatus as spatial processing (Baddeley, 1998; L. R. Brooks, 1967). The interference between reading and spatial processing has formed the basis of Mayer's (2009) multimedia learning theory which distinguishes between textual presentation and image presentation of information.

Later experiments, based on the same tasks Brooks (1967) used, attempted to analyze the dual-task (reading – spatial) interference hypothesis by asking participants to perform the tasks under the original conditions as well as in combination with a pursuit tracking condition (Baddeley, 1998; Baddeley, Grant, Wight, & Thomson, 1975). The

pursuit tracking condition required a participant to track a spot of light following a circular track by keeping a stylus in contact with the dot. The difficulty of this task was controlled by varying the speed of the dot of light and the task was considered to interfere with the capacity of the visuo-spatial sketch pad. Results from this experiment demonstrated the pursuit tracking task interfered with the spatial condition but not with the nonsense verbal condition; a result consistent with the predictions of the phonological loop and visuo-spatial sketch pad model (Baddeley et al., 1975).

The key finding from the evidence related to the working memory model is the suggestion that merely processing both visual and verbal information simultaneously is not enough to interfere with performance. The addition of images to textual presentation in learning interventions should not limit recall performance on the basis of working memory alone.

Activation, Attention and Expertise Working Memory Model: Cowen

While Atkinson and Shiffrin as well as Baddeley and Hitch focused on the storage mechanisms, Cowan (1988, 1995) extended the work of Treisman (1964) who hypothesized that attenuation explained differences in working memory traces rather than storage capacity. Earlier models of processing by Broadbent (1957) proposed a filtering mechanism by which sensory information was either selected for or not selected for processing based on filtering criteria. This mechanism, however, implies there is no room for divided attention or parallel processing (Kahneman, 1973). Treisman proposed an alternate model in which signals activate portions of memory where, unless and until the signals reached a certain threshold, they would not reach perception (Treisman, 1964). These signals, of which there could many in parallel process, may be attenuated by

various analyzers. Some of the signals would still be raised to the level of perception while others would not due to attenuation. Thus either a change in the input signal itself or something in the significance of the signal to the perceiver could trigger the threshold of perceptual awareness (Cowan, 1995; Treisman, 1964).

An additional feature of Treisman's model which Cowan extended was the ability to have divided attention (Cowan, 1995; Kahneman, 1973). Individuals can easily divide their attention between various aspects or attributes of a given input (Lappin, 1967); however, they face great difficulty ignoring one aspect while focusing on the other (Stroop, 1935; Treisman, 1969). Treisman (1964) did not lay out the details regarding subconscious versus conscious processing in her model, however, Cowan (1988, 1995) proposed a model of attenuation which included supraliminal levels of activation. In this model of working memory, all incoming stimuli are processed and achieve some level of activation. Only some attenuated stimuli reach the level of conscious processing while others do not. This distinguishing feature of the model was the notion of STS as activated memory, with conscious processing the result of various levels of attenuation from several constructs such as focused directed attention and habituation leading to an orientation response which is only broken with novel stimuli.

Cowan's (1988, 1995) model was not concerned with differentiating storage mechanisms and thus modeled long-term and short-term memory stores as nested within one another. This model built on two long standing psychological concepts of memory as activation (Hebb, 1949/2002) as well as the concept of memory as attention (James, 1890). Memory as activation proposes the constraint of time as the limiting factor of working memory capacity as activation is not permanent. Memory as attention proposes a

constraint of total item count as the limiting factor of working memory capacity as attention is limited at any given moment. Together these constraints form the foundation of working memory capacity tests (Conway et al., 2005; Daneman & Carpenter, 1980; Turner & Engle, 1989).

Working Memory Capacity

Working memory capacity has been linked to reading comprehension (Daneman & Carpenter, 1980) as well as attention (Engle, Kane, & Tuholski, 1999) and processing visual imagery (Sanchez & Wiley, 2006). Given the nature of seductive details tasks, measures of working memory capacity are important to control for individual differences in performance.

Working memory capacity (WMC) is thought to play a role in learning from visual representations in part due to the dual-task processing required by information presented in images. The Baddeley (1998) structural memory model proposes an articulatory control in the phonological loop that continually refreshes phonological information and a separate visuo-spatial process that acts similarly for both *what* (visual) and *where* (spatial) information. This is consistent with and similar to Paivio's (1986) dual-coding theory delineating two modalities of perception and representation, verbal and nonverbal. The models differentiate in how they treat reading; where Baddeley (1975), Brooks (1967), Mayer (2009), and others considered reading to be a visual task, Paivio considered this a verbal rather than nonverbal task. In either perspective, processing on multiple channels based on modality produces multiple memory traces; however, the processing requires sufficient capacity in working memory.

Various measures for WMC have been proposed, including the operation span (OSPAN) which involves mathematical operations (Turner & Engle, 1989) and the reading span (RSPAN) which involves word recall from sentences (Daneman & Carpenter, 1980). Scores from these measures are considered to have excellent reliability including test-retest reliability and internal consistency with reliability estimates in the range of .70 - .90 for span scores in studies primarily consisting of university undergraduate students (Conway et al., 2005). Performance on span tasks in general and the OSPAN and RSPAN tasks specifically have been found to correlate with each other as well as a range of both higher order and lower level cognitive tasks presumed to be related to WMC indicating good convergent construct validity (Conway et al., 2005).

In a study linking WMC to image processing which utilized the dual-task paradigm, Gyselinck, Cornoldi, Dubois, De Beni, and Ehrlich (2002) presented texts dealing with basic science concepts (e.g., static electricity, gas properties etc.) to learners, some including illustrations, some not. Prior to the intervention, participants were tested for spatial WMC and randomly assigned to either the text only or text plus illustration condition. While reading the text or text plus illustration, participants engaged in one of three concurrent tasks: tapping a spatial pattern; repeating a series of syllables; or a control task. Results indicated participants engaged in the spatial pattern concurrent task had impaired comprehension in the text plus illustration condition but not in the text only condition. Further analysis indicated that participants who scored high in spatial working memory benefited most from the text plus illustrations condition, but their performance was most inhibited by the concurrent spatial pattern task. These results indicate that spatial WMC plays a role in processing images during learning tasks.

In another study linking both reading and image processing to WMC that examined the effects of seductive details on learning from images and text, Sanchez and Wiley (2006) used WMC as a prescreen for participants as measured using the operation span (OSPAN) and reading span (RSPAN) tests. Seven hundred forty-six undergraduates were prescreened for inclusion in the experiment. Two groups were selected, a high WMC and low WMC group, with 36 participants in each group. Participants in these groups were randomly assigned to one of three conditions: text only, relevant illustrations, or seductive illustrations. Results indicated that WMC alone did not impact performance; however, participants with low WMC demonstrated much lower performance with the presence of seductive details. One explanation offered by the authors is that low WMC individuals focus less on relevant details causing a less developed understanding of the material.

Attention

Attention has been a long-studied construct in psychology. Titchener (1908, p. 173) contended "...the doctrine of attention is the nerve of the whole psychological system, and that as men judge of it, so shall they be judged before the general tribunal of psychology." For a period of time in the early history of psychology, the study of attention fell by the wayside when the Gestalt theorists and Behaviorists were only concerned about inputs and outputs rather than describing behavior (Kahneman, 1973). Towards the end of the 1950s there was a revival of interest in the topic of interest and a number of new theories came about (see, Broadbent, 1957; Kahneman, 1973; Treisman, 1964). As seen above, there is overlap between working memory and attention as the stimuli that are attended to interact with the information that is encoded for recall.

Attention encompasses cognitive processes related to all sensory information but the most relevant for the present study is visual attention.

At the heart of visual attention is the human eye. The human eye allows light to shine through the pupil and focuses an image on the retina, the center of which is called the fovea. The fovea has a high concentration of cones, which are the light-sensitive cells most sensitive to high-spatial frequency light which provides high levels of visual detail and color vision (Holmqvist et al., 2011). The fovea only covers about 2° of the field of vision. Since foveal information is prioritized in the visual cortex, increasing linearly, with eccentricity from the center from $0.15^\circ/\text{mm}$ cortical matter at the fovea to $1.5^\circ/\text{mm}$ at an eccentricity of about 20° , this results in roughly 25% of our visual cortex processing coming from about 2.5° of the visual scene (De Valois & De Valois, 1980; Holmqvist et al., 2011). This area represents the focus of our visual attention. The physical structure of the eye lends support to the “spotlight” model of visual attention which posits attention has a focus, a margin, and a fringe (Eriksen & Hoffman, 1972; James, 1890; LaBerge, 1983; Posner & Cohen, 1984; Posner, Snyder, & Davidson, 1980). The main idea behind this metaphor for visual attention is that the spotlight can be expanded or contracted in size to include a larger or smaller area of attention. An alternate model to the spotlight model is the “zoom lens” model in which focusing on some particular stimuli “zooms in” on that object which effectively crowds all others in the visual field out of attention while zooming back out allows for other stimuli to come back into focus again (Eriksen & James, 1986). Both models are based on empirical evidence concentrated on arranging stimuli in circles around a fixation point. Alternate models of visual attention focused more on holistic comprehension of visual scenes.

**Feature Integration Theory:
Treisman and Gelade**

Feature integration theory was one of the early theories that sought to explain visual scene processing and attention and has remained an influential way of organizing subsequent theoretical explanations. The theory posits two separate processes: an early, automatic, and parallel process in which features are detected; and a separate, late, focused attention process in which objects are identified (Treisman, 1988; Treisman & Gelade, 1980). Under this theory, the entire visual scene is processed subconsciously and coded along several dimensions or “activation maps” such as color, orientation, spatial frequency, brightness, movement etc. These features are coded separately and only combined when they are present in a fixation of focused attention. Features combined in this way form objects in which features may be conjunctive. For example, the feature circle and the feature red combine to become the object “a red circle,” but only when those features are present in the same area of focused attention. Once features have been combined into an object, they are encoded in working memory as such and are subject to memory decay or interference at which point the features may disintegrate, float free, or recombine to form “illusory conjunctions” (Treisman & Gelade, 1980; Treisman, Sykes, & Gelade, 1977). The concept of focused attention conjoining features into objects is similar to the spotlight metaphor view of attention and implies that focused attention cannot be split into two different areas of a visual scene at once even though the area of the spotlight can expand or contract (Posner et al., 1980; Treisman, 1988).

The evidence to support the model comes from a series of experiments performed in labs using visual search paradigms. For example when participants search for a target defined by conjunctive properties (e.g., a green “T” among green “X”s and brown “T”s)

search latencies increased linearly as the number of distractor items increased (Treisman & Gelade, 1980; Treisman et al., 1977). When disjunctive targets were defined using separate features such as color and the presence of a curve (e.g., a blue letter or an “S” among green “X”s and brown “T”s), search latencies showed no systematic effect as the number of distractor items was increased or decreased. This evidence supports the idea that conjunctive properties must be searched for serially (e.g., one at a time) whereas disjunctive searches are conducted in parallel, presumably in the pre-attentive stage. According to the model, the disjunctive search should be accomplished when the target with the unique feature calls attention to its location (Treisman, 1988).

Pre-attentive visual scene processing is generally considered to occur between onset and 50 milliseconds for words and more complex scenes (see, Ionescu, 2016; Wickens, 1973) though under certain conditions conscious object recognition can occur in as little as 13 milliseconds (Potter, Wyble, Haggmann, & McCourt, 2014). One of the Treisman and Gelade (1980) experiments demonstrated feature detection occurs at time intervals just above perception (65 ms) while object recognition required more than six times that length (414 ms). Participants were shown a grid of letters in two conditions; disjunctive (feature detection) or conjunctive (object detection). The distractor letters were always pink “O”s and blue “X”s. In the disjunctive condition, the target was either the letter “H” in pink or blue or the color orange in the shape of an “X” or “O.” In the conjunctive condition the targets were pink “X”s and blue “O”s. Target positions were randomized within the array and participants were asked to identify the position of the target. The array was displayed tachistoscopically with a mask following by a fixation dot following but the array and another mask. The stimulus onset asynchrony (SOA) was

determined by the experimenter and regulated to keep accuracy at 80%. The large difference in times for reporting the location of the search target under the two conditions supports the hypothesis of a serial search for objects (attentive processing) and parallel search for features (pre-attentive processing; Treisman & Gelade, 1980).

Related to distractions in visual scenes, the evidence for illusory conjunctions is relevant to the current study. Treisman and Schmidt (1982) defined perception as constructing a temporary representation of entities, states, and events as specific locations and times, usually by matching stored perceptual information with incoming sensory data. In a series of experiments, they gathered evidence to support the hypothesis that features are sometimes incorrectly constructed into objects through faulty conjunctions due to attentional load. Using a tachistoscopic display, participants were presented cards with black digits above and below a series of colored letters. They were asked to report first the two digits and then the names and colors of the letters if possible. Digits were reported with only a 3% error rate indicating successfully forcing attention to the digits and dividing attention across digits and letters. Analysis of the letter responses indicated on average, once per trial, a participant would get either the letter or color in the correct position; however, would make an illusory conjunction and swap the letter or color from another location in the visual scene. At least some of these errors were considered to be perceptual illusions rather than memory errors (Treisman, 1988) giving rise to the question of how reliable memory traces are under divided attention conditions. Regardless of whether the illusory conjunction is a memory error or a memory trace resulting from a perceptual illusion, if the information encoded is not the information

contained in the visual scene, the person who has encoded the information cannot later recall accurate information.

The feature integration theory of attention provides a solid framework for the broad concept of selective attention. The focus of the model is the notion of an individual who is seeking out a particular feature or object (combination of features) in a visual scene. The speed and accuracy of the visual search are determined by the presence or absence and nature of distractors in the scene. What is missing from the model is variability in the nature of the search being conducted by the individual.

Guided Search Theory: Wolfe

Guided search theory extends the two stage model of Treisman and Gelade (1980) by providing a mechanism for cognitive control of the activation map (Wolfe, 1994). In the feature integration theory model, features activate in parallel and automatically (without conscious control). Guided search proposes individuals can combine features in a search and activate multiple feature maps simultaneously, effectively permitting cognitive control of the parallel processing activation maps. Wolfe (1994) distinguished between bottom-up (stimulus driven) and top-down (user driven) activation during visual search. Bottom-up activation is a measure of how novel or unusual an item or feature is in its present context. The strength of the activation is dependent on the differences in the item and neighboring features and is independent of the participants' prior knowledge or the goals of the search task. Top-down activation is focused on the goal of the search and is accomplished by selecting a broadly tuned channel based on the most likely feature to lead to a successful search. Irrelevant stimuli can interrupt this top-down cognitive control by capturing attention with novelty (Yantis & Johnson, 1990; Yantis & Jonides,

1990); however, guided search suggests that through feedback, participants can monitor their own performance and “weight” feature sets according to priority to eliminate these types of irrelevant stimuli (J. M. Wolfe, 1994).

The premise of the Guided Search Theory suggests attention is allocated on the basis of the two-fold processes interacting with one another. That is, the bottom-up feature maps present information from the stimuli that are relative (both feature level and parallel processed object level information) and the top-down cognitive control combines into a single activation map which results in a signal that indicates the likelihood of a target at each location in the visual scene (J. M. Wolfe, 1994). Attention is deployed across this activation map, shifting from signal peak to signal peak until the search target is found, beginning with the strongest signal and working through to the weakest signals. Examples of probable features for pre-attentive guidance under Guided Search Theory are color, orientation, luminance, motion, and number (J. M. Wolfe, 2005). Unlike Feature Integration Theory, Guided Search Theory suggests limited evidence to support novelty or color change as possible or probable features for pre-attentive guidance. In addition, and relative to the current study, threat is considered a probable non-feature for guidance under this theory (J. M. Wolfe, 2005).

Attentional Engagement Theory: Duncan and Humphreys

In a departure from the features and objects model of both Feature Integration Theory and Guided Search Theory, Duncan and Humphreys’ (1989) Attentional Engagement Theory model described a parallel processing stage of perceptual description which generates structural units of varying complexity. Like the other models, Attentional Engagement Theory utilizes a second stage of processing; however, in this model, the

second stage is attentional processing which is a resource limited stage engaged in directing attention based on probabilities and weights but not engaged in building any perceptual structures. Elements in the visual scene are weighted according to how well they fit an attentional template and that weight is then linked to other elements based on perceptual groupings within the scene (Duncan & Humphreys, 1989, 1992). A third segment of the process is described in this model as access to visual short term memory is described as either parallel or serial depending on the scope and duration of a given fixation on a visual scene, thus accommodating different amounts of information at different times (Duncan & Humphreys, 1989).

In the Attentional Engagement Theory model, the probabilities and weights that direct attention at the second stage of processing are linked both to directed attention and the visual elements in the scene. This is similar to the conceptual model of Guided Search theory however in the Attentional Engagement model, this weighting occurs in a resource limited stage of processing. Thus, prior goals or knowledge might override features of the visual scene or vice versa depending on the respective weights.

**Biased Competition Theory:
Desimone and Duncan**

In alignment with the resource limited stage of processing outlined in Attentional Engagement Theory, Desimone and Duncan (1995) proposed a neural mechanism to explain selective visual attention that relied on competition for scarce neuronal pathways while processing many objects in visual scenes. This competition is biased both by bottom-up neural mechanisms that separate figures from background and by top-down mechanisms that select relevant objects based on current behaviors. They proposed top-down selection templates derived from working memory that work on both the ventral

stream (object recognition) and dorsal stream (spatial mapping). According to this view, attention is not a spotlight, rapidly scanning for objects in the visual field but rather a slow, parallel and emergent pattern of resolving competition across the visual field.

Biased Competition Theory suggests as an individual attends to one object it is necessarily at the expense of another; thus, visual inputs that are favored and attended to are processed while others are lost (Desimone & Duncan, 1995; Duncan, 2006). This does not mean different parts of the same object compete for resources as the parts of the whole are processed in parallel (Duncan, 2006). In an extension of visual attention, Duncan (2006) proposed the “multiple-demand pattern” which suggests regardless the cognitive task, similar patterns of neural responses can be seen in imaging studies which indicates the brain is “attending” to these tasks even in the absence of visual stimuli (Duncan, 2006). These systems of attention have biased competition similar to that described for visual attention based on experimental imaging studies.

**Active Vision Attention Model:
Findlay and Gilchrist**

A common feature of many models of visual attention is the view that foveation (angling the eyes to focus on a particular object) is a by-product of attention. In other words, either the features of the object or top-down, bottom-up processing result in an attentional shift which requires the oculomotor function to shift the eyes to the new focus of attention. This concept, implicit in both the spotlight and zoom lens approaches as well as the attentional models outlined above, is referred to as covert attention. An alternate or extended view of attention is to view spatial selection and foveation as active components of attention (Findlay & Gilchrist, 2003). In this view, covert orienting is closely related to but does not drive overt saccadic selection indicating foveation is a product of feature-

based selection which in turn guides the eyes to behaviorally relevant items. This elevates foveation to an active rather than passive construct. This subtle distinction between foveation as active versus passive is useful in making clear the efficacy of eye-tracking in measuring attention. This view is not orthogonal to Guided Search Theory or Attentional Engagement Theory as both of these theories contain elements in which the individual is an active participant in guiding attention. The distinction of Findlay and Gilchrist's model (2001, 2003) is active guiding of attention is paramount and covert attention takes a back seat. This suggests evidence gathered from eye-tracking studies implicates active individual, focused, and selected attention.

Flaws in the Visual Search Paradigm

Treisman and Gelade's (1980) early modeling of attention as a two-stage process quickly became the accepted model in visual attention research. This model of attention arose from the evidence related to speed of locating features and objects as one possible explanation for the data; however, not all subsequent data matched this model closely (see, Schoonveld, Shimozaki, & Eckstein, 2007; J. M. Wolfe, Cave, & Franzel, 1989). Even so, the two-stage model of visual search processing was accepted both in the field of visual cognition as well as other areas such as clinical psychology for measuring attention to facial expressions for threat and Asperberger's syndrome as well as neuroimaging applications (Kristjánsson, 2015). Findings from reaction time measures utilizing the same stimuli but not requiring a response to the "target not found condition" (i.e., the Go-No Go paradigm) demonstrated different results from classic visual search paradigms used to justify the two-stage model of visual attention (Kristjánsson, 2015). This finding leaves open the possibility for alternate explanations for visual search

phenomenon. For example, Nakayama and Martini (2011) proposed pattern recognition as an alternate model for visual search. Wang, Kristjánsson, and Nakayama (2005) suggested perceptual organization might play a larger role in visual search than any of the previous models have allotted. While the alternate models of visual attention are useful for exploring various visual search phenomenon, the current study is grounded in the theoretical underpinnings of the two-stage model of visual attention with both the automatic feature-based and directed attention components being useful to help explain the phenomenon of seductive details.

Seductive Details

Background

The seductive details effect describes the condition of adding irrelevant but interesting details to text or visual learning interventions. Writers and teachers strive to make content more stimulating by including intriguing tidbits of information loosely related or even unrelated to the core concept of the lesson. The hope is to increase learning through heightened interest; however, these details often “seduce” the learner’s attention away from the main topic and research suggests mixed results with this technique. In the current study I seek to explain the role that the emotional salience of the extra details plays as a possible moderator to explain some of the range of results of this research related to learning. Specifically, I addressed the role of seductive details as an inhibitor of working memory and attention, which moderate learning.

Impact of Seductive Details on Learning

Early research into the seductive details effect intuitively demonstrated a positive effect on learning when non-salient, interesting details were added. This subset of

research focused on interestedness of content and found higher levels of comprehension and free recall when learners reported higher levels of interest (Hidi, 1990). This follows intuition as teachers often insert interesting tidbits of information either unrelated or only tangentially related to the main topic in order to retain the interest of students.

More recent research has focused on negative impacts to learning. Rey (2012) conducted a meta-analysis of seductive details research and found overall support for a negative impact on learning with a small to medium effect size for retention and a medium effect size for transfer performance. These types of learning more narrowly focus on asking specific questions of the learner so rather than asking questions of the form “what do you remember?” questions are of the form “do you remember the main point of the content?” Under these conditions, seductive details have been found to inhibit learning to varying degrees. Four main theories have been put forward to explain the negative impact on learning: overloading working memory (Garner, Gillingham, & White, 1989; Mayer, 2009); attention distraction (Harp & Mayer, 1998); schema interference (Harp & Mayer, 1998; Lehman, Schraw, McCrudden, & Hartley, 2007); and inhibiting main idea transition (Harp & Mayer, 1998; Mayer, Griffith, Jurkowitz, & Rothman, 2008). Inhibiting main idea transition can be seen as a special case of overloading working memory as the concept is related to readers linking ideas together in memory as they read. Schema interference can be seen as a special case of attention distraction, particularly in the Guided Search Model where a schema would serve as an activation map. Attention and working memory are themselves closely interrelated albeit distinctly measurable constructs (Baddeley & Hitch, 1974; Conway & Engle, 1994). These theories propose seductive details are a moderator of the impact of attention and

working memory on learning as measured by recall performance. Rey's (2012) meta-analysis proposed these moderators alone do not account for enough of the variation in the results, leaving a gap in the research. Understanding the mechanisms by which seductive details can impair learning provides a potential source of influences on seductive details. The relevant mechanisms of seductive details are visual attention and working memory capacity.

Seductive Details and Visual Attention

The role of attention in harmful seductive details has been the subject of numerous studies. Harp and Mayer (1998) introduced the distraction hypothesis by which seductive details are damaging to learning because they gain and hold a student's selective attention. Their study addressed this hypothesis by asking groups of students to read passages about the causes of lightning, one group with no seductive details, one with seductive details, and a third group with seductive details and the important information highlighted for the learner. Results indicated there was no difference in scoring between the seductive detail groups with highlighting and no highlighting. The researchers interpreted this to mean the seductive details did not sufficiently damage performance based on distraction of selective attention.

Lehman et al. (2007) refined and extended this line of research by taking into account the amount of time spent reading both the base text (non-seductive material) and the seductive details material in order to account for variations in selective attention. In addition, they expanded the outcome measure from 9 broad items to 52 idea units to gain a finer grained view of the learning of relevant concepts as opposed to irrelevant concepts, providing a broader range of scores and a more powerful test. Results from this

experiment indicated support for their reduced attention hypothesis, which predicted decreased reading time for base text sentences and reduced memory for base text information. Since the materials were normed for interest prior to the experiment, Lehman et al. concluded the results were due to reduced attention rather than an interaction effect of interest. A major limitation of this study however was the exclusion of images from the text, meaning the results generalize only to text-based interventions.

The addition of eye tracking technology to the field of attention research yields empirical data for analysis. Rey (2014) conducted an eye tracking study incorporating a measure of selective attention to address the addition of seductive details in images as well as text. In this study, participants were first measured for selective attention control using an anti-saccadic measure on an eye tracker. Next participants proceeded through the instructional material, also presented on the eye tracker, with the seductive materials delineated as Areas of Interest (AOI) for analysis. There was no correlation between selective attention control and total fixation time of text passage AOIs; however, there was a statistically significant correlation between selective attention control and total fixation time for seductive illustration AOIs. This result indicates learners with lower selective attention control are more likely to attend to seductive illustrations. Learning outcome results indicate participants receiving seductive textual details had poorer outcomes (small to medium effect sizes) on transfer learning and participants receiving seductive illustrative details also had poorer outcomes (medium effect size) on transfer learning as compared to participants in control groups. An interesting point of the overall analysis was when viewing selective attention control as a moderating effect of learning, it was only detected for seductive detail text passages and not for seductive illustrations.

The author conceded insufficient sample size and power ($n = 55$, 2×2 factorial design) might explain this learning outcome result considering the correlation with total fixation time reported above. In addition, the researcher concluded future studies should distinguish more precisely between different kinds and characteristics of seductive details.

The research outlined above represents details learners attended to visually. Visual attention is one of the two proposed mechanisms by which seductive details harm learning. Working memory capacity presents another mechanism and another perspective of attention as it relates to details learners attend to through cognitive processing.

Seductive Details and Working Memory Capacity

The role working memory capacity (WMC) plays in how seductive details damage learning is seen as two-pronged: limited information processing capacity and limited attention control. Related to limited information processing capacity, measures of WMC have correlated with reading comprehension and various components of the reading process (Daneman & Carpenter, 1980; Just & Carpenter, 1992; Turner & Engle, 1989; Waters & Caplan, 1996). Of particular interest is the construction and integration model of comprehension (Kintsch, 1988) which requires the reader to temporarily store chunks of constructed meaning temporarily while accessing new information to integrate into the model. In light of these models, learners with lower WMC presented with seductive details would be inhibited from syntactical or semantic processing of key elements of a learning intervention, potentially creating a poor representation of the material to be learned, consistent with the disruption and diversion hypotheses (Harp & Mayer, 1998). Alternately, the limited attention control perspective presents a special-

case of the selective attention control problem outlined above. In this view, WMC is the ability to delineate between relevant and irrelevant information (ignoring the latter) by controlling attention (Conway & Engle, 1994). In this view, the resource of working memory is not a limit on the amount of information processed but rather ability to control which information is attended to while processing.

Sanchez and Wiley (2006) pre-screened participants and selected a stratified sample of high WMC and low WMC participants for a seductive details study with text only, text with relevant images and text with seductive details images conditions. Results indicated high WMC participants performed significantly better in the seductive details condition than low WMC participants with no difference between the non-seductive and non-image groups. The lack of an overall effect of WMC was surprising given the large body of research suggesting WMC is important for text comprehension overall (Daneman & Carpenter, 1980; Just & Carpenter, 1992; Turner & Engle, 1989; Waters & Caplan, 1996). A second experiment in the study utilized an eye tracker for only the seductive details condition to analyze visual attention. Here, results indicated no difference in the amount of time spent processing textual information between low and high WMC groups. However, high WMC individuals viewed the seductive details illustrations significantly less in duration than low WMC suggesting a higher ability to ignore irrelevant information. These results support the limited attention control perspective of WMC as an explanatory moderator of the damage seductive details do in the learning process. One plausible explanation for the differences in performance could be a general difference in reading ability; however, in a text-only reading condition, the researchers did not find

significant differences in understanding of the text, suggesting the learning differences were indeed related to inability to control attention when viewing irrelevant details.

The dual and related constructs of visual attention and working memory capacity outlined above provide a framework for understanding how seductive details moderate learning. Individual differences in visual attention and working memory capacity have been shown to moderate learning with small to medium effect sizes, indicating potentially unexplained sources of variation. One way to explain this variation is to do as Rey (2014) suggested and look at the characteristics of the seductive details to determine whether there are potential factors of the details themselves that impact outcomes. Outlined below is one potential source of moderation of the seductive details effect related to visual attention and working memory capacity: the emotional salience of seductive details.

Emotional Salience

Background

The emotional salience of seductive details is a possible moderator to explain some of the range of results of the evidence, specifically as an inhibitor of working memory and attention. Early seductive details research was based on arousal theory (Weiner, 1990) and Kintsch (1980) referred to this type of interest as emotional interest as compared to cognitive interest. Emotional interest is often viewed as a moderator of motivation to learn and in the context of seductive details, has been seen as harmful to learning (Harp & Mayer, 1997). Another perspective of the role of emotion in seductive details is to view it from the perspective of the impact of cognitive processing of emotional salience as it relates to selective attention and working memory.

Emotion and Attention

Attention and emotion interact during information processing and learning. “Emotion” can exist in both the content as well as within the individual and both can interact to create behavioral differences between the general population and psychopathologic populations. The multi-stage models of attention outlined above (Feature Integration Theory, Guided Search Theory and Attentional Engagement Theory) all rely on a conflation of features of the visual scene and individual attention to determine conscious processing of information. Emotional content as a feature has been demonstrated to both draw selective attention as well as deplete attentional resources (Yiend, 2010). In the two-stage theory models of attention, emotional material is considered to be processed as a highly salient conjunction of features that pops out of the visual environment. In the biased competition models of attention, inherent characteristics of emotional materials such as perceptual distinctiveness and biological preparedness act as increasing relative salience which leads to bottom-up attentional biasing (Yiend, 2010).

As outlined above, Kintsch (1980) identified emotional interest as one type of attention that seductive details may garner, especially when readers engage in text with discussions of the human condition such as violence or sex. Selective attention, particularly to cues that can lead to perceptual encoding issues, is subject to individual differences beyond overt personal preferences. In a cueing task generalizing to psychopathology populations, Mogg and Bradley (2002) examined individual differences in selective attention bias on the basis of social anxiety. Participants ($N = 100$) were pre-screened for trait anxiety using the Profile of Moods States (McNair, Lorr, &

Droppleman, 1981) assessment from which those in the upper and lower quartiles were retained as the high and low trait anxiety groups. During the study, the participants also completed additional assessments of social anxiety. The study used a dot-probe paradigm which consisted of pair of faces on the right and left of the screen, either threat-neutral or happy-neutral displayed for 17 ms then masked with a jumbled face for 68 ms, after which a probe was displayed either on the right or left of the screen. The probe was the only stimulus intended to be visible to the participant and as quickly as possible after seeing it appear, participants were to indicate by pressing a key, which of the two probes had appeared. In this paradigm, the expectation is that if a threat-face causes selective attention to one side of the screen or the other, the reaction time to correctly identify a probe displayed on that side of the screen will be faster than if pre-attention does not occur. Awareness checks were conducted to determine whether participants were able to, with greater than chance, identify the gender of the masked images and two participants results were removed as a result. There was a significant interaction between social anxiety x face emotion type x face location x probe location; when masked threat faces were presented on the left, the high social anxiety group was statistically significantly faster in detecting probes located in the same location. These results support the hypothesis that individuals with high anxiety selectively attend towards threat faces even under conditions of restricted awareness.

The evidence from this study demonstrates the interaction of emotion with attention even when we remove the emotional interest component. The implication for distracted attention as a moderating effect of seductive details is that emotionally arousing details of images can distract individuals pre-attentively. While controlled

attention as a component of working memory is still a consideration for seductive details, attention may not be simply a matter of executive control. Directly measuring attention to emotionally salient versus non-emotional images and text is necessary to explain potential variances in the moderation of the seductive details.

Cueing tasks such as those used by Mogg and Bradley (2002) are useful to determine whether stimuli attract attention to a particular location. Filtering tasks are useful for understanding participants' ability to differentiate between targets and distractors, attending to the former and ignoring the latter. In an emotional Stroop test in the general population, Strauss and Allen (2006) used a combination of positively and negatively valenced words in combination with measures of both trait and state emotional information. Results suggested no attentional bias for positive or negative words alone; however, for participants reporting momentary high levels of positive or negative emotions, an attentional bias was demonstrated. This provides support for a top-down model of selective attention working in conjunction with the bottom-up emotional salience of the words.

Both the Feature Integration Theory explanation of emotional salience as a conjunction of features and the Biased Competition Theory explanation of inherent characteristics of emotional materials seem to suggest an evolutionary basis for bottom-up emotional visual attention. Directly testing this idea, Fox, Griggs, and Mouchlianitis (2007) conducted several visual search experiments in the general population. The visual search paradigm included phylogenetically (e.g., snakes) and ontogenetically (e.g., guns) fear-relevant stimuli. In addition, the search paradigm included non-fear relevant stimuli (e.g., flowers). Contrary to what an evolutionary basis for emotional visual attention

would suggest, no difference was found between the phylogenetic and ontogenetic stimuli in detection speed. This result may still provide support for the Biased Competition Model if emotion is considered to be contextualized by an individual's prior experiences or knowledge providing a top-down attentional bias.

Emotion and Working Memory

Emotion has been shown to have an effect on episodic memory (e.g., Buchanan, 2007; Cahill & McGaugh, 1995), free recall declarative memory (M. M. Bradley, Greenwald, Petry, & Lang, 1992), and cued recall declarative memory (Xu, Zhao, Zhao, & Yang, 2011). The challenge of demonstrating the interaction of working memory and emotion is the relatively transient nature of both. Asking a participant what they feel at a given moment uses working memory; asking a participant what they recall can quickly sterilize an emotional response. Memory is influenced by emotion in that we remember emotionally arousing events better than neutral events (M. M. Bradley et al., 1992; Buchanan, 2007; Xu et al., 2011) but uncovering the specific link to working memory required Dolcos, LaBar and Cabeza (2004) to use an event-related fMRI with subsequent recall paradigm for their experiment. Participants in the study were shown a series of positive, negative, and neutral pictures from the International Affective Picture System (IAPS) database (Lang, Bradley, & Cuthbert, 2008) while in an fMRI and were asked to rate the pictures on a 3-point pleasantness scale. Participants were not instructed to memorize anything so any learning was incidental. Forty-five minutes after the viewing session, participants were given an unexpected cued-recall test in which they were asked to describe as many of the pictures as they could after being given a one or two-word description of the picture. Participant pleasantness ratings of the pictures were consistent

with the ratings provided by IAPS and as expected, emotionally arousing pictures were remembered better than neutral pictures. In order to draw the link between the increased recall and working memory due to emotional valence, fMRI scans were analyzed to dissociate activation regions between positive plus negative and neutral trials as well as analyzing activity associated with remembered versus forgotten images. Areas indicating effects of emotional arousal (and thus correlated with the recall measure) were located primarily in the left dorsolateral prefrontal cortex. This region is typically associated with augmentation of working memory processes (D'Esposito, Postle, & Rypma, 2000; Owen et al., 1999). The results of this study suggest that emotional content not only is remembered better but the effect is likely due to being maintained in working memory longer or perhaps being manipulated more intensely as evidenced by increased arousal of brain regions associated with working memory.

The Dolcos et al. (2004) study found the effect of emotion on encoding was primarily related to arousal rather than valence, meaning the presence of emotional content was more important than whether the content was positive or negative. This is important considering research implicating negative valence as an important predictor in emotional effects. One weakness of this study, acknowledged by the researchers, is the use of a verbal assessment to test picture memory. The verbal assessment necessitated semantic processing; however, perceptual encoding was not assessed and likely not accounted for in this study. Given the prevalence of using pictures as seductive details associated with text, this distinction between semantic and perceptual encoding deserves further attention, particularly regarding emotional arousal. Since both pictures and text can have emotional valence, both were included as seductive details in the study

materials for the current study. The measurement of emotional valence is the next issue to be addressed.

Eye Tracking: Measuring Attention

For the current study, an eye tracker was used to measure the amount of time participants attend to seductive details versus other materials during the study period. The use of the eye tracking equipment allows insight into the on-line processing of information (Rey, 2014). The active vision model of attention indicates that foveation is a strong indicator of focused, intentional attention (Findlay & Gilchrist, 2003).

The time-locked hypothesis proposes that the proportion over time spent viewing text or image coincides with the cognitive development of the linguistic processes of the task (Allopenna, Magnuson, & Tanenhaus, 1998; Tanenhaus, Magnuson, Dahan, & Chambers, 2000; Tanenhaus & Spivey-Knowlton, 1996). This hypothesis comes from the psycholinguistic approach to reading and these studies involve spoken words time-mapped onto activation curves. Given that linguistic processing happens automatically and quickly (hundreds of milliseconds versus 10s of seconds to scan an entire multimedia presentation) we apply the principle of the time-locked hypothesis to pre-defined Areas of Interest (AOIs) in order to understand group differences in cognitive processing of these locations (Holmqvist et al., 2011). For the purpose of this study, AOIs are defined as areas around seductive details.

Chapter Summary

The theoretical foundations of seductive details, including in learning interventions, are working memory and visual attention. This chapter outlined the relevant literature related to the working memory models related to attention. Working memory capacity was also reviewed as measures of this construct have been shown to be

relevant to outcomes in seductive details studies. Visual attention theories are closely related to the reviewed working memory models, particularly about how features of a visual scene attract attention and consume cognitive resources. A short review of the criticisms of the visual search paradigm acknowledged these limitations. The seductive details literature was broadly reviewed with a particular focus on Rey's (2012) meta-analysis which highlighted gaps to be addressed. Some of the gaps include focusing on features of the seductive details and including eye-tracking. The current study focused on the emotional salience of seductive details and the literature related to emotional salience and working memory and attention provided evidence of the usefulness of this avenue of research. This chapter concluded with a short review of the usefulness of eye-tracking in measuring visual attention. The evidence outlined in this chapter demonstrates the emotional salience of seductive details is a possible explanation of the negative effect on learning outcomes and this idea has yet to be studied thoroughly using an eye-tracking paradigm.

CHAPTER III

METHODOLOGY

In this chapter I outline the methodology of the current study to explore whether the emotional salience of seductive details is useful in explaining how seductive details hinder learning outcomes. The research questions are related to attention and working memory capacity as they relate to both visual attending and learning outcomes. The measures used are outlined and explained. The rationale is outlined for the research design and participants. In addition, the materials are explained along with the procedures and data analysis.

Participants

Participants ($N = 39$) were recruited from the introductory psychology pool (PSY 120) at the University of Northern Colorado. This pool has a variety of majors and is a required course for many majors. Only one participant was from an environmental or meteorological related major (“Environmental & Sustainability”). Majors that had several participants in the study were Business Administration ($n = 7$), Psychology ($n = 6$), and Sport and Exercise Science ($n = 5$). The participants were almost evenly split between females ($n = 20$) and males ($n = 18$) with one non-binary participant. Participants ranged in age from 18 to 27 ($M=19.46$). Participants were contacted through classes and through the Sona Systems Pool Software System. Students received course credit for their participation. The tasks were described as presented in the consent form

(see Appendix D for an example); participants were assured of efforts to protect their confidentiality. No special populations were investigated. Participants were recruited and the study was conducted as outlined in the materials submitted and approved by the University of Northern Colorado Institutional Review Board. All participants were treated in accordance with ethical guidelines from the University of Northern Colorado as well as the American Psychological Association (2002).

Measures

Measurement of Emotion in Seductive Details

A prerequisite of an accurate assessment of the impact of emotion on the included seductive details is an accurate measurement of the emotional salience of the images and words that make up the seductive details. Standardized and normed sets of emotional images and words were included in the design of the materials for this study. The Geneva Affective PicturE Database (GAPED; Dan-Glauser & Scherer, 2011) was the source of images and the Affective Norms for English Words (ANEW; M.M. Bradley & Lang, 2017) was the source of words.

The GAPED database is a database of 730 pictures with four categories of negative images (spiders, snakes, human rights violations, and animal mistreatment.) Positive pictures are also included, represented by human and animal babies and nature scenes. Neutral images are largely inanimate objects. All pictures were rated according to valence and arousal as well as congruence with internal (moral) and external (legal) norms. Images were rated by 60 participants on scales from 0 to 100 on both valence and arousal (Dan-Glauser & Scherer, 2011). Each image in the database contains valence and arousal ratings along with standard deviations for rating. Images for this study were

selected based on high levels of arousal and no overlap with neutral images (on either the arousal or valence scales.)

ANEW is a large set of English words (approximately 600 words) that has been normed for valence, arousal, and dominance as well as being rated for frequency of use. To generate the dataset, words were presented to college-aged participants for rating in sets of 100 – 150 words at a time using a 9-point scale. Each word in the database has a unique word number and has a reported valence, arousal, and dominance score along with associated variance and word frequency. For the current study, words were selected for high levels of valence (negative, $0 < \text{valence mean} < 2.5$; positive, $6.5 < \text{valence mean} < 9$) and high levels of arousal ($\text{arousal} > 5.5$) with no overlap of valence or arousal means between selected emotional and neutral words.

Working Memory Capacity

Since WMC has been shown to affect learning performance when learning from images and animations, the OSPAN and RSPAN tasks were used to measure WMC in participants as a possible explanatory variable. Conway et al. (2005) suggested these measures are correlated and recommended utilizing more than one measure of WMC for research in which this construct is relevant. Both the RSPAN and OSPAN are scored by calculating partial credit unit scoring, a percentage correct in each trial, resulting in scores ranging from 0 to 1, summed and averaged over all trials (Conway et al., 2005). Scores from these measures are considered to have excellent reliability including test-retest reliability and internal consistency with reliability estimates in the range of .70 - .90 for span scores in studies primarily consisting of university undergraduate students (Conway et al., 2005).

Prior Knowledge

Perceptual bias refers to the broad category of concepts related to ways in which human perception is biased to attend to (or not attend to) various components of an auditory or visual scene. In the current study, the choice to not use a pre-test, post-test paradigm follows prior research (see, Harp & Mayer, 1998; Rey, 2014; Sanchez & Wiley, 2006) due to the perceptual bias of goal orientation from pre-testing. While the focus of this study is stimulus-driven attentional control, goal-directed attentional control cannot be ignored as the two methods of control, bottom-up and top-down, interact (Yantis, 2000). The simple act of giving a pre-test would likely provide the student with enough cues to focus their attention on the important features of the visual scenes presented. As that is not the focus of the current study, a pre-test for prior knowledge was not given. Instead, after the reading portion of the experiment, as part of the post-test, several questions related to the student's prior knowledge of the domain assessed prior knowledge. These questions were similar to questions asked in prior studies related to seductive details (Harp & Mayer, 1998; Rey, 2014; Sanchez & Wiley, 2006). Prior knowledge scores were ordinally ranked from 1 (lowest knowledge) to 10 (highest knowledge) on a five-step scale. Five questions for each of the content areas were combined to create a single composite, approximately continuous variable representing prior knowledge for each of the content areas. Sample questions from the prior knowledge assessment are in Appendix C.

Demographic Information

To better describe the sample, the participants were asked to identify their sex (male or female) at the beginning of the study. In addition, participants were asked to

identify their major or concentration area as another means of describing the sample and help identify potential problems with the sample given the science nature of the materials. Lastly, participants were asked to provide their age to help describe the sample.

Research Design

The current study was an eye tracking laboratory study with an experimental design manipulating the emotional content of the seductive details in the learning interventions. The study had three conditions: no seductive details, non-emotional seductive details, and emotionally salient seductive details. The conditions were analyzed between-subjects, with participants assigned to a group using random assignment prior to the beginning of the study. Each participant was presented with two different sets of materials on two different science-related topics with a short quiz at the end of each. The materials for the “How Lightning Forms” materials were designed to be similar to a typical PowerPoint presentation with enough information included in the text on each slide to respond to the quiz questions. The materials for “Causes of the Ice Ages” were designed to represent more of a textbook format with columns of text interspersed with photographs. The materials are described in more detail below.

For research questions one and two, the dependent variables were assessed with two learning instruments at the end of each study session combined into a single quiz format for each set of materials: one instrument measuring recall of important information and the other measuring transfer of learning. The independent variable was the group condition (emotion, non-emotion, and no seductive details) controlling for prior domain knowledge. For research question three, the dependent variable was the percentage of fixation duration on the pre-defined AOIs (the seductive details) over the

entire viewing time for each slide or page. The independent variable was the group condition controlling for prior domain knowledge. For research question four, the dependent variable was again the percentage of fixation duration on the pre-defined AOIs (the seductive details) over the entire viewing time while the independent variables are group condition and WMC controlling for prior domain knowledge. For research question five, the dependent variable was the assessment of recall of important information and transfer of learning. The independent variables were the percentage of fixation duration on the pre-defined AOIs and WMC controlling for prior knowledge.

Sample Size

To calculate the a priori minimum sample size required for a power estimate of .80, the G*Power software package (Faul, Erdfelder, Buchner, & Lang, 2009) was used. Based on the most complex data analysis required as outlined below, using the Poisson regression model with the binomial distribution, a small to medium effect size and estimates based on data I gathered in a prior study, a sample size estimate of 40 was calculated. Similar or smaller sample sizes were required for the other analyses listed above; thus, the sample size target for this study was determined to be 42 participants (14 per group in 3 groups). Due to difficulty in recruiting during the semester, only 39 participants (13 in each group) were recruited for the final analysis.

Materials

Intervention

The materials used for the intervention included two sets of science-based study materials (see Appendix A). The first is a set of five slides that utilize vector art images and text similar to a PowerPoint presentation (non-animated) to provide information on

the “How Lightning Forms.” The learners were able to advance through the slides one at a time; however, they were not permitted to move backwards. The instructions included a warning to study each slide thoroughly before advancing to the next slide as there was no back button available. The seductive details included in these materials consist of neutral and emotionally valenced images (see Appendix A examples.) A control group saw the same materials; however, with no seductive details present. The vector image graphics of the seductive details are similar in size and color across the neutral and emotion conditions. The AOIs defined for each of the seductive details are the same size and the same AOI is used for the control condition though there is no seductive detail present at that location in the image, just a continuation of the underlying image.

The second intervention was a set of six slides consisting primarily of text but also including photographic images which describe the “Causes of the Ice Ages,” derived from content developed by Berger and Anderson (2002) and used with permission (see Appendix A). The slides contain approximately 1,700 words and were designed to more closely match an e-textbook learning experience for the learner. Similar to the slide deck described above, these slides could be advanced by the learner but not repeated and instructions were similar for the participant. In these slides, seductive details were present in both image and text form. The image seductive details were photographs taken from the GAPED (Dan-Glauser & Scherer, 2011) database (see Appendix B for examples.) The neutral images were all taken from the neutral set of images, the emotional images were taken from the animal (1), positive (2), spider (1), and snake (1) sets of images. The valence and arousal descriptive statistics of the images are provided in Appendix B. In addition to the seductive detail images, seductive detail text was included in this set of

slides. The words were selected from the ANEW (M.M. Bradley & Lang, 2017) database. The valence and arousal descriptive statistics of the selected words are included in Appendix B. AOIs were defined for the images as well as for the seductive details text. For both the text and image locations in the control condition, the text and images were removed and replaced with “white-noise” gray images to indicate that these were intentional omissions in the slides. The sizes of the AOIs were the same for all conditions. The total time for viewing the slides ranged from 85 to 1,231 seconds ($M = 418$) and the total time for the entire experiment (from signing consent to final debrief) ranged from 40 to 60 minutes.

Reading Span and Operation Span

WMC was tested using computerized assessments designed in E-Prime and used with permission from the Georgia Institute of Technology Attention & Working Memory Lab (Oswald, McAbee, Redick, & Hambrick, 2015). In the RSPAN test, participants are given a sentence that is either logical or illogical (i.e., “I like to run in the sky”), which the participants identify as true if logical or false if illogical. The E-Prime script begins with practice sentences and calculates the amount of time a participant spends reading the sentences, marking them true or false. After the practice sentences, the assessment begins. Sentences appear on the screen that are logical or illogical, and the participant must respond in the average amount of time that was calculated for the individual by the program during practice (this accounts for individual differences in reading speed). Immediately following the sentence, the participant is shown a series of letters, one letter at a time. The letters stay on the screen for approximately 1 second. At the end of the trial, the participant selects the letters that he or she saw from 12 letters displayed on the screen in an array in the correct order that they appeared. The OSPAN test was also

delivered using E-Prime. It has a similar design except instead of utilizing a reading logical interference for working memory, it uses a simple mathematical operation for which the participant must determine whether the answer is correct or incorrect.

Recall and Transfer Assessments

Two types of assessment of learning were utilized: one to assess recall of the main concepts from the science lessons; the second to assess transfer of learning (see Appendix C for example items). For each intervention, three questions per panel were asked to evaluate recall. In addition, for each slide, a transfer question for the main topic was provided. All assessments were provided using the Qualtrics software platform for learning assessments. Both assessments were scored as a range of percentage correct. Internal consistency reliability for the “Causes of the Ice Ages” recall and transfer assessments were calculated using Cronbach’s alpha and were $\alpha = .63$, 95% CI [.46, .8], $\alpha = .53$, 95% CI [.3, .75], respectively. Individual item analysis revealed one potential problem item for the recall assessment (high difficulty, negatively correlated). Internal consistency reliability for the “How Lightning Forms” recall and transfer assessments were calculated as well and were $\alpha = .56$, 95% CI [.36, .76], $\alpha = .41$, 95% CI [.12, .71] respectively. Individual item analysis revealed two potential problem items on the recall assessment and one on the transfer assessment. The internal consistency reliability estimates are relatively poor for these assessments. Given the relatively few numbers of poorly performing items, the reliability of scores based on these assessments likely would have benefited from removing poorly performing items, an increased number of items, an increased sample size, or a combination of these improvements.

Procedure

Participants signed up to come to the lab one at a time. Upon arriving each participant was provided a consent form to read, agree to, and sign. Next, participants were asked to fill out a short demographic survey before being presented with the two tests of working memory capacity: the shortened reading span (RSPAN) and the shortened operation span (OSPAN) test (Oswald et al., 2015). After completing the demographic survey, participants entered only a participant ID number assigned to them by the lab assistant for each of the tasks. No other identifying information was entered in the systems.

After the WMC assessments, participants participated in two instructional interventions on the eye tracker. The first on the topic of “How Lightning Forms” and the second on “The Causes of the Ice Ages.” The interventions consisted of 5 and 6 different slides, respectively, with combinations of text and images (described in the Materials section above). Participants studied the materials while seated at a Tobii T120 eye-tracker. The Tobii T120 eye-tracking system is built into a 17-inch computer monitor, on which the materials were displayed. Cameras and illuminators are hidden behind sunlight blocking filters in the monitor. The Tobii eye tracker hardware uses FDA approved near infrared diodes to produce non-invasive reflection patterns on the user’s corneas. A camera then collects these reflection patterns along with other user characteristics. The user was seated at a distance of approximately 60 cm from the monitor, and the system recorded binocular data with a tolerance for head movements that allows the user relatively normal freedom of motion.

The Tobii eye tracker was used to collect measurements of eye position on screen, which was used to determine how participants allocate visual attention during the study session. Areas of Interest (AOI) were pre-defined in the materials to coincide with the seductive details. These AOIs were invisible to the users and they were unaware of the areas under study.

Participants had the option of studying the images for as long as they wished. The length of time the learner studied was recorded. One third of participants viewed materials with no seductive details. One third of participants viewed materials with non-emotionally salient seductive details. One third of participants viewed materials with emotionally salient seductive details.

As they completed their study of each instructional intervention and were ready, participants notified the lab assistant and asked to take a recall and transfer knowledge-based assessment over the material they just read. The duration of the participation varied individually. Consent forms and WMC assessment took approximately 25 - 30 minutes. The intervention with study and assessments took approximately 25 - 30 minutes. Most participants completed the entire intervention in approximately 50 to 60 minutes.

CHAPTER IV

RESULTS

In this chapter I outline the results of the study. Each research question has a separate analysis to address the specific construct in question. Since there are multiple analyses of the same data, a correction has been made for multiple comparisons. Research questions one and two both utilize an ANOVA / ANCOVA with the outcome variable of the learning assessment scores. Research question five is a multiple regression with the same outcome. Given the nature of these analyses and the shared outcome variable, for the purpose of this study, I considered these analyses in the same family. For these research question analyses an alpha of .025 was considered statistically significant, consistent with a Bonferroni adjustment (Miller, 1981). For each research question, I explain the analysis used, describe the data, and report the results of the analysis. Discussion of the results follows in Chapter V Discussion.

Research Question One

Q1 Does the presence of seductive details in materials have a negative effect on recall and transfer learning? (replication of previous studies)

This question was addressed with one-way ANCOVA with three groups (control, non-emotional, and emotional) using the test scores as the outcome variable. Prior knowledge was planned to be included as a continuous covariate for both recall and transfer with a planned contrast between the control group and the two groups with seductive details.

The scores on the recall assessment ranged from .26 to .86 ($M = .56$) and scores in the transfer assessment ranged from .18 to .91 ($M = .58$). Mean scores in the Lightning assessment were the highest (*range* [.27, .93], $M = .71$) with mean scores in the Ice Ages recall being the lowest (*range* [.19, .81], $M = .44$). The prior knowledge scores for each content area were combined to a single composite, approximately continuous variable and converted to a percentage (0 to 1) to place it on the same scale as the other independent variables. Maurer and Pierce (1998) demonstrated combining Likert items into a Likert scale results in an approximately continuous variable that can be analyzed using interval methods. Combined prior knowledge scores ranged from .1 to .5 ($M = .27$) with mean prior knowledge in the Ice Ages being slightly higher (*range* [.1, .55], $M = .28$) than the Lightning content (*range* [.1, .5], $M = .26$).

Prior to conducting the planned analyses, I determined ANCOVA was not appropriate for the recall assessment scores. The assumption of a one-way ANCOVA include a linear relationship between the dependent variable and the covariate (Elashoff, 1969; Pedhazur & Schmelkin, 2013). A test of the linear relationship between prior knowledge and scores on the recall assessment was not statistically significant ($R^2 = .03$, $p = .31$) indicating an ANCOVA would not provide any additional information over an ANOVA for this analysis (Cochran, 1957). A test of the linear relationship between prior knowledge and scores on the transfer assessment indicated a statistically significant and stronger relationship ($R^2 = 0.17$, $p = 0.008$) therefore the ANCOVA model was used for the analysis of transfer scores.

For the recall assessment ANOVA, the assumptions include homogeneity of variance, normality of residuals, and independence of samples (Pedhazur & Schmelkin,

2013). Levene's test (Levene, 1960) for homogeneity of variance, $F(2, 36) = .08, p = .92$, did not provide evidence to suggest a statistically significant difference in variances between groups. Shapiro-Wilks test (Shapiro & Wilk, 1965), $W = .98, p = .92$, failed to provide evidence of non-normality of residuals from the model. The assumption of independence of samples is met by the experimental design. With the assumptions met, the one-way analysis of variance showed no main effect of treatment group on recall assessment scores, $F(2, 36) = .76, p = .48$. The effect size of treatment group was small to medium, $\eta^2 = 0.04$. Since there was no statistically significant main effect, no post-hoc or contrasts were conducted for the recall assessment.

For the transfer assessment ANCOVA, in addition to the assumption of linearity between the covariate and the dependent variable tested above, the assumptions include homogeneity of slopes, groups not differing on the covariate, homogeneity of variance, and normality of residuals. To test for homogeneity of slope, using the *aov* function in R, an analysis of covariance was conducted with transfer scores as the outcome variable and treatment and prior as independent variables with an interaction term in the model. No evidence was found for a statistically significant interaction between treatment and prior knowledge, $F(2, 33) = 1.35, p = .27$, indicating the slopes of treatment and prior knowledge are homogenous. To test for groups differing on the covariate, the *aov* function was used to build a model with prior knowledge as the outcome variable and treatment group as the independent variable, which failed to provide evidence of a statistically significant difference in group prior knowledge, $F(2, 36) = .16, p = .85$. Levene's test for homogeneity of variance, $F(2, 36) = .52, p = .60$, did not provide evidence to suggest a statistically significant difference in variances between groups.

Shapiro-Wilks test, $W = .96, p = .24$, failed to provide evidence of non-normality of residuals from the model. The assumption of independence of samples is met by the experimental design. The one-way analysis of covariance showed no main effect of treatment group, $F(2, 35) = .38, p = .69$ but a statistically significant main effect of prior knowledge, $F(1, 35) = 7.78, p = .008$. The effect size of treatment group was small, $\eta_p^2 = 0.02$ while the effect size of the covariate, prior knowledge, was large, $\eta_p^2 = 0.18$. With no statistically significant main effect of group, no post-hoc or contrasts were conducted for the transfer assessment.

Research Question Two

- Q2 Does the presence of emotionally salient details in materials influence the level of the negative effect on recall and transfer learning more than non-emotionally salient details?

Since there were no statistically significant main effects of treatment on learning outcomes in Research Question One, no contrasts were conducted to analyze further effects for Research Question Two.

Research Question Three

- Q3 Do learners attend more to emotionally salient seductive details than non-emotional?

This question was addressed using a generalized linear mixed model utilizing a beta distribution. Since participants could study each panel for as long as they desired, the length of time spent on each panel varied both within and between participants. Rather than comparing raw time spent viewing AOIs, the data for the dependent variable in this analysis represents proportions of time spent viewing AOIs, with many observations approaching zero. Smithson and Verkuilen (2006) presented maximum likelihood regression models which assume the dependent variable is beta distributed to

account for scenarios like this with proportion data. One consequence of proportion data with non-normally distributed outcomes and means approaching zero or one is the mean-variance relationship also heavily influences variance (Smithson & Verkuilen, 2006). In addition to using the beta distribution, the use of mixed models allows for conditioning effects of grouped observations (West, Welch, & Galecki, 2014), in this case, groups of observation by slide, to account for variation within those groups. The use of a generalized linear mixed model allows the fitting of the mixed model with maximum likelihood (Vonesh & Chinchilli, 1996) along with the use of the beta distribution using the identity logit link function, which can be accomplished using the R package *glmmTMB* (M. E. Brooks et al., 2017; Ferrari & Cribari-Neto, 2004).

An artifact of using a maximum likelihood regression model with a beta distribution is the data are bounded by 0 and 1, not inclusive. In the experimental design, the control conditions were defined with AOIs even though there were no images of interest or information contained in that region of the slide. This resulted in many observations having zero hits in AOIs ($n = 100$). To accommodate this limitation of the beta distribution, the data were adjusted to add a single 8 ms observation to every slide (both zero and non-zero) slides, shifting the entire dataset up by 1 “hit count.” This resulted in an AOI hit rate that ranged from .00004 to .25 ($M = .027$). Figure 1 shows a boxplot of the AOI hit rate by treatment. There was no theoretical reason to remove the outliers in the figure and removing them did not substantively change the outcome of the model; thus, they were left in the dataset for completeness.

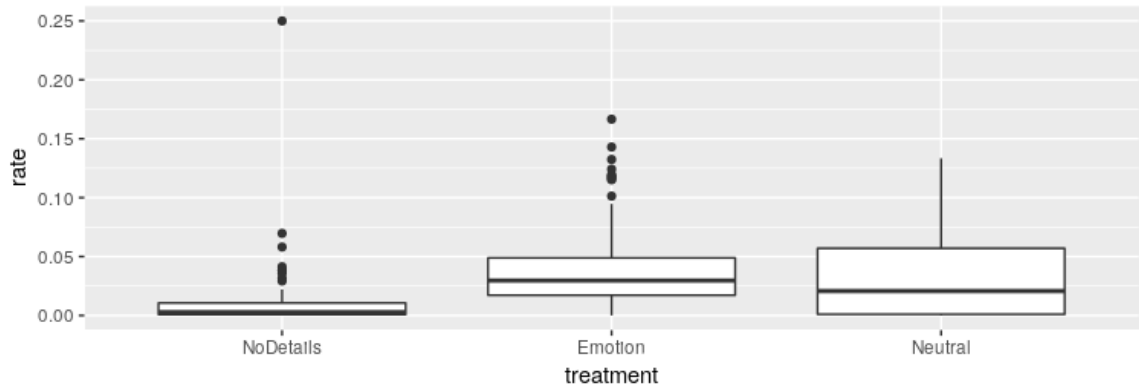


Figure 1. Boxplot of AOI hit rate by treatment

The mixed effects model specified for the effect of treatment and prior knowledge on AOI hit rate conditioned by slide is shown in Figure 2 below. The random effect of slide is modeled as a random intercept under the assumption that the effect of treatment and prior knowledge would not change from slide to slide. Any effect of slide should not have a different slope but may have a different intercept than the fixed effects.

$$Y_{si} = \beta_0 + Slide_{0s} + \beta_1 Treat_i + \beta_2 Prior_i + e_{si}$$

Figure 2. Mixed GLMM model. Y is rate outcome at slide s, observation i, Slide is a random intercept effect, Treat is the treatment group and Prior is the level of prior knowledge for the participant.

The *glmmTMB* package in R was used to fit this model using the eye tracking data combined with the prior knowledge data described above. The assumptions of fit for a generalized linear mixed model using a beta distribution are the random effects come from a normal distribution and that the chosen link function is appropriate for the distribution of the outcome (McCulloch & Neuhaus, 2015). A normal distribution of random effects was assessed by visually analyzing a histogram and Q-Q plot of the random effects (see Figure 3 and Figure 4, respectively, below.) In addition, a Shapiro-

Wilks test failed to provide statistically significant evidence that the random effects were not normally distributed, $W = .94, p = .11$. The evidence as a whole does not strongly support a normal distribution of random effects and while misspecified models for random effects may result in only small bias in maximum likelihood estimates (Neuhauser, Hauck, & Kalbfleisch, 1992), recent work suggests exceptions to this robustness when estimating the intercept. The model was used with caution in interpreting random effects.

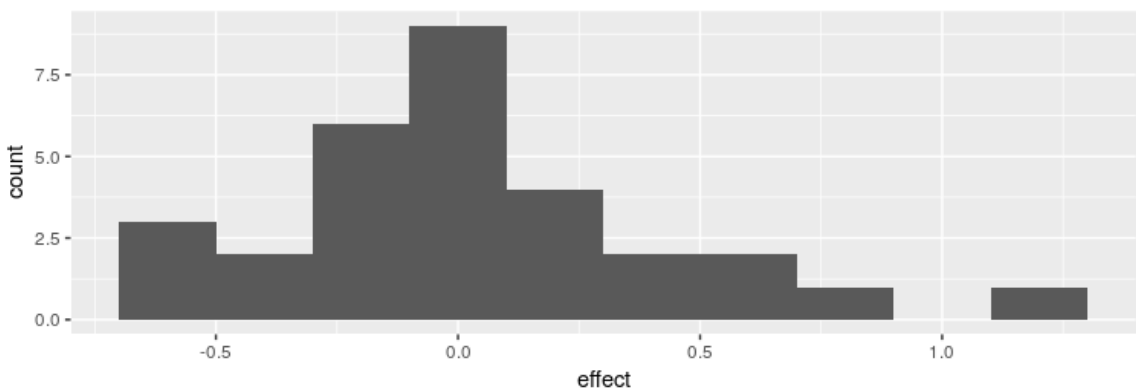


Figure 3. Histogram of random effects from GLMM

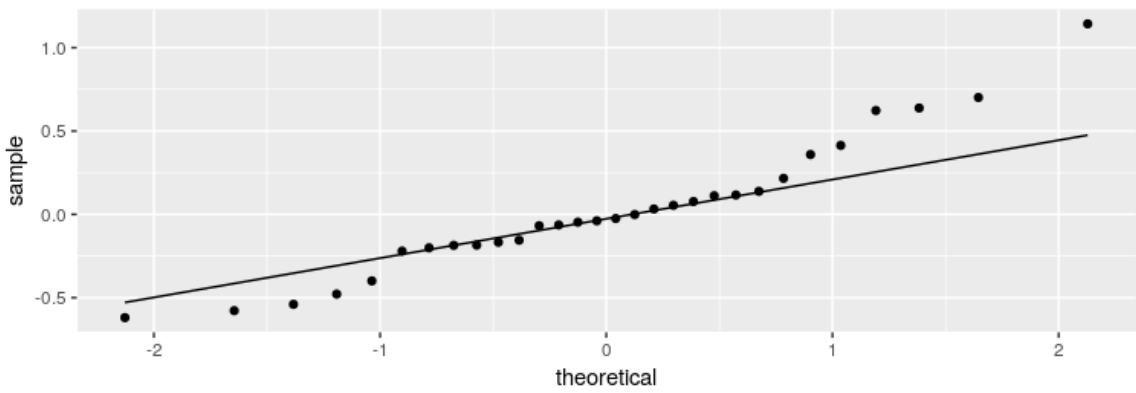


Figure 4. Q-Q plot of effects from GLMM

The *DHARMA* package in R was used to assess whether the link function was appropriate. This assumption is tested by simulating a set of predicted values from the

model and comparing them to the actual values. Figure 5 shows the results of this simulation. The data suggest a reasonable fit of the model for the data.

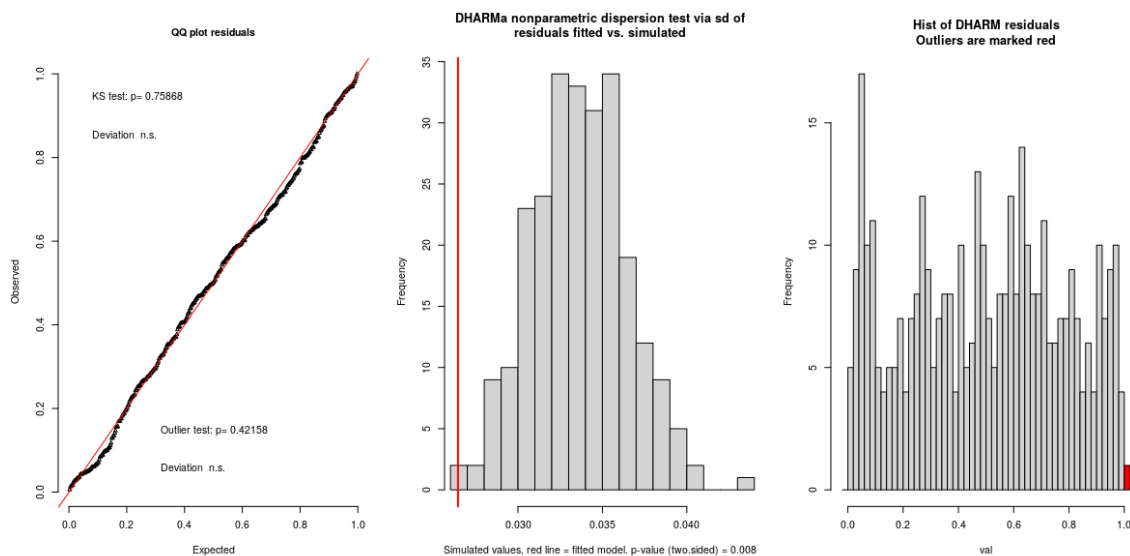


Figure 5. DHARMA model fit output Q3. Results of comparing simulated data against actual. The QQ plot shows deviations of the plotted versus expected residuals. The simulated values is a histogram of actual values simulated. The histogram of residuals shows no discernible pattern.

Using the *glmmTMB* function from the package of the same name in R, the model was analyzed and resulted in the estimated log odds for hit rate in the emotion condition of .888, 95% CI [.444, 1.332] and for the neutral condition .684, 95% CI [.240, 1.128]. The interpretation of this model is accomplished by exponentiating the log odds which results in odds ratios of 2.43 and 1.98 for the emotion and neutral conditions respectively. These odds ratios represent a change in odds from the control condition meaning we should expect 143% greater odds of a hit for an emotion AOI over a control AOI and 98% greater odds of a hit for a neutral AOI over a control AOI.

Research Question Four

Q4 Does WMC predict the level of attention given to emotionally salient seductive details?

To answer this question, the model used for Research Question Three was extended to include the OSPAN and RSPAN scores as a predictor resulting in the model in Figure 6.

$$Y_{si} = \beta_0 + Slide_{0s} + \beta_1 Treat_i + \beta_2 WMC_i + \beta_3 Prior_i + e_{si}$$

Figure 6. Mixed GLMM model with WMC. Y is rate outcome at slide s, observation i, Slide is a random intercept effect, Treat is the treatment group, WMC is working memory capacity, and Prior is the level of prior knowledge for the participant.

The WMC task partial credit unit scores from the RSPAN and OSPAN showed a low correlation ($r = .44$) with each other. The scores were combined into a single composite WMC score for each participant which ranged from .49 to .97 ($M = .78$). Figure 7 demonstrates the distribution had a slightly left skew and does not appear to be normally distributed.

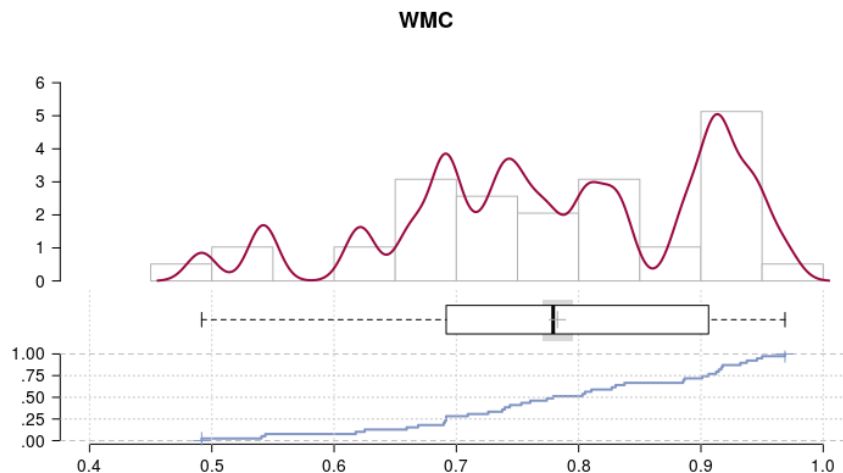


Figure 7. WMC histogram, boxplot, and cumulative frequency

The fit diagnostics for the model were the same as for Research Question Three above, namely: normal distribution of random effects and appropriateness of selected distribution. The Q-Q plot and histogram of random effects were similar for the expanded model and the Shapiro-Wilks resulted in comparable statistics, $W = .95$, $p = .13$. The DHARMA package again was used to simulate values from the model to generate residuals with the results shown in Figure 8. As in Research Question Three above, the data suggest the model fit reasonably well with caution in interpreting results from the random effects model.

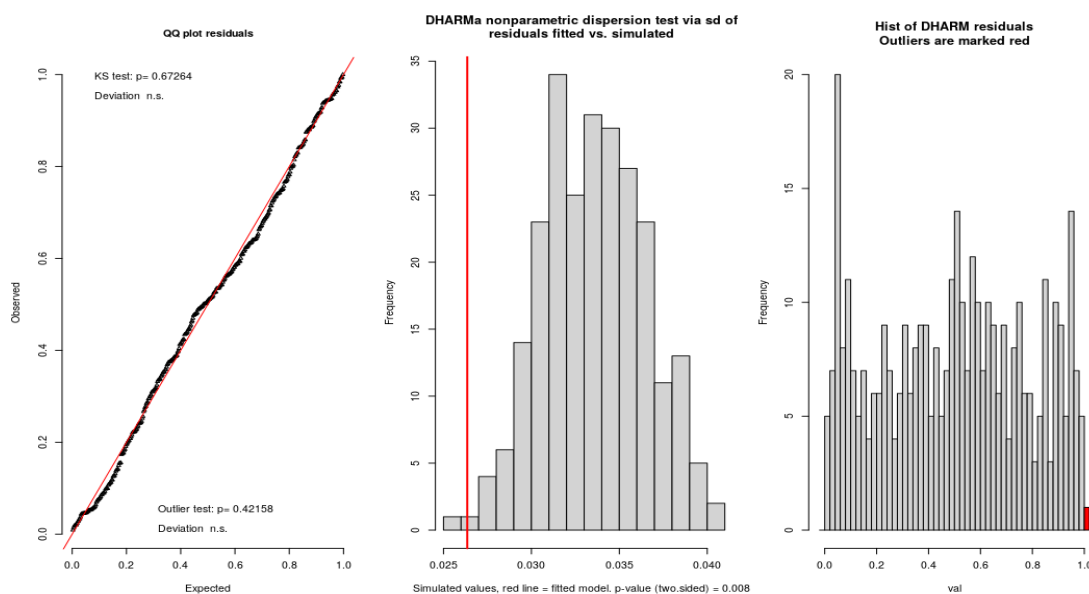


Figure 8. DHARMA model fit output Q4. Results of comparing simulated data against actual. The QQ plot shows deviations of the plotted versus expected residuals. The simulated values is a histogram of actual values simulated. The histogram of residuals shows no discernible pattern.

Using the *glmmTMB* function from the package of the same name in R, the model was analyzed and resulted in the estimated log odds for hit rate in the emotion condition of .888, 95% CI [.440, 1.336]; neutral condition .736, 95% CI [.285, 1.119];

and WMC $-.767$, 95% CI $[-1.56, .026]$. The confidence interval for WMC includes zero suggesting no effect of WMC.

Research Question Five

Q5 Does WMC interact with the amount of time spent viewing seductive details to explain performance on the outcomes of recall and transfer learning?

This question was addressed using a multiple linear regression (MLR) model analyzing the effect of WMC, gaze time on the seductive detail area of interest, and the interaction between the two terms on the outcome of recall and transfer learning. The model was specified as show in Figure 9.

$$Y_{score} = \beta_0 + \beta_1 WMC + \beta_2 Time + \beta_3 (WMC \times Time) + e$$

Figure 9. Multiple linear regression model. Y is assessment score outcome, WMC is working memory capacity, and time is time spent studying.

The assumption of a linear relationship between the IVs and DV was assessed using scatterplots as shown below in Figure 10. These scatterplots show weak linear relationships between the IVs and DV, especially between recall scores and WMC. While weak, the relationship between the IV and DVs are distinct enough to consider meeting this assumption.

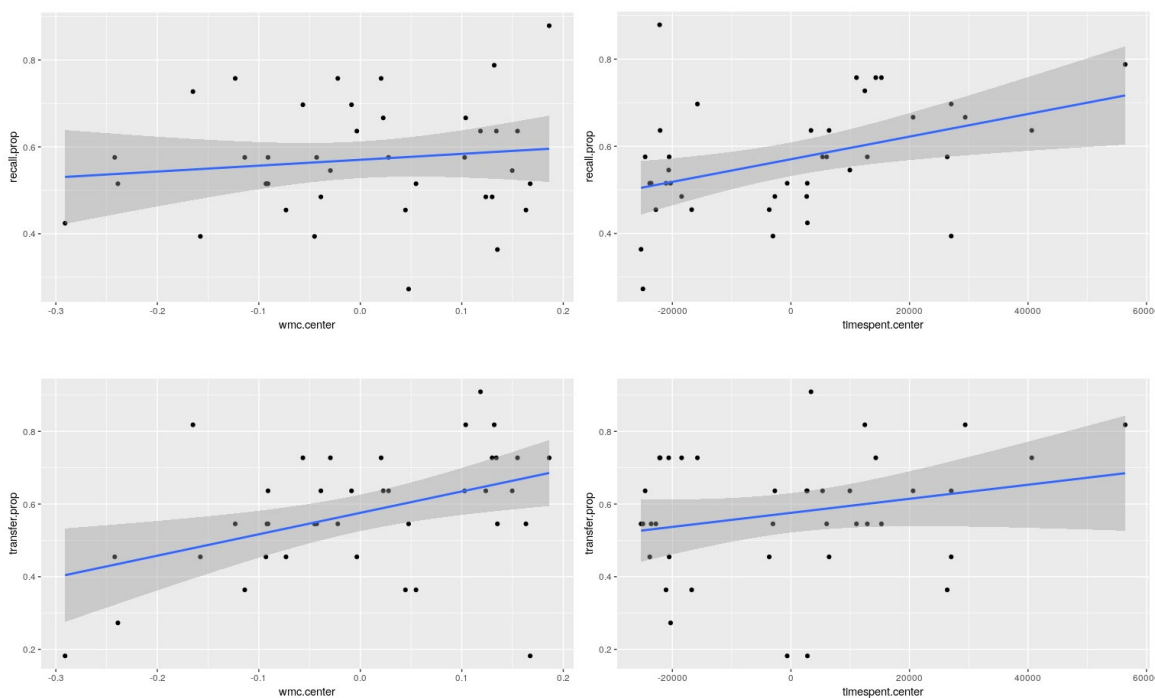


Figure 10. Scatterplots between IVs and DV for multiple linear regression

The assumptions of MLR also include multivariate normality which was assessed using a Shapiro-Wilks test of the residuals for both recall and transfer, $W = .97, p = .41$ and $W = .95, p = .09$, respectively. These tests fail to provide evidence to reject the null hypothesis, suggesting the assumption of multivariate normality is met. Multicollinearity was assessed with Variance Inflation Factor (VIF; Pedhazur, 1997). Given the vastly different scales between the WMC and time spent factors in the interaction term, both variables were centered prior to analysis to better assess multicollinearity (Robinson & Schumacker, 2009). The VIF for each factor in both models (after centering) was: WMC = 1.01; time = 1.13; WMC x time = 1.14. This indicates low levels of multicollinearity in the model suggesting the assumption was met.

The assumption of homoscedasticity was assessed using scatterplots for visual analysis as well as the Breusch-Pagan test, $BP = 6.47, p = .09$ (Breusch & Pagan, 1979).

The scatterplot shown in Figure 11 shows a slight curvilinear pattern to the variance in errors. The Breusch-Pagan test failed to provide sufficient evidence to reject the null hypothesis of homoscedasticity therefore this assumption was deemed to have been met.

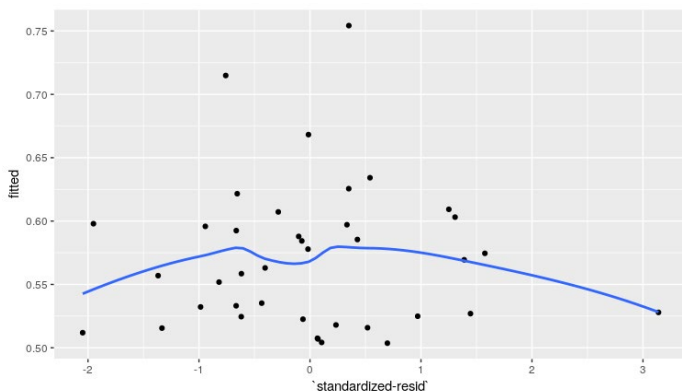


Figure 11. Scatterplot of fitted values against standardized residuals

Results of the multiple regression analysis for the recall assessment outcome indicated there was not a statistically significant effect between WMC, time on seductive details and recall, $F(3, 35) = 2.9, p = .05, R^2 = .20$. Results of the multiple regression analysis for the transfer assessment outcome indicated there was a statistically significant effect between WMC, time on seductive details and recall, $F(3, 35) = 3.9, p = .02, R^2 = .25$. Individual predictors were analyzed and showed that WMC was a statistically significant predictor, $\beta = .601, p = .005$. Neither time spent on seductive details nor the interaction term were statistically significant.

Chapter Summary

In this chapter I reviewed the results of the analysis of each research question. For research question one, a violation of the ANCOVA assumptions required two different analyses for the recall (ANOVA) and transfer (ANCOVA) assessment outcome variables. There were no statistically significant main effects for either model. Because of this

result, research question two was rendered moot as it was an extension of research question one. The results of research question three were the fixed effects of a generalized linear mixed model showing increased odds of attending to emotion versus neutral seductive details. The results of research question four from the GLMM indicated the fixed effects of WMC included 0 in the 95% confidence interval, suggesting no effect. The results of research question number five showed no statistically significant relationship between WMC and time spent on seductive details with outcomes on the recall assessment. A statistically significant relationship was indicated in the multiple regression model for transfer assessment with WMC being the only statistically significant predictor.

CHAPTER V

DISCUSSION

In this chapter I briefly review the purpose of this study and the method used to address the purpose. Next, I discuss the results of each research question in turn and answer each individually. Finally, I address future directions and next steps for this research.

Review of Purpose and Method

Seductive details in learning interventions have been found to inhibit learning to varying degrees and better understanding them will help lead to better understanding of human learning. Harp and Mayer (1998) introduced the distraction hypothesis by which seductive details are damaging to learning because they gain and hold a student's selective attention; however, Rey's (2012) meta-analysis suggested the proposed explanations for inhibited learning do not account for enough of the variation in the results. The emotional salience of seductive details is a possible moderator to explain some of the range of results of the evidence, specifically as an inhibitor of working memory and attention. The current study analyzed the impact of the emotional salience of seductive details on attention and learning outcomes using an eye-tracking methodology, controlling for working memory capacity. The methodology of this analysis was to randomly assign participants to conditions in which a learning intervention contained seductive details that varied by emotional salience and measured the outcomes of

learning assessments based on the materials studied. The working memory of participants was measured using span tasks and prior knowledge of the learning materials was controlled for by asking participants what their experience was with the materials.

Research Questions

In this section I briefly discuss the results of each of the research question analyses from the previous Chapter. This will ground the overall discussion that follows.

Research Questions 1 & 2

The finding of no linear relationship between prior knowledge and recall while this relationship exists between prior knowledge and transfer is unrelated to the research question but interesting nonetheless. An expectation of the relationship between prior knowledge and recall is reasonable within the framework of transfer appropriate processing (Craik & Lockhart, 1972); thus, it is surprising to not find any evidence. There is a need for future research to explore whether the relationship with transfer learning is important. Unfortunately, scores based on all four of the learning assessments used in this study had relatively poor reliability (ranging from $\alpha = .41$ to $\alpha = .63$). The reliability of scores from these assessments should be addressed in any future studies as the lack of reliability makes it difficult to interpret the results from this analysis. Either more items should be added or more participants need to be recruited to increase power. Neither of the analyses, for recall or transfer, revealed a statistically significant effect of treatment group on learning outcomes. I would hesitate to conclude this is a lack of evidence of an effect of seductive details but rather is more likely a lack of sufficiently precise psychometric instruments to assess learning outcomes. Whether an effect existed or not would be undetectable using the instruments as designed but this study could not

conclude that the presence of seductive details in materials have a negative effect on recall and transfer learning.

Research Question 3

The use of eye tracking data results in a wide array of statistical analyses given the large number of physiological measurements gained from each session. A few recent studies have utilized GLMM to analyze this data (see for example, Strobel, Grund, & Lindner, 2019; and Strobel, Lindner, Saß, & Köller, 2018) and a few used logistic (or other distribution) regression (see for example, Barr, 2008). Given the number of studies utilizing count data (saccades, fixations, etc.) over a scene in which time is not held constant, analyses like these seem more appropriate than the traditional ANOVA or linear regression models. One explanation for alternative methods being less utilized is difficulty of interpretation. The coefficients resulting from the GLMM beta regression model are log-odds and are interpreted by exponentiating them. These log-odds exponentiate to the following values: emotion = 2.43, neutral = 1.98 which represent the odds ratios. For these data, the estimated odds that a learner would attend to an AOI with an emotionally salient seductive detail increases by 143% over an AOI with no seductive detail in that location, while holding prior knowledge constant. The estimated odds that a learner would attend to an AOI with a neutral seductive detail increases by 98% over an AOI with no seductive detail in that location, while holding prior knowledge constant. This is consistent with prior research using similar materials. One purpose of this study was to extend prior research using the textbook materials and photographic images rather than just the vector art images. A prior study had similar results for attention; however, a concern was that the attention draw was due to violation of expectations rather than

emotional valence. This is still a potential explanation, but the current study seems to suggest that learners attend more to emotionally salient seductive details than non-emotional.

Research Question 4

The low correlation between the OSPAN and RSPAN scores was unexpected ($r = .44$) given the reported correlation ($r = .68$) of scores from the same instruments used in a large-scale study ($n = 2,442$) with undergraduate students (Oswald et al., 2015). Long form versions of the span tasks are available and may be useful for future assessments as they may yield better reliability estimates. In addition, while most prior seductive details research has utilized span tasks for assessing WMC, it may be fruitful to investigate other tasks. Particularly with regard to the differences in prior knowledge and transfer learning it may be that short term memory capacity (STMC) which is domain-specific is a more important construct than WMC which is a domain general and related more to executive control and attention (Conway et al., 2005). The use of span tasks is relevant in the attention – memory paradigm but using n-back or other working memory tasks may be more appropriate for other frameworks. For the current study, and this specific question, span tasks are indeed the appropriate instrument as the outcome variable is attention; however, future studies may take a different theoretical approach. The results of the current study suggest that WMC had no ability to predict level of attention given the confidence interval included zero.

Research Question 5

The relationship between WMC and learning outcomes was weak as was the relationship between the amount of time spent viewing seductive details and learning

outcomes. The poor between-test reliability of the WMC instruments used may help explain the lack of a stronger relationship between learning outcomes and WMC. The use of the Bonferroni adjustment meant the p-value of .05 for the recall regression was not statistically significant for this study; however, the interaction was not statistically significant in either the recall or transfer model. The variance explained was relatively large in both models, $R^2 = .20$ for recall and $R^2 = .25$ for transfer, indicating the model performed well but was potentially underpowered. Based on the data from the study it was clear that WMC does not interact with the amount of time spent viewing seductive details to explain performance on the outcomes of recall or transfer learning.

General Discussion

The results of this study failed to demonstrate a clear link between the emotional salience of seductive details and the effects of seductive details on learning outcomes. The simplest explanation is there is no link to be found. In order to draw that conclusion with reasonable certainty, the assessment of learning outcomes would need to be reliable and, as demonstrated in the data, that is not the case. The data clearly indicate learners give more visual attention to details which have more emotional salience than to those which are neutral. We can safely state that learners are more distracted by these types of seductive details but not that learning is impaired. There is not strong evidence provided by this study that learning outcomes are not impaired; however, given the relatively weak learning outcome assessments. Additional investigations into the role of working memory capacity suffered from similar score reliability concerns based on the measures used. Conclusions about the relationship between working memory capacity and attention and learning outcomes do not have strong evidence either for or against the

existence of a relationship. The strongest conclusion to be drawn from this study is that learners give more visual attention to emotionally salient seductive details included in learning interventions.

Future Directions

One future direction for this research is to develop better assessments to address the reliability issue. Separate instruments to reliably assess recall and transfer learning should be developed, revised, and validated. This will help ensure if an effect of seductive details exists in the learning materials, it will be revealed in the results of the learning assessments. Along with the learning assessments, using different working memory assessment would be beneficial. Future research should carefully analyze whether the working memory component of this research is purely attentional or if there are domain-specific components that may be better assessed with other instruments. In addition to the assessments, the materials design should be revised. The textbook materials seemed engaging for the participants and are likely a better direction for this research. Photographs should be selected from a larger set of normed images. The GAPeD database has a limited set of images and a larger set such as the International Affective Picture System (Lang et al., 2008) would yield better, more naturally flowing images for the textbook materials. The result of these improvements in the materials and study design for the future would be a stronger ability to better describe the relationship, if any, between the emotional salience of seductive details and the effects of seductive details on learning outcomes.

Conclusion

Given current advances in technology, more learning intervention materials are being designed by teachers for students often utilizing electronic media. The design of these materials often includes seductive details which may detract from learning. A primary goal of this study was to explore if the emotional salience of seductive details might help explain whether and how seductive details detract from learning. The design of the study accounted for WMC and directly measured visual attention using eye-tracking. The study provided little evidence to suggest that the seductive details used in the materials detracted from learning or that WMC helped explain visual attention. The evidence does suggest that learners do visually attend to seductive details when they are present, and they are more likely to attend to emotionally salient seductive details than neutrally valenced details. Future work should focus on designing better assessment instruments as well as explore different learning intervention materials.

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APPENDIX A
EXAMPLE STUDY MATERIALS

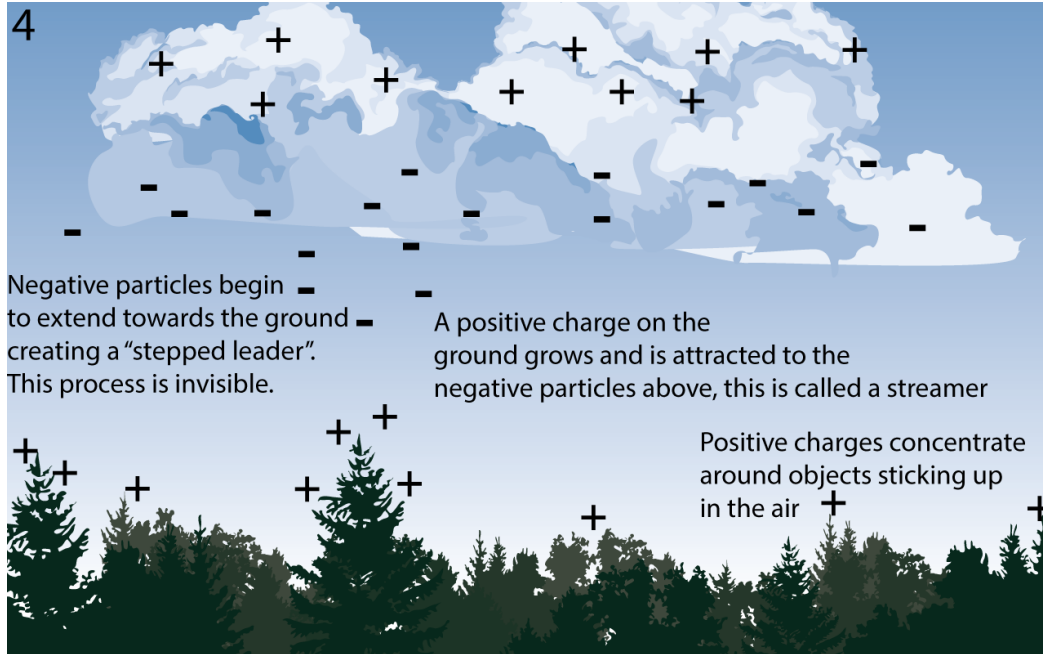


Figure 12. No seductive details sample image from "How Lightning Forms". This image has no seductive details and is representative of the images that will be seen by the control group.

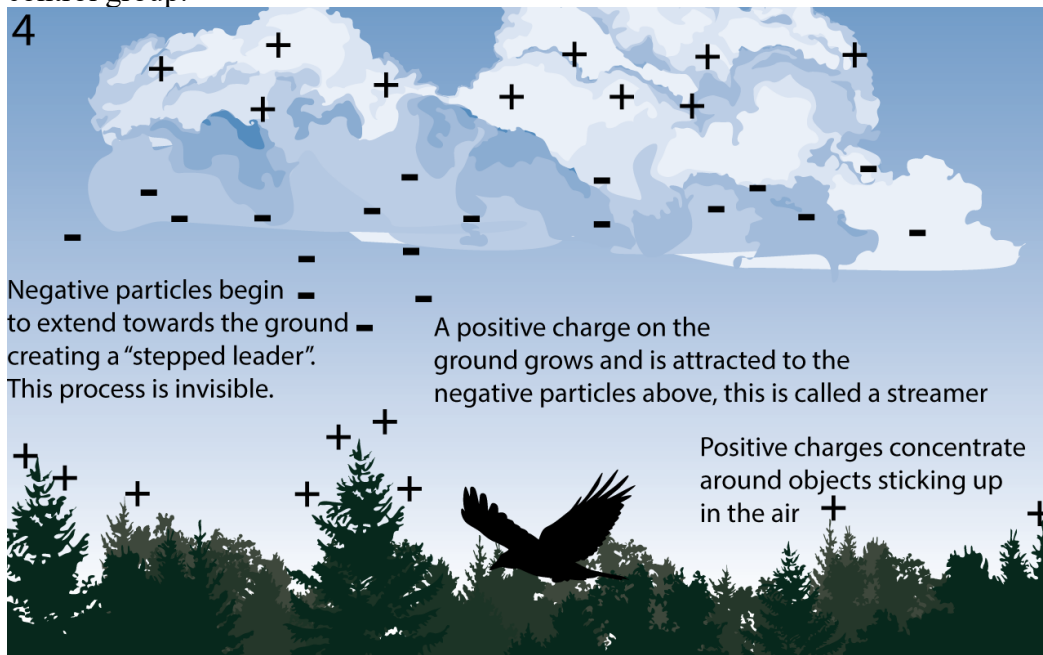


Figure 13. Neutral seductive details sample image from "How Lightning Forms". This image has neutral seductive details and is representative of the images that will be seen by the non-emotional seductive details group.

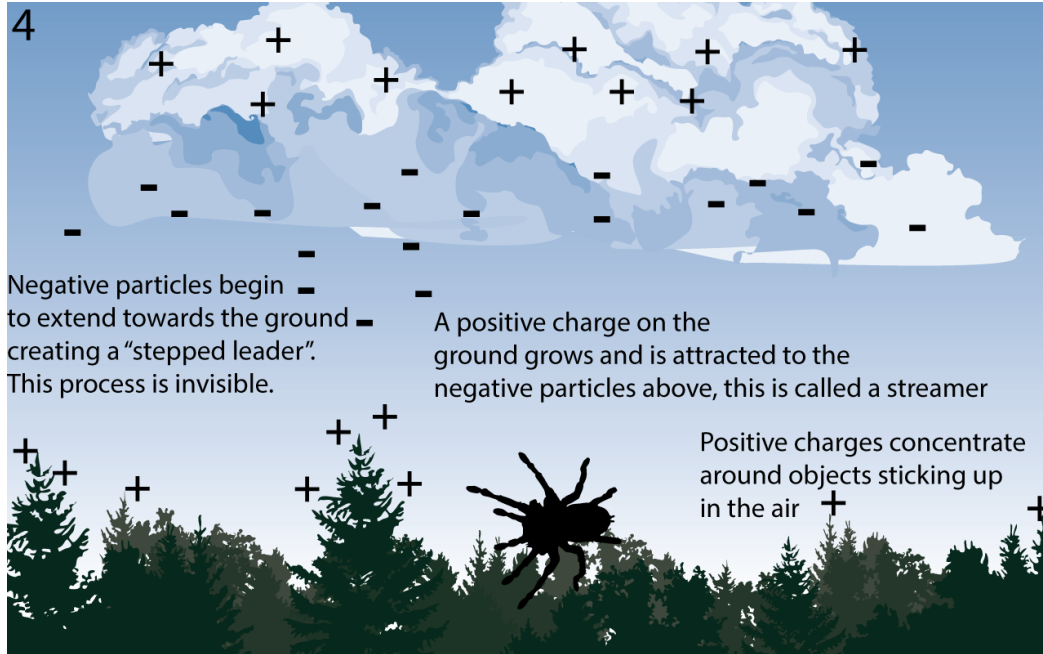
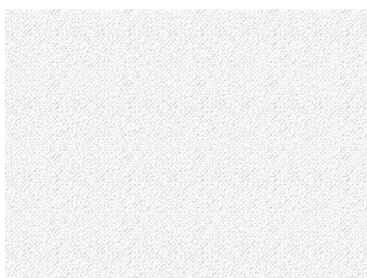


Figure 14. Emotional seductive details sample image from “How Lightning Forms”. This image has emotional seductive details and is representative of the images that will be seen by the emotional seductive details group.

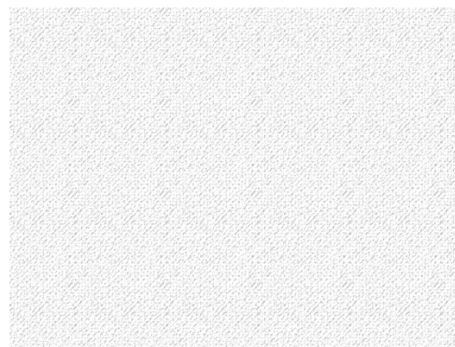
General Overview of the Ice Ages

Geologically speaking, we live in a time period of intense climatic change. Since the last 1 million years, our species and our human forebears experienced a dozen or so major glaciations of the northern hemisphere, with the greatest ever occurring around 650,000 years ago. During this period of extreme ice buildup, the ice advanced deep into the Midwest, from its center around Hudson Bay in Canada, and deep into Germany, from its center on the Scandinavian Shield. So much ice collected in these two major regions and several lesser ones that the sea level dropped by some 400 feet and the overall global temperature was lowered by around 5°C (about 9°F).



The glaciation that occurred 650,000 years ago lasted some 50,000 years. It had a profound

effect on the landscape, carving great glacial valleys and fjords and lakes, and making moraines and glacial outwash plains around the perimeter of its extent. The greatly lowered sea level allowed rivers to cut deeply into the shelves of the continents and into the edges of the shelves, where the sea floor drops off into the deep ocean. Here canyons could form which would later serve to funnel sediments from the shelf into the deep sea.



After this great glaciation, a succession of smaller glaciations has followed, each separated by about 100,000 years from its predecessor, according to changes in the eccentricity of the Earth's orbit (a fact first discovered by the astronomer Johannes Kepler, 1571-1630).

Figure 15. No seductive details sample image from “Causes of Ice Ages”. This image has no seductive details and is representative of the images that will be seen by the control group. The gray squares represent the areas occupied by seductive details in the other conditions. In this condition, the gray and white noise pattern is designed to fill space on the page, indicating to the reader that the space is left blank on purpose, however there is nothing interesting to look at in these spaces.

General Overview of the Ice Ages

Geologically speaking, we live in a time period of intense climatic change. Since the last 1 million years, our species and our human forebears experienced a dozen or so major glaciations of the northern hemisphere, with the greatest ever occurring around 650,000 years ago. During this period of extreme ice buildup, the ice advanced deep into the Midwest, from its center around Hudson Bay in Canada, and deep into Germany, from its center on the Scandinavian Shield. So much ice collected in these two major regions and several lesser ones that the sea level dropped by some 400 feet and the overall global temperature was lowered by around 5°C (about 9°F). Mammoth, mastodon, woolly rhinoceros, giant bison, camels, horses, and many large predators (cats, wolves, bears) roamed the grasslands well south of the rim of the miles-high ice, both in North America and in Europe escaping the attention from human hunters that would happen later. Small bands of humans made a living by hunting and gathering in Africa, and perhaps elsewhere, completely unaware of what life had been like for humans before the ice age began. The glaciation that occurred 650,000 years ago lasted some 50,000 years. It had a

profound effect on the landscape, carving great glacial valleys and fjords and lakes, and making moraines and glacial outwash plains around the perimeter of its extent. The greatly lowered sea level allowed rivers to cut deeply into the shelves of the continents and into the edges of the shelves, where the sea floor drops off into the deep ocean. Here canyons could form which would later serve to funnel sediments from the shelf into the deep sea.



After this great glaciation, a succession of smaller glaciations has followed, each separated by about 100,000 years from its predecessor, according to changes in the eccentricity of the Earth's orbit (a fact first discovered by the astronomer Johannes Kepler, 1571-1630).

Figure 16. Neutral seductive details sample image from “Causes of Ice Ages”. This image has neutral seductive details and is representative of the images that will be seen by the non-emotional seductive details group. The image on the right is of a clay pot which can loosely be related to the discussion of the hunters or the sediment; however, it is not relevant for learning the information on this screen. The highlighted text will not be highlighted for the participants but is highlighted here for illustration. The yellow text is the same in both the non-emotional and emotional seductive details condition, the green text is related to changes for the emotional condition (see Figure A6).

General Overview of the Ice Ages

Geologically speaking, we live in a time period of intense climatic change. Since the last 1 million years, our species and our human forebears experienced a dozen or so major glaciations of the northern hemisphere, with the greatest ever occurring around 650,000 years ago. During this period of extreme ice buildup, the ice advanced deep into the Midwest, from its center around Hudson Bay in Canada, and deep into Germany, from its center on the Scandinavian Shield. So much ice collected in these two major regions and several lesser ones that the sea level dropped by some 400 feet and the overall global temperature was lowered by around 5°C (about 9°F). Mammoth, mastodon, woolly rhinoceros, giant bison, camels, horses, and many large predators (cats, wolves, bears) roamed the grasslands well south of the rim of the miles-high ice, both in North America and in Europe, escaping the slaughter from human hunters that would happen later. Small bands of humans made a living by hunting and gathering in Africa, and perhaps elsewhere, completely unaware of the nightmare that the ice age had brought. The glaciation that occurred 650,000 years ago lasted some 50,000 years. It had a profound

effect on the landscape, carving great glacial valleys and fjords and lakes, and making moraines and glacial outwash plains around the perimeter of its extent. The greatly lowered sea level allowed rivers to cut deeply into the shelves of the continents and into the edges of the shelves, where the sea floor drops off into the deep ocean. Here canyons could form which would later serve to funnel sediments from the shelf into the deep sea.



After this great glaciation, a succession of smaller glaciations has followed, each separated by about 100,000 years from its predecessor, according to changes in the eccentricity of the Earth's orbit (a fact first discovered by the astronomer Johannes Kepler, 1571-1630).

Figure 17. Emotional seductive details sample image from “Causes of Ice Ages”. This image has emotional seductive details and is representative of the images that will be seen by the emotional seductive details group. The image on the right is of penguins in an arctic landscape which can loosely be related to the discussion of the glaciers; however, it is not relevant for learning the information on this screen. This is a positively valenced photograph. The highlighted text will not be highlighted for the participants but is highlighted here for illustration. The yellow text is the same in both the non-emotional and emotional seductive details condition, the green text is related to changes for the non-emotional condition and the red highlights indicate emotional words from the ANEW database.

APPENDIX B

EXAMPLE EMOTIONAL MATERIALS USED



Figure 18. Negatively valenced image. Selected from the animals subset in the GAPED database. Valence = 9.94, Arousal = 80.9.



Figure 19. Negatively valenced image. Selected from the animals subset in the GAPED database. Valence = 13.9, Arousal = 61.1.



Figure 20. Negatively valenced image. Selected from the spiders subset in the GAPED database. Valence = 9.52, Arousal = 78.4.



Figure 21. Negatively valenced image. Selected from the snakes subset in the GAPED database. Valence = 18.0, Arousal = 69.8.



Figure 22. Positively valenced image. Selected from the positive subset in the GAPED database. Valence = 95.3, Arousal = 12.1.



Figure 23. Positively valenced image. Selected from the positive subset in the GAPED database. Valence = 91.3, Arousal = 57.6.

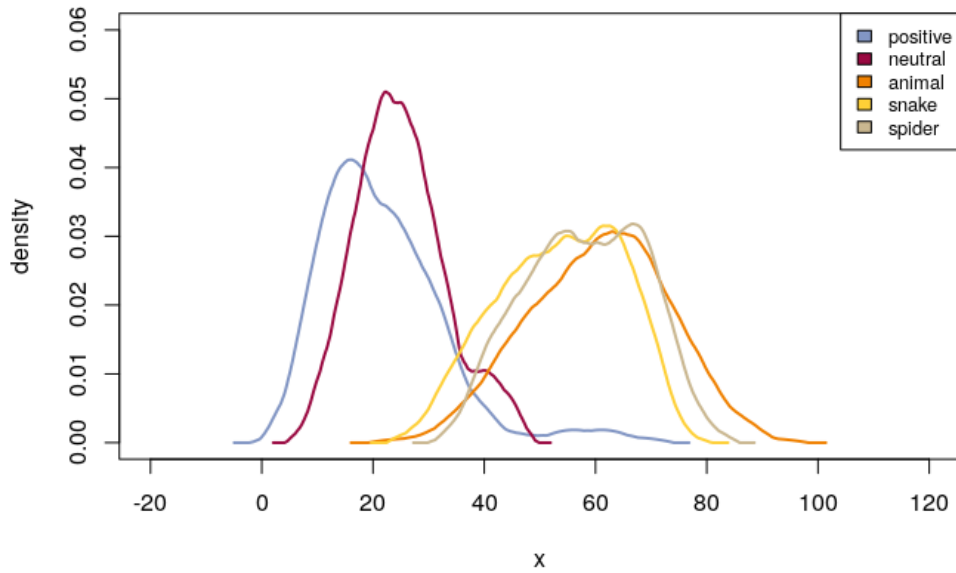


Figure 24. Image subset density curves for arousal. The scale is 0 to 100 with 0 representing no arousal with 100 representing maximum arousal.

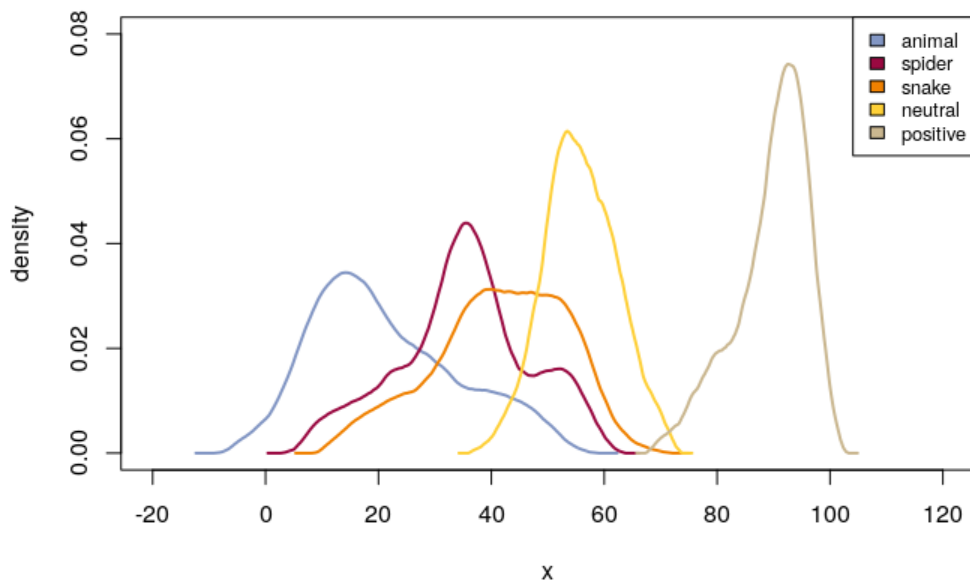


Figure 25. Image subset density curves for valence. The scale is 0 to 100 with 0 representing more negative and 100 representing more positive valence.

Table 1

Valence and Arousal Scores from the ANEW Database

Word	Valence	Arousal
Afraid	2.0	6.67
Cancer	1.5	6.42
Thrilled	8.05	8.02
Nightmare	1.91	7.59
Holiday	7.55	6.59
Poisoning	1.98	6.05
Slaughter	1.64	6.77
Traumatic	2.1	6.33
Vacation	8.16	5.64
Wars	2.08	7.49

Note. Valence and arousal are on a scale from 0 to 9. Valence is scored as 0 is most negative and 9 is most positive. Arousal is scored as 0 is least arousing and 9 is most arousing.

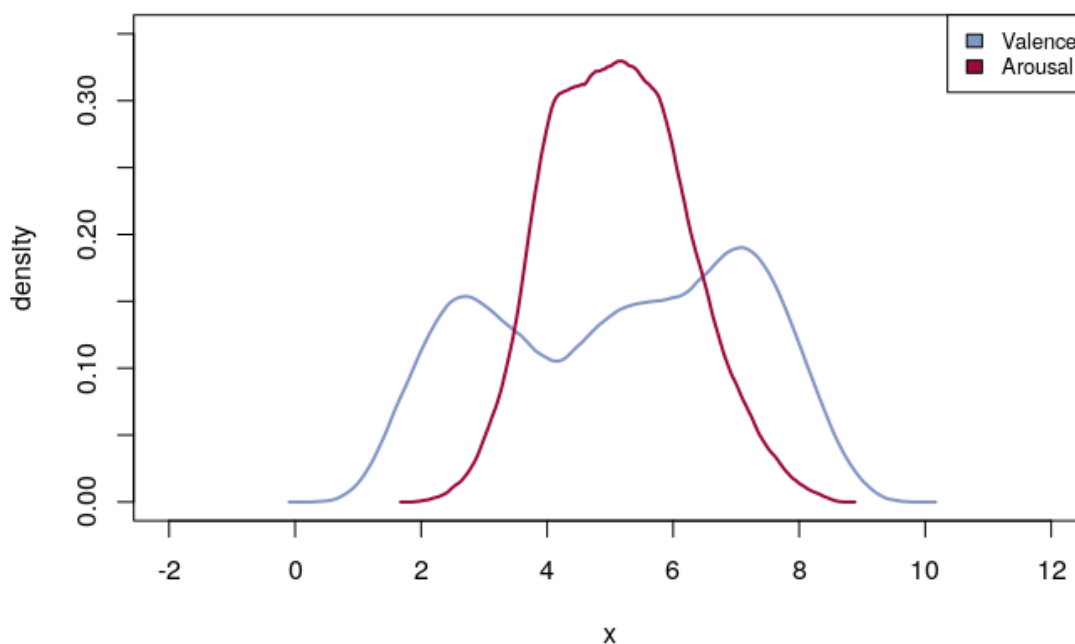


Figure 26. ANEW word subset density curves for arousal and valence. The scale is 0 to 9 with 0 representing more negative and 9 representing more positive valence and 0 representing least arousal and 9 representing maximum arousal.

APPENDIX C
EXAMPLE ASSESSMENT ITEMS

- Q1.1 Water vapor is formed by
- Clear
- # Rapid melting of glaciers and ice sheets
- # Water particles attaching to helium in the air
- # Heat from the sun causing bodies of water to evaporate
- 1 Heat from the ground warming the moist air above it
- Q1.2 **True or False:** lightning formation starts when warm vapor starts to collide with cooler air below it
- Clear
- # True
- 1 False
- Q1.3 Which of the following statements explains cloud formation most accurately?
- Clear
- 1 Condensation happens faster than evaporation
- # Evaporation happens faster than condensation
- # Evaporation and condensation happens simultaneously
- Q1.T Thinking about how clouds form, think about how fog forms on a bathroom mirror when taking a shower. Which of the following statements best explains how this fog forms?
- Clear
- # Warm water vapor from the shower rises to the ceiling, condenses and falls onto the mirror
- 1 Warm water vapor from the shower condenses on the cold mirror faster than it can evaporate
- # Warm water vapor from the shower collides with tiny crystals in the air and collects on the mirror

Figure 27. Sample of questions from Qualtrics for “How Lightning Forms”. The first three questions are general knowledge questions gathered from information on the screen. The fourth question represents a transfer of learning question.

Panel 1

Q1.1 How often have ice ages or glaciations happened over the past 1,000,000 years?

Clear

Every 1,000 years

Every 11,500 years

Every 50,000 years

1 Every 100,000 years

Q1.2 The largest Ice Age in the last 1,000,000 years occurred approximately how many years ago?

Clear

15,000 years ago

55,000 years ago

450,000 years ago

1 650,000 years ago

750,000 years ago

Q1.3 Changes in the eccentricity of earth's orbit contributed to which of the following phenomenon?

Clear

Increased number of sun spots

1 A succession of smaller glaciations following the great ice age

The extinction of polar bears, seals, and some early human tribes

Eruption of massive volcanoes reducing earth's temperature

Q1.T Thinking about the issue of global warming, if the temperature of earth rises by 5°C , what would be the most likely outcome?

Clear

The polar ice caps would help keep the earth cool near the poles

The polar ice caps would melt bringing much needed fresh water to farmers in Africa

1 The polar ice caps would melt causing sea levels to rise dramatically

The polar ice caps would reflect the sun's rays keeping the surface of the earth cool

Figure 28. Sample of questions from Qualtrics for “Causes of Ice Ages”. The first three questions are general knowledge questions gathered from information on the screen. The fourth question represents a transfer of learning question.



The following questions are related to your past experience with this material.

How much did you study the causes of the Ice Ages in high school?

A great deal

A lot

A moderate amount

A little

None at all

How much did you study Climate Change in high school?

A great deal

A lot

A moderate amount

A little

None at all

How much have you studied either the Ice Ages or Climate Change on your own?

A great deal

A lot

A moderate amount

A little

None at all

How knowledgeable do you feel you are on the issue of Climate Change compared with your peers?

Extremely knowledgeable

Very knowledgeable

Moderately knowledgeable

Slightly knowledgeable

Figure 29. Sample of questions from Qualtrics related to prior

APPENDIX D
INSTITUTIONAL REVIEW BOARD APPROVAL
AND INFORMED CONSENT



Institutional Review Board

DATE:	October 12, 2017
TO:	Matt Swaffer, MA
FROM:	University of Northern Colorado (UNCO) IRB
PROJECT TITLE:	[1136363-1] Does the Emotional Salience of Seductive Details Moderate the Seductive Details Effect
SUBMISSION TYPE:	New Project
ACTION:	APPROVAL/VERIFICATION OF EXEMPT STATUS
DECISION DATE:	October 12, 2017
EXPIRATION DATE:	October 12, 2021

Thank you for your submission of New Project materials for this project. The University of Northern Colorado (UNCO) IRB approves this project and verifies its status as EXEMPT according to federal IRB regulations.

Matt -

Thank you for a clear and thorough IRB application for an interesting study.

All materials and protocols are verified/approved exempt and you may begin participant recruitment and data collection.

Best wishes with your study and please don't hesitate to contact me with any IRB-related questions or concerns.

Sincerely,

Dr. Megan Stellino, UNC IRB Co-Chair

We will retain a copy of this correspondence within our records for a duration of 4 years.

If you have any questions, please contact Sherry May at 970-351-1910 or Sherry.May@unco.edu. Please include your project title and reference number in all correspondence with this committee.

This letter has been electronically signed in accordance with all applicable regulations, and a copy is retained within University of Northern Colorado (UNCO) IRB's records.



College of Education and Behavioral Sciences

School of Psychological Sciences

CONSENT FORM FOR HUMAN PARTICIPANTS IN RESEARCH

UNIVERSITY OF NORTHERN COLORADO

Project Title: Does the Emotional Salience of Seductive Details Moderate the Seductive Details Effect?

Researcher: Matthew Swaffer, PhD Candidate, Educational Psychology

Phone: 970-590-3242

Email: Matthew.swaffer@unco.edu

Research Advisor: Dr. James Kole, School of Psychological Sciences, University of Northern Colorado

Phone: (970) 351-2422

Email: James.kole@unco.edu

Purpose and Description: The purpose of this research is to examine how students learn from materials using different types of images. In this study you will be asked to participate in two short units of learning (10 – 15 minutes) about science-based information. After the instruction, you will be asked to answer questions demonstrating knowledge of the topic studied. In addition,

either before or after this intervention, you will also be asked to participate in a 2-part, 15 to 25 minute task designed to measure working memory capacity.

What we will ask you to do: We will ask you to read material or view images on the science-based subject matter. Some of the images may be designed to have a mildly emotional impact but nothing more than you would normally encounter in reading a college level textbook. After completing this task, we will ask you to respond to questions utilizing the information from the instruction.

Confidentiality: All electronic records for all tests will include a participant number only and no other identifying information (e.g., name). The electronic records are encrypted and kept on a password-protected computer in the lab. The list of names linked to participant numbers will be kept in a separate file cabinet in the Primary Investigator's office. All of your responses will be strictly confidential. Results of the study will be presented in group form only (e.g., averages).

Risks and benefits: There are minimal risks involved in this study. A student may feel some anxiety to perform in the testing environment, but no more anxiety than would be expected with college coursework. A student may feel some emotional responses to images but no more than would expected with reading a normal college textbook. A benefit of this study would be the acquisition of new knowledge on science based material, as well as contributing to a body of research on how students learn new material. Reasonable safeguards have been taken to minimize both the known and the potential, but unknown risks.

Compensation: Participants who are a part of the PSY120 pool will be compensated with credit to fulfill the research experience requirement for Psychology 120; students may also participate to receive extra credit in a course; or as volunteers without compensation.

Taking part is voluntary: Taking part in this study is completely voluntary. You may skip any questions you do not want to answer and may terminate participation in the study at any time and for any reason. If you choose not to participate in this study, you may select an alternate assignment instead of being a research participant. You may withdraw your consent and discontinue your participation at any time without penalty.

If you have questions: The researchers conducting this study is Matthew Swaffer with supervisor Dr. James Kole. Please ask any questions you have now. If you have questions later, you may contact Matthew Swaffer at Matthew.swaffer@unco.edu or at (970) 590-3242. You can reach Dr. Kole at James.kole@unco.edu. If you have any questions or concerns regarding your rights as a subject in this study, you may contact the Institutional Review Board (IRB) at (970) 351-1907 or access their website at <http://www.unco.edu/osp/ethics/irb/>

Participation is voluntary. You may decide not to participate in this study, and if you begin participation you may still decide to stop and withdraw at any time. Your decision will be respected and will not result in loss of benefits to which you are otherwise entitled. Having read the above and having had an opportunity to ask any questions, please sign below if you would like to participate in this research. This form will be given to you to retain for future reference. If you have any concerns about your selection or treatment as a research participant, please contact Nicole Morse, IRB Administrator, in the Office of Sponsored Programs, Kepner Hall, University of Northern Colorado Greeley, CO 80639: 970.351.1910.

Statement of Consent: I have read the above information, and have received answers to any questions I asked. I consent to take part in the study.

Participant's Signature

Date

Researcher's Signature

Date

The research advisor will keep this consent form for at least three years beyond the end of the study.