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REIMAGINING THE CHALK TALK: ANIMATED HANDWRITING

AS A SOCIAL CUE TO IMPROVE MOTIVATION

IN MULTIMEDIA VIDEO LESSONS

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Old Dominion University in Partial Fulfillment of the
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May 2018

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ABSTRACT

REIMAGINING THE CHALK TALK: ANIMATED HANDWRITING AS A SOCIAL CUE TO IMPROVE MOTIVATION IN MULTIMEDIA VIDEO LESSONS

Hillary C. Kaplowitz
Old Dominion University, 2018
Director: Dr. Ginger S. Watson

Animated handwriting in multimedia video lessons, such as those popularized by the Khan Academy, has reimagined the classic teaching technique of writing on a chalkboard while lecturing for online delivery. This digital chalk talk effect mimics classroom lectures where words are written letter by letter on a chalkboard as they are spoken. Low-cost applications, tablets, and document cameras allow instructors at all levels to easily create their own animated handwritten videos. As adoption increases, it is important to understand the effects of this strategy.

This study employed a true experimental, between-subjects, posttest design that compared multimedia lessons with different text display formats on outcomes of motivation, mental effort, and learning. Undergraduate student volunteers (n = 234) from a large U.S., West Coast, regional, four-year public university were randomly assigned to one of three treatments: Animated handwritten, animated typewritten, or static typewritten. Each group watched a different version of a five-segment, twelve-minute multimedia lesson about cryptography. Lessons differed only in the visual text display format and contained identical narration and content.

Results indicated that multimedia with animated handwritten text produced strong social cues motivating learners. Participants who viewed the animated handwriting reported significantly greater social agency attitudes toward the learning experience than with static typewritten text. They perceived the narrator’s voice as more dynamic with animated

handwriting when compared to static, even though the voice was identical. They also reported more attention to the lesson and materials with animated handwriting than either animated typewritten or static typewritten. These motivational gains are accomplished without introducing extraneous cognitive load or negatively impacting learning outcomes.

Significant findings from this research demonstrated that animated handwritten text is more than just a signaling strategy. The combination of text being hand-drawn and appearing as if a real person is writing it in real time adds a powerful social cue. Results of this study demonstrate that using animated handwriting in multimedia video lessons is an effective way to increase motivation through social cues that can be accomplished without requiring expansive technical knowledge, expensive equipment or extensive time investments.

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This dissertation is dedicated to every person who I have learned something from in my life. Thank you to my partner, family, sensei, advisor, mentors, instructors, colleagues, and most importantly to all my students over the years who have truly been my greatest teachers.

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CHAPTER 1

INTRODUCTION AND LITERATURE REVIEW

Introduction

Multimedia lessons have become one of the staple sources of learning across many educational settings. The nonprofit Khan Academy boasts the delivery of over one billion lessons since the founding of their online resource library in 2008 (Khan Academy, 2018; Khan, 2011). These lessons are most well known for their animated text effect, where handwritten words appear on the screen, synchronized with the audio narration. The effect is similar to watching someone write on a chalkboard or whiteboard as they give a lecture, where words are written letter by letter as they are spoken and drawings are completed along with explanations. In higher education settings, many instructors have access to low-cost solutions to create their own animated text videos. As adoption of this text display format increases, it becomes increasingly important to understand the effects of this strategy on student experience and performance, if any, and how it compares to other commonly used presentation strategies.

Prior to modern technology-based instructional media, the tools for instruction were simply the teacher, chalkboard and textbook (Reiser, 2001). Writing on a chalkboard while lecturing is one of the most widely used teaching techniques, known informally as the chalk talk (Artemeva & Fox, 2011; Maclaren, 2014). This pedagogical strategy is central to mathematics and other problem-solving domains where it is essential to provide a written narrative along with verbal descriptions during a lesson, giving learners opportunities to witness stepwise problem-solving strategies in real time in ways not supported by static material.

Over time, classroom presentation technology has evolved away from the chalkboard. Some formats maintain the handwritten format, such as the overhead transparency and document camera, while other formats no longer enable the chalk talk style; one in particular is the pervasive computer-based slide presentation (e.g., Microsoft PowerPoint). While these types of advances provide the ability to create professional looking classroom presentations, they do not allow instructors to easily create or change the materials as they present. Instead the instructional materials must be created prior to the lecture. Video-based instruction also mimics this progression, as software was developed to capture the text-based presentation graphics to create professional looking multimedia lessons (Maclaren, 2014).

While technology continues to evolve, its impact is not always clear. The history of instructional media repeats itself as new technologies bring the promise of radical improvements, only to fall short (Reiser, 2001). Professionals in instructional design and educational technology have long debated whether or not learning is affecting by delivery method, media type or technology (e.g., Clark, 1983, 1994; Kozma, 1994; Tennyson, 1994). With each new advance, there is the potential for a negative effect as something important may be supplanted. In his commentaries on media, Marshal McLuhan (1964) describes how as new technology is adopted there is often a trade-off where some aspect is discarded often resulting in something of value being lost. Critics of PowerPoint point out that while its use is near ubiquitous in educational and corporate settings there is no consistent evidence of improved motivation or increased learning gains, and it has potentially negatively impacted the way teachers deliver information, students' perceptions, and was partially implicated in the NASA shuttle tragedy (Adams, 2006; Buchko, Buchko, & Meyer, 2012; Norvig, 2003; Savoy, Proctor, & Salvendy, 2009; Susskind, 2005; Szabo & Hastings, 2000; Tufte, 2003). If the chalk talk has a pedagogical value over PowerPoint style presentation graphics, then it is important to revive its use, instead of letting technology advances drive instructional design decisions.

Instructors now can recreate the chalk talk in the classroom and in multimedia lessons. Not only is it being resurrected in classroom for live lectures with the aid of tablet PCs connected to projectors in classrooms (Choate, Kotsanas, & Dawson, 2014; Derting & Cox, 2008; Maclaren, 2014; Mock, 2004; Scott, 2011; Venema & Lodge, 2013), its potential affordances are recaptured through the use of animated handwritten text in multimedia lessons. While he has no empirical evidence, Khan (2012) states that he believes that seeing elements written by hand helps the learner better process the information then they would with static text-based slides.

In fact, very little research has been done on the digital versions of the chalk talk. Research by Luzón and Letón (2015) provides one of the few empirical studies in this area. They found that animated text compared to static text yielded positive results for learning. Another study looked at similar outcomes but also included specific measures to investigate the effects of animation including the hand and body on motivation through social cues (Fiorella & Mayer, 2016). Results from a pilot qualitative study and subsequent mixed-methods pilot study extended these two studies and suggest that animated text in multimedia lessons may help manage cognitive load, focus attention, and be a cue that promotes social agency, thereby increasing the motivation to learn (Kaplowitz, 2017; Kaplowitz & Watson, 2017).

Text in multimedia can be displayed using traditional PowerPoint style formats that employ typewritten text using standard fonts or using digital pen technology to create handwritten text. The text can appear all at once, in a static presentation, or be animated so the text appears as if it being typed or written. The current study sought to further extend this research area by comparing the effects of different text display formats on various outcomes of motivation, cognitive demands, and learning to inform instructional design heuristics for multimedia lesson creation.

Literature Review

Media-based instruction is an area that has been widely examined in the literature. When media combines auditory and visual presentation modes it is considered "multimedia" (Seel, 2007). The auditory mode refers to word-based information, whether it is printed or spoken text, and the visuals refer to picture-based information, whether it is still images or motion formats such as video or animation. Instructional multimedia messages are defined as requiring two components; the presentation must contain both "words and pictures" and be "designed to foster meaningful learning" (Mayer, 2003, p. 128).

Animated handwritten text in spoken-written presentations is a promising instructional multimedia lesson format. However, it has remained largely uninvestigated in the multimedia learning literature. The following literature review explores research on the design of effective multimedia instruction in relation to cognitive architecture and motivational factors to provide context for examining text display formats in spoken-written multimedia presentations.

Cognitive Architecture

Information-processing theory uses a computer metaphor to describe the flow of basic cognitive processes such as sensation, perception, attention, learning, remembering, and knowing within cognitive architecture models (Martinez, 2010). Though most cognitive architecture models were not specifically created to inform the design of multimedia instruction, they have been used to help explain cognitive processing in multimedia learning (Reed, 2006). Richard Mayer's (2009) cognitive theory of multimedia learning (CTML) is the most well-known model created specifically to describe multimedia learning, explaining why learning from both words and pictures is superior to learning from either words or pictures on their own. The theory draws assumptions from three of the cognitive architectures from Reed's (2006) review: Paivio's dual coding theory (Paivio, 1969, 1991), Baddeley's working memory model (Baddeley, 1994, 2000; Miller, 1956), and Sweller's cognitive load theory (Sweller & Chandler, 1994; Sweller, Van Merrienboer, & Paas, 1998). CTML also draws from generative learning theory (Wittrock, 1974).

Together these assumptions form the theoretical foundation of CTML (Mayer, 2009):

1. Dual Channel: Audio and visual information are processed in separate channels.
2. Limited Capacity: Each channel can only process limited amounts of information.
3. Active Process. Learning requires active processes such as attention, selection, organization, and integration with prior knowledge.

Based on these assumptions numerous research studies were conducted, ultimately leading to the development of the 12 research-based principles of CTML (Mayer, 2009). The goal of CTML is to inform the design of instructional multimedia to maximize learning by reducing extraneous processing, managing essential processing, and fostering generative processing. Mental effort is required for active learning so managing cognitive load through instructional design is crucial.

Synchronizing visual and auditory information in multimedia lessons takes advantage of simultaneous processing, which helps manage cognitive demands. If they are not synchronized, then learners will need to exert extraneous mental effort by using working memory to hold auditory or visual representations while waiting for the other format to be presented (Mayer, 2009; Mayer & Moreno, 2003). The synchronized, multi-modal nature of animated text may be an important affordance of the format that can help manage cognitive load for learners.

Attention. The information processing model indicates that information must filter through the cognitive system for learning to occur (Martinez, 2010). Before information can be recorded in long-term memory it must pass through the processes of sensation, perception and attention. Paying attention means working memory is being focused on the something. Without attention it is difficult for learning to occur. Kahneman (1973) summarizes attention as limited, demand-based, divisible, and selective. In discussing visual instruction Dwyer (1978), emphasizes that learning requires sustained attention, which is difficult as learners must distinguish between what is relevant and irrelevant, attend to that information, and interact with it. Animated text may have the ability to help sustain attention and guide learners to relevant information (Kaplowitz, 2017; Kaplowitz & Watson, 2017).

Signaling. Cueing is a useful device that can help focus the learner's attention on essential characteristics, especially in visual aspects of instruction. Strategies have been developed for text-based materials through typographic emphasis techniques such as boldface, underlining, headings, indenting, and related text and spacing cues (Hartley, 2004; Lorch Jr, 1989) as well as in image-based materials by using visual emphasis techniques such as color, arrows, shading, and contrast (Dwyer, 1972, 1978). These strategies have been extended to multimedia learning and include additional verbal and visual cues. For example, vocal emphasis can be used to signal learners about important topics or visual emphasis can take the form of animation to emphasize areas through shading, flashing, or even onscreen agents to point at areas. Focusing attention in this way can help reduce extraneous cognitive load by guiding the learner's attention more appropriately. In CTML this is known as the signaling principle (Mautone & Mayer, 2001; Mayer, 2009; van Gog, 2014).

Another signaling strategy used in multimedia presentations is to display key words. This strategy produces greater learning gains than using fully redundant on-screen text, which is explained by the redundancy principle in CTML. When spoken and written text is concurrently presented, learners will expend extraneous mental effort to compare the spoken and written text (Mayer, 2009). However, a boundary condition exists if the text is only partially redundant, as in the case with key words, by aiding in the formation of schema by signaling key concepts (Adesope & Nesbit, 2012; Mayer & Johnson, 2008). When key words are used in animated text presentations, it can help focus learner's attention to facilitate cognitive processing of important concepts.

Leading Gaze. Animation in multimedia can be a powerful signal to focus the viewer's gaze to the correct location at the correct time. Motion attracts attention and people will direct their gaze to follow moving objects (Kahneman, 1973). Signals such as flashing colors can facilitate learning. For example, eye-tracking research with signaled multimedia demonstrated that the signals guide attention and cue information, which led to increased transfer and matching when compared to non-signaled multimedia (Ozcelik, Arslan-Ari, & Cagiltay, 2010).

Animated handwritten text by design has built in signaling. As each word is written, there is motion at the point of writing. The continual animation can serve to lead the gaze and orient learners to key information at the time it is presented. By focusing attention, animated text can help reduce potential distractions that may occur if the learners were to scan the screen.

Motivational Factors

While the information processing model explains cognitive architecture using a computer metaphor, it does not accommodate the less cognitive and more affective aspects of human processing such as emotion, motivation, and volition — the "hot cognitions" (Martinez, 2010, p. 153). However, the "trilogy of the mind" taxonomy of cognition, affection, and conation can accommodate the different aspects of human thinking (Hilgard, 1980). Cognition refers to rational thought described by cognitive architecture models. Affection refers to emotions and feelings. Conation can be subdivided further into motivation and volition, where motivation is the drive that moves a person to pursue a goal and volition is the actions that a person takes to achieve that goal.

Without motivation for learning, the learner does have the volition to expend mental effort in learning situations (Keller, 2008). Learning tasks require significant cognitive demands (Gagne & Driscoll, 1988). This requires mental effort in the form of specifically allocated attention. When the learner is motivated to learn, they will expend the mental effort to learn.

Keller (1987) synthesized psychological research on motivation to create an organized, systemized set of prescriptions that instructional designers could apply in their designs to specifically motivate learners. This provides a framework for designing and assessing attributes of attention, relevance, confidence, and satisfaction, all of which influence learner motivation. Of all of these factors, the construct of attention is often cited as the first and most important (e.g., Gagné, 1965) while also being the most salient in multimedia, due to its relationship to arousal, interest, and curiosity. In addition to these design heuristics, Keller (2010) developed instruments that can be used to measure motivation in courses and for instructional materials.

Motivation is not directly addressed as a specific construct in the 12 principles of CTML, though some researchers have extended CTML to include motivational factors (Astleitner & Wiesner, 2004; Hede, 2002; Mayer, 2014a; Moreno & Mayer, 2007). One of these is Moreno's cognitive affective theory of learning with media (CATLM), where the impact of motivational factors are more clearly specified, especially in regard to positive and negative effects on cognitive engagement (Moreno, 2007; Moreno & Mayer, 2007). There is a gap in the literature regarding motivation in multimedia lessons especially when it comes to factors that promote generative processing and guide essential processing without introducing extraneous load (Mayer, 2014a).

Emotion. One way that motivation in multimedia learning has been investigated is through the incorporation of emotional design supported by interesting and personified graphics in multimedia lessons. Results from a series of replication studies in this area demonstrate that using appealing colors and adding human-like features can motivate learners as evidenced by increased learning outcomes; consistent with CATLM, affective qualities can be important moderators in multimedia learning (Mayer & Estrella, 2014; Plass, Heidig, Hayward, Homer, & Um, 2014; Um, Plass, Hayward, & Homer, 2012).

Humanization. When instruction is perceived to be impersonal, it can negatively interfere with the motivation and volition to learn. Multimedia lessons inherently introduce a physical and psychological separation between learners and instructors, referred to as "transactional" distance (Moore, 1997). In classroom settings, bridging this gap is possible through positioning, self-disclosure and personalization strategies to increase communication immediacy (Andersen, 1980; Baker, 2010; Mehrabian, 1969). In multimedia instruction this is more difficult, but strategies that humanize the lesson can increase immediacy and social presence. For example, better learning outcomes were achieved in a multimedia lesson when using a human voice versus a computer-generated one (Atkinson, Mayer, & Merrill, 2005; Mayer, Sobko, & Mautone, 2003).

Personalizing the narration can also positively affect learning (Mayer, 2014b; Moreno & Mayer, 2000). This includes using a conversational tone that is aimed directly at the learners. Addressing the learners using "you" and "I" rather than third person is a social cue that can motivate learners to extend more mental effort in actively engaging with the instructional material. Changes to the tone do not affect the instructional content, but can produce a social response that promotes higher-quality learning outcomes (Mayer, 2014b; Moreno & Mayer, 2000).

This personalization does not always have to be human-generated. People ascribe social identity to technology such as computers, television, new media (Reeves & Nass, 1996), and websites (Kumar & Benbasat, 2002), giving them para-social presence (Horton & Wohl, 1956). Life-like, animated pedagogical agents have been shown to increase motivation and learning through social cueing based on their voice (Atkinson et al., 2005; Park, 2015) and/or embodiment of human-like actions (Lester et al., 1997; Mayer & DaPra, 2012).

Social Agency. Social cues in instructional multimedia promote “social agency,” which can motivate learners by producing the impression of a “human-to-human conversation,” even though the interaction is between human and computer (Mayer et al., 2003, p. 419). Instead of interpreting the learning experience in terms of strictly information delivery, the social cues evoke the feeling of participating in an educative conversation. This primes the learner to engage more in making meaning and knowledge construction, because, based on human conversational conventions, the learner assumes the computer is conveying information that makes sense, so the learner should try to understand it. This in turn leads to increased motivation and learning outcomes (Mayer, 2014b; Mayer & DaPra, 2012; Mayer et al., 2003; Moreno & Mayer, 2000; Moreno, Mayer, Spires, & Lester, 2001).

Multimedia instructional design strategies that employ social cues, such conversational style and humanlike voice and gestures, are useful for extending principles of multimedia learning beyond the cognitive domain to include the social considerations (Mayer, 2014b). Humanlike gestures and motion are social cues that produced increased performance on transfer tests and higher ratings of social affinity in instructional multimedia messages with animated pedagogical agents (Mayer & DaPra, 2012). People often respond to media as if they are responding to real people and apply the same conventions that they would in social relationships; a phenomenon known as "the media equation" (Reeves & Naas, 1996, p.5). If animated handwritten text generates those same reactions, then it could be another type of social cue that activates a social response to increase motivation. Results from pilot studies indicate that animated text does evoke real-life educational experiences of being a student, having a real person explain things, and may have had a social cue effect (Kaplowitz, 2017; Kaplowitz & Watson, 2017).

Seductive Details. It is important to recognize that including interesting but irrelevant material can increase extraneous processing and can impair learning. This element is known as a "seductive detail" or "seductive augmentation" and can have negative effects on learning outcomes by shifting processing towards nonessential elements (Harp & Mayer, 1998; Mayer, Griffith, Jurkowitz, & Rothman, 2008; Thalheimer, 2004). Therefore, it is important to consider the effect of affective and social elements in the design of instructional multimedia lessons to determine if the additions increase essential and generative processing without increasing extraneous processing. Animated text has not been investigated enough to determine any boundary effects for its role as a potential seductive detail.

Spoken-written Presentations

Multimedia lessons that include audio narration with verbally redundant on-screen text are referred to as "spoken-written presentations" in a meta-analysis of verbal redundancy in multimedia learning (Adesope & Nesbit, 2012). Redundant on-screen text had been considered detrimental to learning (Kalyuga, Chandler, & Sweller, 2004), however the meta-analysis demonstrated benefits of spoken-written presentations for students with low prior knowledge, system-based presentations, and materials that do not include images as well as the use of displaying short redundant phrases or key words (mentioned previously in this review).

Unfortunately, the meta-analysis did not include any studies with presentations that used animated handwritten text. Searching the literature, there are a number of publications on the use of "digital inking" technology (such as digital interactive whiteboards, tablet PCs, recording pens, tablet applications) to create handwriting in spoken-written presentations (referred to as audiographs, touchcasts, pencasts, screencasts, etc.) (Loomes, Shafarenko, & Loomes, 2002; Palmer, 2011; Shea, 2011; Stasko & Caron, 2010). This text display format was applied across many learning situations such as recorded lectures with annotated Microsoft PowerPoint slides (Choate et al., 2014; Lumkes, 2009; Yoon & Sneddon, 2011), to replace live lectures in an inverted classroom model (Barreto et al., 2014), or as supplemental videos demonstrating worked examples (Kay & Kletskin, 2012). However, these examples are mainly focused on use cases and student perceptions and are not situated in the multimedia literature, though they report subjective positive attitudes towards this technology from students.

A variation of the animated text format includes showing a human instructor on-screen as they are writing. In a series of experiments comparing drawing to static presentations teaching the Doppler Effect to undergraduate students, researchers found learning was greatest when the instructor's hand is visible in the frame, somewhat when their body is visible, but there is no benefit when the instructor is not visible (Fiorella & Mayer, 2016). According to the researchers, the use of the hand (and less so the body) in multimedia lessons further support the cognitive and social aspects of multimedia learning.

While the authors of that study failed to find learning gains for animated text without the instructor visibly drawing, another study did find positive learning outcomes for animated text versus static text in a basic mathematics multimedia lesson on probability using worked examples for Spanish secondary students without showing the hand or body of the writer (Luzón & Letón, 2015). Their materials used symbolic text instead of a drawn diagram and their screens did not include the whiteboard but rather used a presentation format that was more standard for a computer-mediated learning environment. The static version was presented as a block of symbols on each screen with accompanying narration, while the animated text version displayed symbols being written character-by-character synchronized with the narration. To increase instructor immediacy, both treatments included a small video window of the instructor in the upper corner. From the positive results for learning, the researchers concluded that animated text's affordances include focusing attention, controlling pace, and synchronizing audio and video.

These two studies provide some promising results about animated handwriting, but it is unclear what factors contribute to those results. Further research is needed to better understand how motivational qualities such as social cues can increase student motivation and learning (Mayer, 2014a), but these studies need to be conducted in more ecologically valid scenarios (Mayer, 2014b). Previous research with text display formats has limited generalizability. For example, one used a very short video that covered one only concept (Doppler effect), so length may have been a factor (Fiorella & Mayer, 2016). Another had content that contained mathematical symbolic information, but no words (Luzón & Letón, 2015). Additionally, they included video of the instructor which may have had an effect coupled with the animated text.

More research is needed to further understand the effects of animated handwritten text on motivation and learning compared to other text display formats in multimedia lessons.

Purpose of Research

The focus of this study was to investigate various text display formats in multimedia lessons. This study sought to discover differences between text display formats in terms of motivation (attitudes, speech evaluation, attention and satisfaction), cognitive load (mental effort), and learning (post-test performance).

Research Questions

This research examined the differences between text display formats based on motivational and cognitive factors. The following research questions guided the study:

1. To what extent does text display format in multimedia lessons impact motivation?
2. To what extent does text display format in multimedia lessons impact cognitive load?
3. To what extent does text display format in multimedia lessons impact learning?

CHAPTER 2

METHODS

This chapter describes the study methodology including participants, research design, instructional treatments, delivery, measures, procedure, and the data analyses used to report the findings for the research questions.

Participants

Participants in this study were 386 undergraduate students enrolled at a large, regional, four-year, public university in the West Coast Region of the United States. Participation was voluntary and students received course extra credit for their participation.

Instructors with large numbers of undergraduates were invited by the researcher to offer extra credit for participation in the research study. Instructors from Biology, Communication Studies, and Sociology agreed to participate and notified their students of the extra credit opportunity (see Appendix A). Participating instructors shared directions regarding study completion with their students through email list and/or the learning management system. A few instructors declined to participate because they were either already offering extra credit in their course or do not offer extra credit in their course design.

Of the 386 students who attempted the study, 234 completed the requirements qualifying them for inclusion. Criteria for inclusion were examined in the following order. Participants with mean scores of greater than five on the pretest were excluded (n = 15). Participants were also excluded for their lack of completion or quality of effort for the following scenarios: did not complete all items (n = 59), did not spend sufficient time on the videos to have watched them in their entirety (n = 72), or spent less than 60 seconds on the posttest (n =3). Some participants could have been excluded on multiple criteria. Three additional subjects were also excluded for not meeting the participant requirement of undergraduate student status. A total of 152 participants were excluded from the original 386 who attempted the experiment.

Included participants ranged in age from 18 to 50 (M = 23.1, SD = 5.43) and were 69% female. The diverse ethnicity of the participants mirrored the diversity of the university. Tables 1 and 2 provide demographic distributions by treatment and for the total sample.

Table 1

Participant Age, Sex and Academic Standing Distribution by Treatment and Total Sample

		Age		Sex			Academic Standing			
Treatment	*n*	Mean	SD	F	M	*	Fr	So	Ju	Se
Animated Handwritten	85	23.7	6.51	57	26	2	7	26	33	19
Animated Typewritten	75	22.9	5.66	51	23	1	1	25	22	27
Static Typewritten	74	22.5	3.49	54	20	0	3	23	29	19
Total	234	23.1	5.43	162	69	3	11	74	84	65

Note. F = Female; M = Male; * = Trans*/Intersex/Non-binary; Fr = Freshman; So = Sophomore; Ju = Junior; Se = Senior.

Table 2

Participant Ethnicity Distribution by Treatment and Total Sample

	Ethnicity					
Treatment	AI/ AN	Asian/ PI	Black/ AA	White/ Caucasian	Hispanic/ Latino	Multi-ethnic
Animated Handwritten	0	10	2	18	46	9
Animated Typewritten	0	9	4	16	36	7
Static Typewritten	0	8	4	18	37	7
Total	0	27	10	55	119	23

Note. AI/AN = American Indian or Alaskan Native; PI = Pacific Islander; AA = African American; Multi-ethnic = selected two or more from the listed options.

Research Design

This study employed a true experimental, between-subjects, posttest design. The treatments were presentation formats (animated handwritten, animated typewritten, static typewritten). Dependent variables were motivation (attitudes toward learning, speech evaluation, attention, and satisfaction), cognitive load (mental effort) and learning (post-test performance total, as well as by recall and transfer questions). Cognitive load was measured multiple times during instruction and was treated as a repeated measure design for the associated analysis.

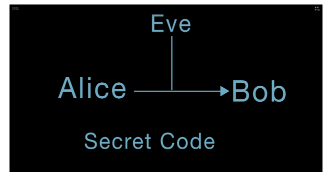
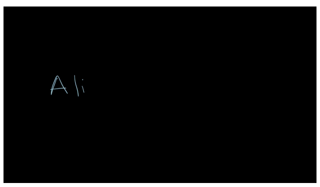
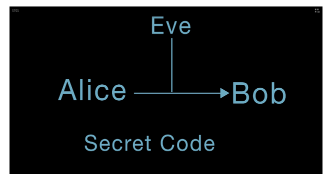
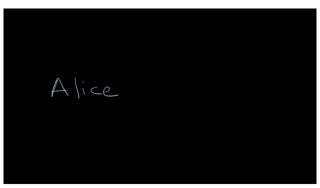
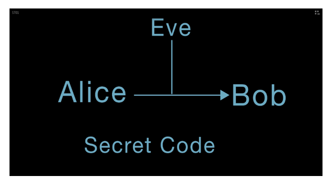
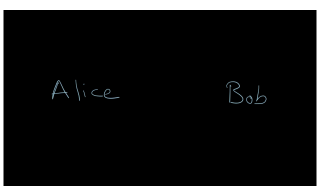
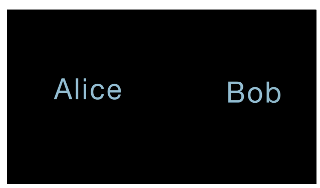
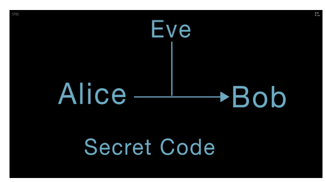
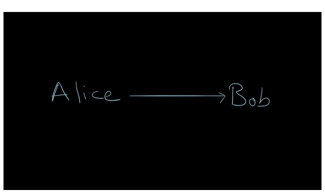
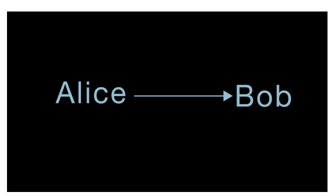
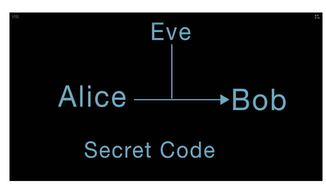
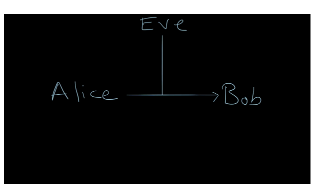
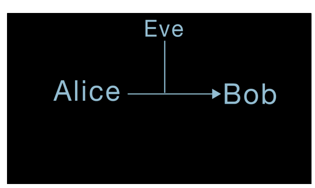
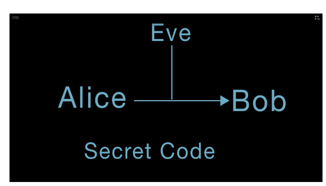
Instructional Treatments

Participants were randomly assigned to one of three treatments: Animated handwritten, animated typewritten, and static typewritten. Each watched a different version of a twelve-minute multimedia lesson adapted from a Creative Commons licensed Khan Academy lesson, *Journey into Cryptography (Cruise, n.d.)* (see Appendix G for transcript of content). The instructional content covered the ancient history of cryptography and key terminology. It also addressed cryptographic processes and concepts, strengths of different ciphers, and application of encoding and decoding messages. This subject matter was deemed to be interesting enough to sustain attention and new material for most participants. It was successfully employed in two pilot studies and participants commented that they found the material novel and interesting.

Each treatment contained the identical narration (from the original lesson). The lesson was broken down into five segments of two to four minutes in length. The segmentation of each treatment was also identical (see Appendix G for segmentation). The visual material consisted mainly of text on screen with some simple diagrams. The differences across treatments were in the visual text display style being hand drawn or computer generated, and the timing of the content displayed being animated or static. Table 3 illustrates a portion of the instructional material to demonstrate the alignment of content across identical time points and differences in text display treatment formats.

Table 3

Comparison of Text Display Format by Treatment

Timecode	Animated Handwritten	Animated Typewritten	Static Typewritten
TIME 1 00:09			
TIME 2 00:10			
TIME 3 00:11			
TIME 4 00:14			
TIME 5 00:19			
TIME 6 00:24			

Animated handwritten. Treatment videos displayed handwritten text that appeared on the screen synchronized with audio narration. This treatment was created by replacing the original video and still images with animated handwritten text drawn in primary colors on a neutral black background using the interactive whiteboard application Explain Everything™ (2017) on an Apple iPad and then exported to digital videos.

Animated typewritten. Treatment videos displayed typewritten text that appeared on the screen synchronized with audio narration. This treatment was created by replacing the video and still images with typed text using primary colors on a neutral black background using the presentation graphics software Microsoft PowerPoint to create the graphics and the screencasting program Camtasia (2017) to create the multimedia. Typed text was animated using "wipe" transitions to match the animated handwritten condition as much as possible.

Static typewritten. Treatment videos displayed typewritten text with each screen displayed at once without any animation. The animated typewritten video was modified using Camtasia to remove all animation effects so that material was presented screen by screen.

A static handwritten treatment was considered but not included in this study design due to its lack of ecological validity. It is unlikely that a multimedia lesson would be created in that format. Static text is much more likely as it requires the least amount of work to create, is perhaps the commonly used presentation format, and therefore was selected as the representative for a static treatment.

Delivery

The experiment was created using the online survey software Qualtrics (2017) and included all the instruments and instructional materials. Using the branch logic feature, a single link was provided to participants and the software randomly assigned them to one of three treatment branches for the instructional content. This provided a streamlined and efficient delivery system. All items in the instruments were set to be required so that participants could not move on without completing each item in each section. The timing feature was added to collect data about how long participants stayed on each screen and was useful in making decisions for inclusion and exclusion based on expected versus actual time spent viewing videos. Participants used their own internet-connected devices. Before beginning, participants were reminded to find a quiet location or use headphones and were told to allot up to 45 minutes for completion of the study. A free online tool flippity.net (2017) was used to allow participants to generate certificates of completion to provide to their instructor for extra credit after completing all experimental tasks.

Measures

Prior knowledge survey. A six-item knowledge survey (Nuhfer & Knipp, 2003, 2006) was created by the researcher to assess participants' subjective prior knowledge about cryptography through confidence judgments (see Appendix B). Questions on the pretest knowledge survey were based on learning outcomes and underwent expert review by two university faculty in computer science to ensure construct and content validity for assessing self-reported prior knowledge of cryptography.

Confidence question prompts asked participants to rate their level of confidence in relation to statements like "Overall knowledge of cryptography" and "Apply a substitution cipher to messages when given a shift word." The rating scale ranged from 1-7 (1 = not at all confident to 7 = very confident).

This study was aimed at learners with low prior knowledge on the topic of cryptography since the material is introductory. The pretest was used to assess prior knowledge as a qualification for participation. Participants with a pretest mean score of five or above were excluded from dataset used in the study (*n* = 15). Exclusion occurred during analysis since there was no way to pre-screen participants.

Criterion-referenced posttest. Learning outcomes were measured with a 15-item, multiple-choice, criterion-referenced posttest developed by the researcher (see Appendix F). The test included three items from each of the five video segments, with two recall items and one transfer level item per video, as outlined in the blueprint table of specifications (see Appendix E). Transfer items were included because most of the multimedia literature is focused on transfer (Mayer, 2009, 2014b).

Items were based on learning outcomes and underwent expert review to ensure content validity. Two university faculty in computer science reviewed the materials to ensure content validity and two instructional designers with experience in human performance assessment provided expert review of the test construction. Test items were revised based on feedback to clarify content as well as improve question and response wording. Example items included: “What is an encrypted communication?” (recall), and “Which of the following is the strongest shift word for a polyaphabetic cipher?” (transfer). Each item was worth one point and scores were tallied for recall (*n*=10), transfer (*n*=5) and total (*n*=15). A Kuder-Richardson Formula 20 (KR-20) reliability of .62 was calculated for the posttest scores in this study. Since the KR-20 was above .5, this is an acceptable result for a researcher-created test, especially with the low number of test items.

Mental effort. Cognitive load was measured through participants’ self-reported perceptions of the amount of mental effort they expended during instruction. Mental effort can be measured by asking participants to provide subjective estimates of their workload as they perform tasks (Hart & Staveland, 1988) or during problem solving (Paas, 1992). The number of scales used vary in the research, but results from a meta-analysis of cognitive load studies indicated that reliable measurements can be gathered from a one-dimensional scale, such as the one employed in this study (Paas, Tuovinen, Tabbers, & Van Gerven, 2003).

The mental effort scale developed by Paas (1992) was used to collect participants' subjective assessment of cognitive load (see Appendix C). This scale consisted of a single item which asked participants to rate how much mental effort they invested in learning the material. After each of the five videos, participants were presented with an onscreen prompt: "How much mental effort did you invest in learning the material?" They were asked to rate the amount of mental effort on a single scale of 1-7 (low to high). This scale was adjusted to seven points to match other scales used in this study.

Motivation surveys. A combination of three surveys were administered to measure participants' motivational attitudes (see Appendix D). While there are no standard measures for social agency (Mayer, 2014b), studies have used different instruments to measure a variety of motivation-related constructs such as: feelings about social presence, engagement, and motivation (Fiorella, 2016), perceptions of motivation, interest, understanding and difficulty (Moreno, 1999), opinions about social characteristics attributed to speakers (Zahn & Hopper, 1985), or perceived social presence of a pedagogical agent (Baylor & Ryu, 2003; Park, 2015). After a comparison of motivation surveys from the literature, aspects of three instruments were selected for this study for their applicability and reliability.

Attitudes toward learning. The nine-item survey developed by Fiorella (2016) was used to measure attitudes toward learning. Permission was granted by the author to use this instrument (Fiorella, personal communication, November 13, 2017). The survey measures attitudes toward the content and social agency. Example items include: “I felt like the instructor was working with me to help me understand the material,” “I found the instructor’s teaching style engaging,” and “I felt motivated to try to understand the material.”

For each item, participants were asked to indicate their agreement with each statement on a scale of 1-7 (1= strongly disagree to 7= strongly agree). The first item required reverse scoring prior to data analysis. An overall score was calculated for each participant by calculating the mean of all items. In addition, two subscales were derived a priori by the researcher in order to focus on the social agency aspects (none were provided by the original researcher). The subscales were: attitudes toward the content (four items) and attitudes toward social agency (five items). To establish the independence of the subscales, correlations were compared. The subscales have moderate to high reliability and correlate highly with the overall scale, but not with each other. Both subscales correlate highly with the mean on the overall survey ($r^2_{\text{content subscale, total attitude mean}}$=.84, r^2=.70) and ($r^2_{\text{social agency subscale, total attitude mean}}$=.93, r^2=.86) indicating that 70% of the variance in the total mean is explained by the content subscale and 86% is explained by the social agency subscale. The subscales appear to measure different constructs/traits as indicated by their moderately low correlation ($r^2_{\text{content subscale, social agency subscale}}$ =.58, r^2=.33) such that only 33% of the variance in the content subscale is explained by variance in the social agency subscale and means were calculated for each of the subscales for each participant and compared between treatments.

Cronbach’s alpha reliability estimates for the survey were acceptable at .84 for the combined instrument, .61 for the content subscale and .86 for the social agency subscale. No reliability data were reported for this instrument in the original study (Fiorella, personal communication, November 13, 2017).

Speech evaluation. The next instrument employed was the adaption of Zahn and Hopper's (1985) Speech Evaluation Instrument that Mayer et al. (2003) used to measure the narrator's voice in a multimedia lesson. Atkinson et al. (2005) used the same adaption to measure participants' ratings of a pedagogical agent's voice. Permission was granted by the original researcher to use the instrument (Zahn, personal communication, August 15, 2017). This instrument provides insight into opinions about the social characteristics of a speaker. The instrument consists of fifteen, semantic differential word pairs, containing an adjective and the opposite adjective. The pairs are literate–illiterate, unkind–kind, active–passive, intelligent–unintelligent, cold–warm, talkative–shy, uneducated–educated, friendly– unfriendly, unaggressive–aggressive, fluent–not fluent, unpleasant–pleasant, confident–unsure, inexperienced–experienced, unlikable–likeable, and energetic–lazy. These translate to three subscales: superiority, attractiveness, and dynamism. Participants were asked to rate the speaker on each dimension on a scale of 1-7 (adjective to opposite adjective). The original instrument used an eight-point scale but was converted to seven points to match other scales used in this study. Seven items (numbers 2, 5, 7, 9, 11, 13, and 14) required reverse scoring prior to data analysis. An overall speaker rating was calculated as a mean of all items for each participant. A prior study with undergraduate students reported high reliability ($\alpha = .90$, $n=50$) for the overall instrument (Atkinson et al., 2005). Means of each subscale was also calculated to compare differences within the subscales. Cronbach's alpha reliability estimates for the survey scores collected and analyzed in this study were .88 for the combined instrument, .78 for the superiority subscale, .89 for the attractiveness subscale, and .57 for the dynamism subscale.

Instructional materials motivation. The final motivation instrument employed consisted of two subscales from Keller's (2010) Instructional Materials Motivation Survey (IMMS). This instrument was used by Park (2015) to measure motivation in research examining social cue principles in animated pedagogical agent multimedia learning. Permission was granted by the developer to use the instrument (Keller, personal communication, November 5, 2017).

The IMMS instrument measures student motivational attitudes in a specific self-directed learning context across four subscales: attention, relevance, confidence, satisfaction (Keller, 2010). To minimize the added length of using the entire instrument (*n* = 36) two subscales, attention (*n* = 12) and satisfaction (*n* = 6), were selected for inclusion because they fit best with a one-time short instructional intervention where relevance and confidence would not be appropriate in this situation. The instrument documentation indicated that subscales could be used in any combination (Keller, 2010). Wording was also updated to better match the situation for a multimedia lesson versus a written unit (e.g., "writing" was changed to "content" and "pages" changed to "screens"), per the documentation (Keller, 2010). Example items include: "The way the information is arranged on the screens helped keep my attention" (attention subscale), and "I enjoyed this lesson so much that I would like to know more about this topic" (satisfaction subscale).

For all items, participants were asked to indicate their agreement with each statement on a scale of 1-5 (not true to very true). Some items required reverse scoring prior to data analysis. Scores were calculated as the means of all items in each subscale. Published reliability estimates indicate .89 for the attention subscale and .92 for the satisfaction subscale (Keller, 2010). Cronbach's alpha coefficients from this study were similar with .87 for the attention subscale and .88 for the satisfaction subscale.

Procedure

Potential participants enrolled in participating courses were contacted via e-mail or via the course learning management system (see Appendix A) and used their own device to open a link in a web browser to access the online-delivered experiment. The initial screen provided an overview of the experiment, including how they would receive extra credit and reminding participants to set aside 45 minutes in a quiet location. At this point they could decide to opt out if they did not want to participate. If they continued, they were then presented with the participant information document (see Appendix A) to review before proceeding. This document concluded by informing participants that beginning the pretest would indicate that they have read and understood the information provided, that they were willing to participate, and that they understand that they could withdraw at any time and discontinue without penalty.

If they proceeded, they were presented with the prior knowledge survey (see Appendix B). Participants who completed the survey moved on to the next portion of the experiment regardless of their score. A mean score of five or above disqualified participants but exclusion occurred during analysis since there was no way to pre-screen participants. After the prior knowledge survey, participants were asked to complete a short demographic survey (see Appendix B). Survey settings were set to require participants to complete all items.

Participants were randomly assigned to one of three branches created for the three instructional treatments. Each participant was branched to their specific treatment where the first segment of that lesson was played, and time duration data was collected. After each segment, the participant was presented with the mental effort question (See Appendix C). The remaining segments were played in sequence while time duration data were collected, and the mental effort question was presented for completion at the end of each segment. After all five segments were completed, the remaining instruments were administered to the participant for completion in this order: Attitudes Toward Learning, Speech Evaluation Instrument, Instructional Materials Motivation Survey (Attention and Satisfaction Subscales), and the criterion-referenced posttest. The survey settings for each instrument were set to require completion of each item, prohibiting participants from moving on until all items were complete.

At the completion of the posttest they were presented with a conclusion screen and instructions for receiving their extra credit. Participants were given a link and a code word to generate a digital certificate. They were informed that they needed to provide this certificate to their instructor to receive the extra credit.

Participant names and course numbers were collected in the demographic survey to assist instructors with documenting extra credit when needed. Only one instructor requested information to assist in awarding extra credit. After providing these data, all identifiable information was removed for data analysis.

Data Analysis

Table 4 shows the research questions, dependent variables, and the statistical analysis methods that were used to evaluate the data collected. Raw data was first reviewed based on the exclusion criteria as explained in the Participants section. Initially there was equal distribution among treatments during the experiment, but after the exclusions there were differences in sample sizes: Animated Handwritten was the largest (n = 85), while Animated Typewritten (n = 75) and Static Typewritten (n = 74) were closer in size. This minor variance of size was taken into consideration during Post Hoc analysis.

Table 4

Statistical Analyses Conducted for Research Questions

RQ	Description	Dependent Variable(s)	Statistical Analysis
1	To what extent does text display format in multimedia lessons impact motivation?	Mean Attitudes (1-7) Mean Speech Evaluation (1-7) Mean IMMS Attention (1-5) Mean IMMS Satisfaction (1-5)	One-Way ANOVA's
2	To what extent does text display format in multimedia lessons impact cognitive load?	Mental Effort (1-7)	3 (between) X 5 (within) Repeated-Measures ANOVA
3	To what extent does text display format in multimedia lessons impact learning?	Posttest Performance: Total (0-15) Recall (0-10) Transfer (0-5)	One-Way ANOVA's

CHAPTER 3

RESULTS

This chapter presents the findings and results from the statistical analyses used to examine the effects of different text display formats in multimedia lessons on motivation, cognitive load, and learning outcomes for college undergraduates. Analyses were conducted with SPSS statistical analysis software, and the significance level for each analysis was .05.

Research Question 1 – To what extent does text display format in multimedia lessons impact motivation?

This question explored the extent to which text display format in multimedia lessons impacts motivation by looking at attitudes toward learning, speech evaluation, and motivation in relation to instructional materials.

Attitudes toward learning. A one-way analysis of variance (ANOVA) was conducted to examine the relationship between mean attitude toward learning ratings on the nine-question survey and different text display formats. Participants were asked to indicate their agreement with each of nine statements on a scale of 1-7 (1=strongly disagree to 7=strongly agree). Mean attitude toward learning calculated across the nine items was significantly different between treatments, $F(2, 231) = 4.04$, $p = .019$, $\eta^2 = .03$.

Gabriel's post hoc analysis was used because the sample sizes for the treatments were slightly different and results revealed the Animated Handwritten treatment (M = 4.90, 95% CI [4.67, 5.12]) reported significantly higher positive attitudes toward the instruction compared to the Static Typewritten treatment (M = 4.43, 95% CI [4.19, 4.67]), $p = .015$. No other differences were statistically significant. On the nine-question survey, responses ranged from most positive:

Animated Handwritten (M = 4.90, SD = .93), Animated Typewritten (M = 4.63, SD = 1.11) and Static Typewritten (M = 4.43, SD = 1.10).

Next, a one-way analysis of variance (ANOVA) was conducted for each of the two attitude subscales (content and social agency) to examine the relationship between the mean attitude on each and different text display formats. There was no significant difference on the content subscale (four items) between treatments, $F(2, 231) = .10$, $p = .37$, $\eta^2 = .01$. On the four content subscale questions, responses ranged from most positive: Animated Handwritten (M = 4.61, SD = 1.03), Animated Typewritten (M = 4.50, SD = 1.08), and Static Typewritten (M = 4.36, SD = 1.12).

Mean attitude toward learning for the social agency subscale (five items) was statistically significantly different for the treatments, $F(2, 231) = 5.41$, $p = .005$, $\eta^2 = .04$. Levene's test of homogeneity of variances ($p = .047$) was significant and thus the Brown-Forsythe test statistic was used. Games-Howell post hoc analysis results revealed that participants in the Animated Handwritten treatment (M = 5.13, 95% CI [4.86, 5.40]) reported statistically higher agreement on the Social Agency subscale than for the Static Typewritten treatment (M = 4.48, 95% CI [4.19, 4.77]), $p = .004$. No other treatment differences were statistically significant. On the five social agency subscale questions, responses ranged from most positive: Animated Handwritten (M = 5.13, SD = 1.11), Animated Typewritten (M = 4.73, SD = 1.29), and Static Typewritten (M = 4.48, SD = 1.35).

Speech evaluation. A one-way analysis of variance (ANOVA) was conducted to examine the relationship between mean speech evaluation ratings on the fifteen-question survey and different text display formats. Participants were asked to rate the speaker on each dimension on a scale of 1-7 (semantic differential). There was no significant difference detected in the mean ratings between treatments, $F(2, 231) = 1.91$, $p = .151$, $\eta^2 = .02$. On the fifteen-question survey, ratings by treatment ranged from highest to lowest: Animated Typewritten (M = 2.39, SD = .73), Animated Handwritten (M = 2.39, SD = .90), and Static Typewritten (M = 2.61, SD = .76).

Next, a one-way analysis of variance (ANOVA) was conducted for each subscale (superiority, attractiveness, and dynamism) of the Speech Evaluation Instrument to examine the relationship between speech evaluation ratings on each subscale and different text display formats. There were no significant differences on the five questions from the superiority subscale between treatments, $F(2, 231) = 1.74$, $p = .179$, $\eta^2 = .02$. Mean superiority ratings by treatment ranged from highest to lowest: Animated Typewritten (M = 6.50, SD = .66), Static Typewritten (M = 6.32, SD = .71), and Animated Handwritten (M = 6.27, SD = .98).

In addition, there was no significant difference on the five questions from the attractiveness subscale between treatments, $F(2, 231) = 1.40$, $p = .249$, $\eta^2 = .01$. On the five attractiveness items ratings by treatment ranged from highest to lowest: Animated Handwritten (M = 5.64, SD = 1.21), Animated Typewritten (M = 5.56, SD = 1.11), and Static Typewritten (M = 5.33, SD = 1.26).

Mean attitude toward the instruction as measured by the five questions on the dynamism subscale was statistically significantly different for different treatments, $F(2, 231) = 4.37$, $p = .014$, $\eta 2 = .04$. Gabriel's post hoc post hoc analysis revealed the Animated Handwritten treatment (M = 4.93, 95% CI [4.74, 5.12]) reported significantly higher ratings on the dynamism subscale compared to the Static Typewritten treatment (M = 4.52, 95% CI [4.32, 4.72]), $p = .011$.

Instructional materials motivation. A one-way analysis of variance (ANOVA) was conducted on each of the two subscales (attention and satisfaction) of the Instructional Materials Motivation Survey to examine the relationship between motivation ratings on each subscale and different text display formats. Participants were asked to indicate their agreement with each statement on a scale of 1-5 (1=not true to 5=very true).

Mean motivation on the attention subscale questions was statistically significantly different across treatments, $F(2, 231) = 8.64$, $p < .001$, $\eta^2 = .07$. Gabriel's post hoc analysis revealed that the Animated Handwritten treatment (M = 3.85, 95% CI [3.70, 4.00]) reported significantly higher agreement on the attention subscale compared to the Static Typewritten treatment (M = 3.18, 95% CI [3.11, 3.53]), $p < .001$. In addition, the Animated Handwritten treatment also reported significantly higher agreement on the attention subscale compared to the Animated Typewritten treatment (M = 3.51, 95% CI [3.32, 3.71]).

On the twelve attention items, ratings by treatment ranged from highest to lowest: Animated Handwritten (M = 3.85, SD = .71), Animated Typewritten (M = 3.51, SD = .85), and Static Typewritten (M = 3.32, SD = .90).

Mean motivation on the satisfaction subscale questions was statistically significantly different across treatments, $F(2, 231) = 3.06$, $p = .049$, $\eta^2 = .03$. On the six satisfaction items ratings by treatment ranged from highest to lowest: Animated Handwritten (M = 3.39, SD = .86), Animated Typewritten (M = 3.10, SD = 1.07), and Static Typewritten (M = 3.04, SD = .97). Gabriel's post hoc analysis revealed no statistically significant differences for any paired comparisons.

Table 5 summarizes the results of the three motivation instruments: Attitudes Toward Learning Survey, Speaker Evaluation Instrument, and the Instructional Materials Motivation Survey.

Table 5

Summary of Motivation Results

Instrument	Scale/Subscale	Statistically Significant
Attitudes Toward Learning Survey	Total	Yes
	Content	-
	Social Agency	Yes
Speaker Evaluation Instrument	Total	-
	Superiority	-
	Attractiveness	-
	Dynamism	Yes
Instructional Materials Motivation Survey	*Attention*	Yes
	Satisfaction	-

Note. Italics indicates subscale

Research Question 2 – To what extent does text display format in multimedia lessons impact cognitive load?

This question sought to explore the extent that text display formats in multimedia lessons impact cognitive load. Participants were prompted after each video segment to answer the question: "How much mental effort did you invest in learning the material?" on a scale of 1-7 (low to high). A 3 (treatments) X 5 (trials) repeated-measures ANOVA was conducted to examine the relationship of text display format with mental effort across the five video segments in the lesson. There was no statistically significant difference in main effect of mean mental effort between treatments, $F(2, 231) = .10$, $p = .906$, $\eta^2 = .001$.

However, the main effect showed a statistically significant difference in mean mental effort for different videos, $F(2, 1167) = 11.57$, $p < .001$, $\eta 2 = .05$. Pairwise comparisons indicated that mean mental effort for the first video was significantly lower (M = 4.28, 95% CI

[4.07, 4.49]) than each of the subsequent videos, indicating that the content in the first video was less taxing on cognitive load than the other videos [Video 2 (M = 4.83, 95% CI [4.65, 5.02]), $p < .001$, Video 3 (M = 4.73, 95% CI [4.54, 4.92]), $p < .001$, Video 4 (M = 4.70, 95% CI [4.50, 4.90]), $p < .001$, and Video 5 (M = 4.62, 95% CI [4.41, 4.83]), $p = .008$]. No other pairwise comparisons were statistically significant.

There was no statistically significant interaction between the treatment and videos on mental effort, $F(233, 934) = .64$, $p = .721$, $\eta^2 = .01$. Note that Mauchly's test of sphericity indicated that the assumption of sphericity was violated, $\chi2(2) = 74.36$, $p < .001$ so the Greenhouse-Geisser test statistic was used.

Table 6 summarizes the results of the cognitive load main effects by treatment and video, as well as the interaction effect of treatment and video.

Table 6

Summary of Cognitive Load Results

Instrument	Main/Interaction Effect	Statistically Significant
	Treatment	-
Mental Effort	Video	Yes
	Treatment + Video	-

Note. Italics indicates interaction effect

Research Question 3 – To what extent does text display format in multimedia lessons impact learning?

This question sought to examine the extent that text display format in multimedia lessons impact levels of learning on posttest scores for recall and transfer questions.

A one-way analysis of variance (ANOVA) was conducted to examine the relationship between posttest scores and different text display formats. There was no significant difference detected in the mean total scores between treatments, $F(2, 231) = .81$, $p = .447$, $\eta^2 = .01$. On the fifteen-question posttest mean scores by treatment ranged from highest to lowest: Animated Typewritten (M = 8.96, SD = 2.81), Static Typewritten (M = 8.80, SD = 2.77), and Animated Handwritten (M = 8.42, SD = 2.68).

A one-way analysis of variance (ANOVA) was conducted to examine the relationship between recall scores as measured by the posttest and different text display formats. There was no significant difference detected in the mean total scores for recall questions between treatments, $F(2, 231) = .71$, $p = .495$, $\eta^2 = .01$. On the fifteen-question posttest, ten questions were recall level and mean scores by treatment ranged from highest to lowest: Animated Typewritten (M = 5.48, SD = 2.06), Static Typewritten (M = 5.34, SD = 2.24), and Animated Handwritten (M = 5.08, SD = 2.16).

Another one-way analysis of variance (ANOVA) was conducted to examine the relationship between posttest scores for transfer questions and different text display formats. There was no significant difference detected in the mean total scores for transfer questions between treatments, $F(2, 231) = .39$, $p = .680$, $\eta^2 = .003$. On the fifteen-question posttest, five questions were transfer level and mean scores by treatment ranged from highest to lowest: Animated Typewritten (M = 3.48, SD = 1.20), Static Typewritten (M = 3.46, SD = 1.05), and Animated Handwritten (M = 3.34, SD = 1.01).

Table 7 summarizes the results of learning by total score and separated by recall questions and transfer questions.

Table 7

Summary of Learning Outcomes Results

Instrument	Scale/Subscale	Statistically Significance
	Total	-
Posttest	*Recall*	-
	Transfer	-

Note. Italics indicates subscale

Summary

This study sought to answer three research questions addressing broad areas of motivation, cognitive load, and learning outcomes in relation to different text display formats in multimedia lessons. The most noteworthy findings are around the motivational effects of animated handwriting. Participants who viewed the animated handwritten treatment reported significantly greater attitudes toward the learning experience than with static typewritten text, especially in relation to social agency. Furthermore, they perceived the narrator's voice as more dynamic with animated handwriting when compared to static typewritten, even though the voice was identical across treatments. Participants also reported more attention to the lesson and materials with animated handwriting than either the animated typewritten or static typewritten treatments. There were no significant differences between treatments for mental effort, however there was significance for mental effort between the first video and the other subsequent videos, which is likely due to the first video's introductory content. For learning outcomes, there was no significant differences between treatments on total posttest scores or separately for recall or transfer questions. These non-significant results for mental effort and posttest scores indicate that the motivational increases were accomplished without introducing any negative effects on cognitive load or learning outcomes.

CHAPTER 4

DISCUSSIONS AND CONCLUSIONS

The focus of this research was to explore the effects of animated handwritten text in spoken-written multimedia video lessons. Using identical voice-over narration and matching content, three styles of text display treatments (animated handwritten, animated typewritten, and static typewritten) were compared to examine the effects of presentation format on motivation, cognitive load, and learning.

Significant results indicate that designing multimedia with animated handwritten text creates a social cue that increases positive attitudes towards learning, gives the impression that the speaker is more dynamic, and helps capture and maintain attention toward instructional materials, without introducing extraneous cognitive load or negatively impacting learning outcomes. This chapter discusses the results and implications of this work.

Motivation Effects

Results of this study indicate that using an animated handwritten text display format produces a social cue that can motivate learners. This outcome was supported through significance found for multiple measures in the results.

Attitudes. First, participants who viewed the animated handwritten treatment reported significantly higher agreement with attitude statements related to social presence and immediacy, such as finding the teaching style engaging and feeling motivated to try to understand the material, when compared to those who viewed the static typewritten treatment. They also reported higher levels of enjoyment about the lesson. This is in line with social agency theory (Mayer et al., 2003) that identifies a positive motivational impact when learners interpret aspects of multimedia lessons as a social exchange instead of just the delivery of information. These feeling of social partnership can lead to deeper engagement and in some cases increased learning outcomes (Atkinson et al., 2005; Mayer & DaPra, 2012; Mayer et al., 2003; Moreno et al., 2001).

This effect from animated handwriting most aligns with the embodiment principle from Mayer's (2014b) categories of the effects of social cues in multimedia learning (personalization, voice, image, and embodiment). Embodiment in these studies refers to human motion and gestures demonstrated by pedagogical agents. However, animated handwriting is more than just human-like in nature. It is, in fact, human-generated. To create this effect, a person's hand motions are captured as they write. Watching typewritten text unfold across the screen did not produce the same results. It was the handwriting itself, not the effect of the animation, that produced the significant results in the social agency related attitudes about the instruction. This is in alignment with results from previous qualitative and mixed method pilot studies with these instructional materials where participants associated the animated handwritten format as "someone writing on the board" and "teaching it to you" (Kaplowitz, 2017; Kaplowitz & Watson, 2017).

Dynamism. In addition, participants who viewed the animated handwritten treatment identified the speaker as significantly more dynamic than those who viewed the static typewritten version, even though audio narration was identical across treatments. While there was significance for the dynamism dimension on this measure of the speaker's social characteristics, no significant differences were found for the other two dimensions of superiority and attractiveness. Researchers have used speech evaluation instruments to measure speaker characteristics in other social cue studies examining the voice effect in multimedia learning. They found that a human voice was interpreted more positively than machine-generated voice or a voice with an accent (Atkinson et al., 2005; Mayer et al., 2003).

Results of this study further extend those findings by highlighting the strong social cue effect of animated handwriting on how participants evaluated the dynamism of the speaker. In the previous studies in multimedia lessons, voice treatments were varied as dependent variables and differences were examined in light of how the speech was evaluated (Atkinson et al., 2005; Mayer et al., 2003). In the current study, the voice was identical across treatments, yet the evaluation differed significantly for dynamism. In other words, participants experienced the speaker as more "active," "talkative," "aggressive," "confident," and "energetic" when the visuals included animated handwritten text. These higher ratings on the dynamism dimension demonstrate that the text display format influenced how participants perceived the social characteristics of the speaker, and that even though the audio was identical, the speaker was perceived as more dynamic when the visuals were animated handwritten text compared to static typewritten text.

Attention. Participants indicated the instructional materials fostered significantly stronger attention in the animated handwritten treatment when compared to either the animated typewritten or the static typewritten treatments on the attention dimension of the IMMS - Instructional Materials Motivation Survey (Keller, 2010). Of the motivational outcomes, this is the only one that demonstrated significant differences between the two treatments that included animation. In the other results, the differences were only demonstrated when both the writing style and the use of animation was varied. This indicates that the handwriting itself is the main element to explain the results in relation to the attention dimension.

The satisfaction dimension of IMMS (Keller, 2010) was also administered and results demonstrated significant treatment differences at first analysis, but were not significant in post hoc tests. The two questions that were significant focused on enjoyment, which aligns with results from the attitudes toward learning instrument.

The attention dimension focuses on directing attention from the outset and maintaining it throughout the instructional intervention (Keller, 1987). Participants agreed with statements regarding the visual appeal of the instruction ("eye-catching," not "dry or unappealing," and how it was "arranged"), the content ("quality," and not "boring," or too "abstract") and the sequencing ("variety," not too much "repetition," and "stimulated my curiosity"). This aligns with studies that used the IMMS in investigating social cue principles in multimedia instructional design with pedagogical agents and found significantly higher attention scores when using pedagogical agents (Dinçer & Doğanay, 2017; Park, 2015).

These significant results for the attention dimension of the IMMS also align with the literature on attention and signaling. The eye is attracted to motion (Kahneman, 1973) and when multimedia contains visual cues, it signals the learner to attend to the information (Mautone & Mayer, 2001; Ozcelik et al., 2010; van Gog, 2014). However, this does not fully explain the impact of animated handwriting in this study. The animated typewritten treatment also included motion, which should have signaled the viewer in similar ways and gained their perceptual attention, however this did not translate to reported motivational attention. The key point is that the motion in the animated handwritten version mimicked human motions associated with actual handwriting. The difference may be that in this situation the viewer interprets the experience as actually watching someone hand write the text versus watching the text be revealed in the animated typewritten version. These results indicate that it is the combination of handwriting plus animation that increased motivation toward attending to the instructional materials.

In their verbal redundancy meta-analysis, Adesope and Nesbit (2012) found no advantages of including images or animation for learning outcomes in spoken-written presentations. However, it is not clear exactly what kind of animation was used in these studies, but it does not appear to be text animation. This study extends those results by introducing additional formats of spoken-written presentations with animation of both handwritten and typewritten text. Further, it identifies that animation of text alone is not enough to increase motivation toward instructional materials. Rather it is the combination of the social cue of handwritten text and the animation effect of seeing it be written that demonstrates significantly higher motivation toward the instructional materials on the attention dimension of the IMMS.

Social Cue. Taken together, the significant results across these different motivational measures demonstrate that animated handwritten text produces a strong social cue that can motivate learners. The effects include increasing participants' attitudes about the learning experience, including their level of enjoyment and feelings of connection with the instructor. Animated handwriting also influenced how participants perceived the narrator's voice, causing them to identify the speaker as more dynamic. Lastly, it influenced how participants perceived the instructional materials, making them more attentive to the lesson. These results were achieved through the two elements of animated handwritten text: the text is hand-drawn, and it appears as if a real person is writing it in real time.

Cognitive Load Effects

Varying the text display format did not have an impact on reported mental effort across treatments. This is an important finding because a potential negative side effect of incorporating social cues in multimedia is that it can increase extraneous cognitive load thereby negating any benefits (Mayer, 2014b). Extraneous cognitive load can be reduced through signaling in animation (Ayres & Paas, 2007; Mayer & Moreno, 2003; van Gog, 2014), so perhaps it was the inherent signal of the animation point of the animated handwriting that mitigated any additional cognitive load the social cues may have introduced. Similarly, Atkinson et al. (2005) interpreted no significant differences in cognitive load as a positive result when examining cognitive load in the context of social cues.

There were some significant differences of reported mental effort between the videos. The first video was significantly consistently rated with lower mental effort when compared to each of the other videos. This can be explained by the introductory nature of the content delivered in the first video. However, this difference in mental effort across videos does indicate that participants were thoughtfully evaluating their mental effort based on the complexity of the material delivered.

Learning Outcomes

First, it should be noted overall scores on the posttest were relatively low across all treatments, which may be indicative of a lack of overall effort employed by participants who knew they would receive extra credit in their course regardless of their scores on the posttest. The lack of significance between treatments on posttest learning outcomes (total, recall, or transfer) indicates that animated handwritten text does not introduce a seductive detail or augmentation that interferes with learning (Harp & Mayer, 1998; Thalheimer, 2004). This is an important finding since a potential concern in pedagogical agent research is that the social cues introduced may distract the learner (Mayer, 2014b). Additionally, the use of key words has been shown in literature to be effective in spoken-written presentations (Adesope & Nesbit, 2012; Mayer & Johnson, 2008), which may have equalized any differences in learning based on the treatments.

It is important to note that social agency theory goes beyond the notion that social cues can increase motivation, social cues can promote deeper engagement, which can lead to increases in learning outcomes (Mayer et al., 2003; Moreno et al., 2001). Mayer (2014b) reviews numerous studies that demonstrate the effect of social cues of voice, personalization, image and embodiment on learning outcomes. However, not all social cue studies find significance for learning gains. For example, Park (2015) found similar results to the present study for motivation but did not find learning gains and attributes this to a potential lack of individual interest. Similar effects may explain results from this study. It is also possible that participants just did not put forth the effort on the posttest because they were not being held accountable for their scores.

However, there is promise that the motivational attributes of animated handwritten text could produce deeper engagement that could in turn lead to increases in learning gains in other learning contexts. Animated handwriting has shown promising results and did demonstrate increased learning in other multimedia learning studies (Fiorella & Mayer, 2016; Luzón & Letón, 2015).

Limitations

Several limitations in the current study should be acknowledged. This was an opt-in study that undergraduate students completed online on their own time to earn extra credit at the end of a semester. Low scores on the posttest may be due to participants' lack of effort resulting from little perceived accountability, as well as pressure of other commitments at the end of term. Because the participation was not in a laboratory setting, it was not possible to regulate the time on task, both in terms of the actual time spent and the level of attention. It is likely that some of the participants were multitasking and engaging in off-task distractions, which can interfere with focus and attention (Calderwood, Ackerman, & Conklin, 2014). In retrospect, it may have been beneficial to design the study so that students would receive extra credit based on how well they did on the posttest to provide stronger incentive for them to strive to achieve higher scores.

The overall length of the instruction is another limitation. The motivational outcomes of this study may be due somewhat to a novelty effect, which could exhaust over time with longer instructional lessons. In addition, continued exposure to animated handwriting has the potential to produce fatigue and/or may increase extraneous cognitive load. Furthermore, the ecological validity of the experiment was low. The instruction only covered a portion of a content area and was not part of a larger unit in the participants' area of study. In addition, the delivery mode was passive and did not provide any opportunities for meaning making using instructional design elements such as generative strategies or inserted questions. Finally, an immediate posttest without any additional opportunities to review or practice is also not very ecologically valid. These issues could be addressed in future studies by targeting students in a specific domain, lengthening exposure to treatment over a longer period, adding interactive and generative elements, and delaying posttest assessment until after some practice activities have been made available.

Finally, a static handwritten treatment was deemed unnecessary for this study because it lacked ecological validity as instructors would not likely create static presentation graphics using this method. However, it may have been useful to have this treatment for further comparison of the effects and be able to better separate the effect of handwritten text with the effect of watching handwriting being written.

Implications

The present study demonstrates the value of using animated handwritten text in spoken-written multimedia video lessons to increase motivation. Instructional materials that employ this type of text display format can benefit from the motivational effects of this social cue. The inclusion of animated handwritten text significantly impacted participants' motivation on many dimensions, from their attitudes about the learning experience to how they perceived the speaker to how they attended to the instructional materials.

Animation of text alone is not enough to produce the effect, as evidenced by the non-significant results with the animated typewritten treatment. It is the human motion and realism of animated handwritten effect that produces strong social cues, which impacted the motivational responses in this study. This is similar to the results from pedagogical agent research where human-like behaviors and actions produced social cues that led to increased learning through an embodiment effect (Mayer, 2014b; Mayer & DaPra, 2012). Extending on those results, animated handwritten text conveys another type of embodiment, which evokes an educational experience where it feels like a teacher is explaining something to the learner.

The advantage of animated handwritten text over the use of pedagogical agents is that instructors and instructional designers can easily create animated handwritten text using digital tablets and low-cost applications. Similarly, animated handwriting can be created using video recordings of document cameras that include the hand or the use of the other digital inking technologies. Most practitioners in higher education do not have the technical knowledge, equipment, or time to create extensive multimedia lessons with pedagogical agents. This study demonstrates that some of the same motivational affordances of an embodiment effect from animated pedagogical agents can be gained by using animated handwriting within multimedia lessons.

While this study successfully used a combination of instruments to investigate the motivational effects of animated handwritten text, future research would benefit from the development of a single, robust instrument to measure the effects of social cues in multimedia lessons. The lack of a multimedia social agency instrument has been noted previously (Mayer, 2014b) and would be useful in researching many different social cue methodologies beyond animated handwriting.

Future research is needed to examine the extent of the effect of animated handwritten text as a social cue to not only increase motivation, but also to increase engagement that leads to deeper learning as evidenced by increased learning outcomes. Additionally, by investigating the effect on different levels of learners, it will be possible to see if this effect benefits novice and experienced learners differently. Furthermore, it may be useful to examine if some domains derive more impact from the inclusion of animated handwriting in multimedia, such as those fields that employ mathematical or symbol-based formulas. Being able to observe problem solving through worked examples has been a successful strategy in static formats for reducing cognitive load (e.g., Cooper & Sweller, 1987; Sweller & Cooper, 1985) and may be replicated or enhanced through animated handwriting in multimedia lessons.

Another interesting outcome of this study that warrants further investigation is the impact of animated handwritten text on the dynamism dimension from the speech evaluation instrument. Future studies should compare variations of narration styles using animated handwritten text to investigate the extent the visuals can impact speech evaluation to discover how strong this effect is and if it is possible to make less energetic speakers appear more dynamic to learners.

Research on social cues in multimedia has been focused primarily in a single content area or aligned to a small number of instructional objectives. However, the use of social cues to further humanize multimedia lessons can have far reaching influence when considering the increase in online, hybrid, flipped, and other distance learning scenarios (Adams Becker et al., 2017; Seaman, Allen, & Seaman, 2018). As new technologies such as artificial intelligence (e.g., chatbots) are investigated for their potential use in educational settings, it will be important to consider design elements that emphasize social cues, such as animated handwriting, to increase the humanization of the human-to-computer interactions. Further, methods used in this study can be used to investigate the social cue effect of other types of multimedia and computer-based design elements.

Beyond animated handwritten text's ability to potentially humanize multimedia and computer-based instruction in terms of immediacy and social presence, it may also have far-reaching implications for other psychological constructs. Many educational institutions are struggling with low retention and graduation rates. Some of those challenges can be traced to issues with a sense of belonging (Baumeister & Leary, 1995), especially in first-generation college students and those from traditionally underrepresented groups (Walton & Cohen, 2011; Yeager, Walton, & Cohen, 2013). At universities where these are campus priorities, such as the one from this study, having design heuristics that can potentially help learners have a more connected experience with their instructors and course materials by humanizing them should be further investigated.

Conclusions

Using animated handwritten text in multimedia can accomplish many of the same affordances that the classic teaching technique of writing on a chalkboard while lecturing accomplished. Though computer generated digital text-based presentation graphics have become very popular, the current study demonstrates the benefits of returning to elements from the traditional method of synchronized writing and narration but modernized through animated handwritten text in multimedia video lessons, such as those popularized by the Khan Academy.

Further, instructors and instructional designers can use animated handwritten text in their own multimedia lessons, as it does not require expansive technical knowledge, expensive equipment, or extensive time investments.

Findings from this study contribute to the research related to social cues in multimedia learning. Most of the research in this area is focused on type of voice, personalized content, or the use of pedagogical agents (Mayer, 2014b). While a few studies have investigated animated handwriting, this study is unique in the examination of the social cues as a motivational element across several dimensions. Results from this research demonstrate that animated handwritten text is more than just a signaling strategy; it adds a powerful social cue that can improve motivation in terms of attitudes toward the learning experience, dynamism of the speaker's voice, and attention to the instructional materials. These motivational gains were all accomplished without introducing extraneous cognitive load or negatively impacting learning outcomes. The results of this study demonstrate that using animated handwriting in spoken-written presentations is an effective way to increase motivation through social cues.

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APPENDICES

APPENDIX A

RECRUITMENT AND ENROLLMENT INFORMATION

An extra credit opportunity is available for anyone who would like to participate in a research study. This study examines different formats of instructional multimedia lessons. If you decide to participate, you will watch a 15-minute multimedia lesson. You will also be asked to answer survey questions and be given a short quiz via computer. If you say YES, then your participation will last for approximately 45 minutes online. Approximately 200 undergraduate students will participate in this study. If you complete the participation you will receive extra credit.

To participate in the study, go to this link and follow the directions: ________________. **Once you start the study, you will need to allot 45 minutes to complete the study and receive the participation document to give to your instructor.**

This study is part of the doctoral work of Hillary Kaplowitz at Old Dominion University, who is also staff and faculty at CSUN. If you have questions about the study, please contact Hillary Kaplowitz at hillary.kaplowitz@csun.edu

PARTICIPANT INFORMATION

The Effects of Text Display Format in Multimedia Video Lessons

You are being asked to participate in a research study. The Effects of Text Display Format in Multimedia Video Lessons, a study conducted by Hillary Kaplowitz as part of the requirements for the Ph.D. degree in Instructional Design and Technology at Old Dominion University. Participation in this study is completely voluntary. Please read the information below and ask questions about anything that you do not understand before deciding if you want to participate. A researcher listed below will be available to answer your questions.

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PURPOSE OF STUDY

The purpose of this research study is to examine different formats of instructional multimedia lessons.

SUBJECTS
Inclusion Requirements
You are eligible to participate in this study if you are at least 18 years of age or older.

Exclusion Requirements
You are not eligible to participate in this study if you have extensive prior knowledge of cryptography or have participated in the other version of this study (online or eye tracking/lab).

Time Commitment
This study will involve approximately 45 minutes of your time.

PROCEDURES
The following procedures will occur:
1) *Project Information/Pre-Questionnaire*. You will review the project information and then complete a pretest and demographic questionnaire. This procedure will take approximately 10 minutes.
2) *Instruction*. You will view an instructional unit consisting of a series of short video segments. Between each video segment you will answer a few questions. This procedure will take approximately 15 minutes.
3) *Post-Questionnaire* You will complete several questionnaires about the materials you viewed. This procedure will take approximately 20 minutes.

RISKS AND DISCOMFORTS
The possible risks and/or discomforts associated with the procedures described in this study include: fatigue, boredom, visual discomfort symptoms (e.g. headaches, eye strain, sensitivity to light, blurred text or double vision) that may be typically experienced when performing near work. You can pause the procedure or withdraw from the study at any time without penalty. This study involves no more than minimal risk. There are no known harms or discomforts associated with this study beyond those encountered in normal daily life.

BENEFITS
Subject Benefits
There are no direct benefits to you for participation in this study. However, you may gain knowledge in the area of cryptography. In addition, your participation may help us better understand multimedia learning. No additional benefits are anticipated for individual subjects.

Benefits to Others or Society
Benefits to society include gaining a better understanding of how people learn from multimedia.

ALTERNATIVES TO PARTICIPATION
The only alternative to participation in this study is not to participate.

COMPENSATION, COSTS AND REIMBURSEMENT
Compensation for Participation
You will receive extra credit from your instructor for participation in this study.

WITHDRAWAL OR TERMINATION FROM THE STUDY AND CONSEQUENCES
You are free to withdraw from this study at any time. **If you decide to withdraw from this study, you should notify the research team immediately**. The research team may also end your participation in this study if you do not follow instructions, miss scheduled visits, or if your safety and welfare are at risk.

CONFIDENTIALITY
Subject Identifiable Data
Your name and course number will be collected via survey for the online portion of this study and will kept separate from the other data collected from you. This information is used to insure that you receive extra credit for your participation in the study.

Data Storage
All research data will be stored on computers that are password protected or stored electronically on secured online drives for the purpose of analysis and only available to the researchers. The file with identifiable information will be kept separate from the research data and deleted within one year of study completion and after all study credit has been awarded.

Data Access
The researchers named on the first page of this form will have access to your study records. Any information derived from this research project that personally identifies you will not be voluntarily released or disclosed without your separate consent, except as specifically required by law. Publications and/or presentations that result from this study will not include identifiable information about you.

Data Retention
The researchers intend to keep the research data in a repository indefinitely

Mandated Reporting
Under California law, the researchers are required to report known or reasonably suspected incidents of abuse or neglect of a child, dependent adult or elder, including, but not limited to, physical, sexual, emotional, and financial abuse or neglect. If any researcher has or is given such information, he or she may be required to report it to the authorities

IF YOU HAVE QUESTIONS
If you have any comments, concerns, or questions regarding the conduct of this research please contact the research team listed on the first page of this form.

If you have concerns or complaints about the research study, research team, or questions about your rights as a research participant, please contact Research and Sponsored Projects, 18111 Nordhoff Street, California State University, Northridge, Northridge, CA 91330-8232, or phone 818-677-2901.

VOLUNTARY PARTICIPATION STATEMENT

Participation in this study is voluntary. You may refuse to answer any question or discontinue your involvement at any time without penalty or loss of benefits to which you might otherwise be entitled. Your decision will not affect your relationship with California State University, Northridge.

By beginning the pretest, you indicate that you have read and understand the information provided above, that you willingly agree to participate, and that you may withdraw at any time and discontinue without penalty. If you do not wish to participate in the study, you may discontinue at any time.

APPENDIX B

PRIOR KNOWLEDGE CONFIDENCE AND DEMOGRAPHIC SURVEY

Prior Knowledge Confidence Survey
Directions: Rate your confidence about the following statements using the scale below from 1 = Not at all confident to 7 = Very confident

1. Overall knowledge of cryptography
2. Describe the cryptographic process of sending secret messages
3. Apply a substitution cipher to messages when given a shift word
4. Determine the strongest shift word for a polyalphabetic cipher
5. List the two properties of randomness
6. Explain the frequency stability property

Biographical and Demographic Information
1. What is your full name
2. Enter the name of the course and instructor for the course that offered you the extra credit for completing this study (NOTE: You will still need to give the instructor the proof of participation that you will get upon completion at the end):
3. What is your age:
4. What is your current academic standing?
    a. Freshman
    b. Sophomore
    c. Junior
    d. Senior
    e. Post-Baccalaureate
    f. Non-degree
5. Are you a full-time or part-time student?
    a. Full-time
    b. Part-time
6. What is your sex?
    a. Male
    b. Female
    c. Trans*/Intersex/Nonbinary
7. Which of the following best represents your ethnicity? (Select all that apply)
    a. American Indian or Alaskan Native
    b. Asian
    c. Black or African American
    d. Native Hawaiian or Other Pacific Islander
    e. Caucasian
    f. Hispanic or Latino
    g. Other, please specify____

APPENDIX C

MENTAL EFFORT

Mental Effort (Repeated Measure):
How much mental effort did you invest in learning the material?
(1= Low, 7 = High)

APPENDIX D

MOTIVATION SURVEYS

Attitudes Toward Learning Survey
Directions: Select your response using the following scale.
From 1 = Strongly Agree to 7 = Strongly Disagree

1. I felt that the subject matter was difficult.*

2. I enjoyed learning about Cryptography this way.

3. I would like to learn this way in the future.

4. I feel like I have a good understanding of how Cryptography works.

5. After this lesson, I would be interested in learning more about Cryptography.

6. I found the lesson about Cryptography to be useful to me.

7. I felt like the instructor was working with me to help me understand the material.

8. I found the instructor's teaching style engaging.

9. I felt motivated to try to understand the material.

Question breakdown by subscale:
Note: subscale labels were not visible to participants

Content Subscale:
- I felt that the subject matter was difficult.*
- I feel like I have a good understanding of how Cryptography works.
- After this lesson, I would be interested in learning more about Cryptography.
- I found the lesson about Cryptography to be useful to me.

Social Agency Subscale:
- I enjoyed learning about Cryptography this way.
- I would like to learn this way in the future.
- I felt like the instructor was working with me to help me understand the material.
- I found the instructor's teaching style engaging.
- I felt motivated to try to understand the material.

* indicates items that were reversed scored

Speech Evaluation Instrument
Directions: Please rate the speaker from the videos on each of the following items, marking nearest the adjective you feel best represents your reaction to their speech. As you complete each item, keep in mind the phrase "The speaker sounded."

1. literate:__:__:__:__:__:__:__:illiterate
2. unkind:__:__:__:__:__:__:__:kind*
3. active:__:__:__:__:__:__:__:passive
4. intelligent:__:__:__:__:__:__:__:unintelligent
5. cold:__:__:__:__:__:__:__:warm*
6. talkative:__:__:__:__:__:__:__:shy
7. uneducated:__:__:__:__:__:__:__:educated*
8. friendly:__:__:__:__:__:__:__:unfriendly
9. unaggressive:__:__:__:__:__:__:__:aggressive*
10. fluent:__:__:__:__:__:__:__:not fluent
11. unpleasant:__:__:__:__:__:__:__:pleasant*
12. confident:__:__:__:__:__:__:__:unsure
13. inexperienced:__:__:__:__:__:__:__:experienced*
14. unlikable:__:__:__:__:__:__:__:likeable*
15. energetic:__:__:__:__:__:__:__:lazy

Question breakdown by subscale:
Note: subscale labels were not visible to participants

Superiority Subscale:
- Literate-illiterate
- Intelligent-unintelligent
- Uneducated-educated*
- Fluent-not fluent
- Inexperienced-experienced*

Attractiveness Subscale:
- Unkind-kind*
- Cold-warm*
- Friendly-unfriendly
- Unpleasant-pleasant*
- Unlikable-likeable*

Dynamism Subscale:
- Active-passive
- Talkative-shy
- Unaggressive-aggressive*
- Confident-unsure
- Energetic-lazy

* indicates items that were reversed scored

Instructional Materials Motivation Survey
There are 18 statements in this questionnaire. Please think about each statement in relation to the instructional materials you have just studied and indicate how true it is. Give the answer that truly applies to you, and not what you would like to be true, or what you think others want to hear.

Think about each statement by itself and indicate how true it is. Do not be influenced by your answers to other statements.

Use the following scale to indicate your responses to each item.

1 = Not true
2 = Slightly true
3 = Moderately true
4 = Mostly true
5 = Very true

1. There was something interesting at the beginning of this lesson that got my attention.
2. Completing the sections in this lesson gave me a satisfying feeling of accomplishment.
3. These materials are eye-catching.
4. The quality of the content helped to hold my attention.
5. This lesson is so abstract that it was hard to keep my attention on it.*
6. I enjoyed this lesson so much that I would like to know more about this topic.
7. The presentation of this lesson looks dry and unappealing.*
8. The way the information is arranged on the screens helped keep my attention.
9. This lesson has things that stimulated my curiosity.
10. I really enjoyed studying this lesson.
11. The amount of repetition in this lesson caused me to get bored sometimes.*
12. I learned somethings that were surprising or unexpected.
13. The wording of the lessons helped me feel rewarded for my effort.
14. The variety of imagery, examples, narration, illustrations, etc. helped keep my attention on the lesson.
15. The style of presentation is boring.*
16. There are so many words on each screen that it is irritating.*
17. It felt good to successfully complete this lesson.
18. It was a pleasure to work on such a well-designed lesson.

Question breakdown by subscale:
Note: subscale labels were not visible to participants

Attention Subscale:

- There was something interesting at the beginning of this lesson that got my attention.
- These materials are eye-catching.
- The quality of the content helped to hold my attention.
- This lesson is so abstract that it was hard to keep my attention on it.*

- The presentation of this lesson looks dry and unappealing.*
- The way the information is arranged on the screens helped keep my attention.
- This lesson has things that stimulated my curiosity.
- The amount of repetition in this lesson caused me to get bored sometimes.*
- I learned somethings that were surprising or unexpected.
- The variety of imagery, examples, narration, illustrations, etc. helped keep my attention on the lesson.
- The style of presentation is boring*
- There are so many words on each screen that it is irritating.*

Satisfaction Subscale:

- Completing the sections in this lesson gave me a satisfying feeling of accomplishment.
- I enjoyed this lesson so much that I would like to know more about this topic.
- I really enjoyed studying this lesson.
- The wording of the lessons helped me feel rewarded for my effort.
- It felt good to successfully complete this lesson.
- It was a pleasure to work on such a well-designed lesson.

* indicates items that were reversed scored

APPENDIX E

TEST BLUEPRINT

For the 15-question criterion-referenced posttest, there are three questions drawn from each video. Two of the questions are recall level and one is transfer. The test blueprint table below shows the breakdown of questions by video/topic, question types and item numbers (two recall and one transfer item per video). The posttest questions are in APPENDIX F.

Video Topic	Recall 1	Recall 2	Transfer
Video 1 – Encryption and Decryption	1	2	3
Video 2 – Substitution Cipher	4	5	6
Video 3 – Polyalphabetic Cipher	7	8	9
Video 4 – One Time Pad	10	11	12
Video 5 – Frequency Stability	13	14	15

APPENDIX F

POSTTEST

Criterion-referenced Posttest
Note: Correct answers are indicated below using "*"

1. What is an encrypted communication?
    a. A scrambled message*
    b. A descrambled message
    c. A decocted message
    d. An integrated message

2. What phrase best describes a cipher?
    a. Probability
    b. Message
    c. Number theory
    d. Virtual lock*

3. Jean is planning a surprise birthday party for Sam and doesn't want Sam to find out ahead of time, so Jean sends guests a coded message. What will the guests need to do to understand the message?
    a. Decrypt the message*
    b. Encrypt the message
    c. Decoct the message
    d. Entrust the message

4. What kind of cipher is the Caesar cipher?
    a. Probability cipher
    b. Substitution cipher*
    c. Frequency cipher
    d. Alphabetic cipher

5. How was the weakness of the Caesar cipher discovered?
    a. Shift coding of letters
    b. Frequency analysis of letters*
    c. Decryption of letters
    d. Ciphering of letters

6. Using Caesar Cipher of +2, code the following message: HELLO
    a. JGNNQ*
    b. KHIIP
    c. OLLEH
    d. FQJJU

7. What is the difference between the Caesar and Polyalphabetic ciphers?
    a. Caesar uses one alphabet; polyalphabetic uses multiple alphabets
    b. Caesar is based on Latin words; polyalphabetic is based on Greek words
    c. Caesar uses numbers; polyalphabetic uses words*
    d. Caesar uses one letter; polyalphabetic uses multiple letters

8. What is the key in decoding a Polyalphabetic cipher?
    a. Determining the letter frequency
    b. Determining the cipher language
    c. Determining the length of the number shift
    d. Determining the length of the shift word*

9. Which of the following is the strongest shift word for a polyalphabetic cipher?
    a. Gaze
    b. Quick
    c. Banana*
    d. Ibix

10. What is the ideal way to hide the fingerprint of a cipher?
    a. Randomness*
    b. Frequency
    c. Encryption
    d. Brute force

11. There are two properties of randomness related to cryptography. One is that randomness never repeats, and the other is the:
    a. Disparate Frequency Distribution
    b. Uniform Frequency Distribution*
    c. Significant Frequency Occurrence
    d. Encrypted Uniform Distribution

12. Using a one-time pad, which is the best shift list for “Happy Birthday”
    a. 9888695878837*
    b. 56776329127
    c. 12345678
    d. 09820982098

13. True randomness features the frequency stability property, which means that true randomness contains the following:
    a. Every sequence of every length*
    b. A uniform shift distribution
    c. Multiple ciphers
    d. Every letter of the alphabet

14. When making guesses what do humans tend to do?
    a. Favor certain sequences*
    b. Underestimate frequency
    c. Overestimate frequency
    d. Count responses

15. If you flip a coin 4 times, what is the most likely outcome:
    a. Heads, heads, heads, heads
    b. Tails, heads, heads, heads
    c. Heads, tails, heads, tails
    d. All are equally likely*

APPENDIX G

AUDIO NARRATION AND KEY WORDS

The audio narration and content used in the treatments come from the Khan Academy instructional video lesson, *Journey into Cryptography,* by Brit Cruise, available under a Creative Commons Attribution-NonCommercial-ShareAlike 3.0 license.

The transcript and on-screen written text (key words) used in the treatments are displayed below. Different colors indicate the different videos. Screen numbers are noted along with running timecode per video. This content is identical across all treatments (only differs by text display format).

#	Time	Audio Narration	Written Text
1	0:00	[1][What is cryptography?] [Text Heavy]	Cryptography
2	0:07	Imagine two people who share an important secret	Alice --> Bob
	0:10	have to split up	
	0:14	This requires them to communicate	[arrow]
	0:16	private information from a distance.	
	0:19	However, an eavesdropper named Eve	Eve
	0:21	also wants this information	
	0:22	and has the ability to intercept their messages.	[line]
	0:25	So, Alice decides to communicate	
	0:27	using letters written in some kind of secret code.	Secret Code
	0:31	The following analogy is helpful.	
	0:33	First, Alice locks her message in a box	
	0:36	using a lock that only she and Bob	
	0:38	know the combination to.	
3	0:39	This is known as 'encryption.'	Encryption
	0:42	Then, the locked message is sent to Bob.	Alice --> Bob
	0:45	When Bob receives the box, he opens it	
	0:47	using the code they shared in advance.	
	0:51	This is called 'decryption.'	Decryption
	0:54	Cryptography begins when we abandon physical locks	
4	0:57	and use 'ciphers' instead.	Ciphers
	1:00	Think of [ciphers] as virtual locks.	Virtual Locks
	1:02	Ciphers allow Alice and Bob to scramble	Scramble/Descramble
	1:04	and descramble their messages	
	1:06	so that they would appear meaningless	
	1:08	if Eve intercepted them.	
5	1:11	Cryptography has been around for thousands of years.	Cryptography
	1:13	It has decided wars, and is at the heart of	
	1:15	the worldwide communication network today.	
	1:18	The fascinating story of cryptography	
	1:20	requires us to understand two very old ideas	
	1:23	related to number theory and probability theory.	

6	0:00	[2][The Caesar cipher] [Mixed Text with Diagram]	Cryptography
7	0:04	The first well known cipher, a substitution cipher	Substitution cipher
	0:08	was used by Julius Caesar around 58 BC.	
	0:11	It is now referred to as the Caesar Cipher.	Caesar Cipher
	0:14	Caesar shifted each letter in his military commands	
	0:17	in order to make them appear meaningless	
	0:19	should the enemy intercept it.	
	0:22	Imagine Alice and Bob decided to communicate using the Caesar	
	0:25	Cipher First, they would need to agree in advance on a shift	Shift
	0:29	to use-- say, three.	3 [three]
	0:31	So to encrypt her message, Alice would	
	0:33	need to apply a shift of three to each letter	[alpha example]
	0:36	in her original message.	
	0:38	So A becomes D, B becomes E, C becomes F, and so on.	
8	0:43	This unreadable, or encrypted message	[lake example]
	0:45	is then sent to Bob openly.	
	0:51	Then Bob simply subtracts the shift of three	[decode lake example]
	0:53	from each letter in order to read the original message.	
	0:58	Incredibly, this basic cipher was	
	1:00	used by military leaders for hundreds of years after Caesar.	
	1:04	JULIUS CAESAR: I have fought and won.	
	1:07	But I haven't conquered over man's spirit	
	1:10	which is indomitable.	
	1:12	However, a lock is only	
	1:14	as strong as its weakest point.	
9	1:16	A lock breaker may look for mechanical flaws.	Flaws
10	1:19	Or failing that, extract information	Info
	1:21	in order to narrow down the correct combination.	
	1:25	The process of lock breaking and code breaking are very similar.	Lock = Code
	1:29	The weakness of the Caesar Cipher	
	1:31	was published 800 years later by an Arab mathematician	
	1:34	named Al-Kindi.	
	1:36	He broke the Caesar Cipher by using a clue based	
	1:38	on an important property of the language	
	1:41	a message is written in.	
10	1:43	If you scan text from any book and count	[graph]
	1:45	the frequency of each letter, you	
	1:47	will find a fairly consistent pattern.	
	1:49	For example, these are the letter frequencies of English.	
11	1:53	This can be thought of as a fingerprint of English.	Fingerprint
	1:57	We leave this fingerprint when we	
	1:58	communicate without realizing it.	
	2:00	This clue is one of the most valuable tools	Clue
	2:03	for a codebreaker.	
	2:05	To break this cipher, they count up	Count
	2:07	the frequencies of each letter in the encrypted text	

	2:10	and check how far the fingerprint has shifted.	
	2:14	For example, if H is the most popular letter	[H-E-3 example]
	2:16	in the encrypted message instead of E	
	2:19	then the shift was likely three.	
	2:22	So they reverse the shift in order	
	2:23	to reveal the original message.	
	2:26	This is called frequency analysis	Frequency analysis
	2:27	and it was a blow to the security of the Caesar cipher.	
12	0:00	[3][Polyalphabetic cipher] Text Heavy]	Cryptography
13	0:04	A strong cipher is one which disguises your fingerprint.	Disguises
	0:08	To make a lighter fingerprint is to flatten	Flatten
	0:11	this distribution of letter frequencies.	
	0:17	By the mid-15th century, we had advanced	
	0:19	to polyalphabetic ciphers to accomplish this.	Polyaphabetic
14	0:23	Imagine Alice and Bob shared a secret shift word.	Shift word
	0:27	First, Alice converts the word into numbers	Converts
	0:30	according to the letter position in the alphabet.	[SNAKE example]
15	0:33	Next, this sequence of numbers is repeated along the message.	[Lake example 2]
	0:39	Then each letter in the message is	
	0:41	encrypted by shifting according to the number below it.	
	0:45	Now she is using multiple shifts instead of a single shift	
	0:48	across the message, as Caesar had done before.	
16	0:53	Then the encrypted message is sent openly to Bob.	Alice --> Bob
	0:58	Bob decrypts the message by subtracting the shifts	
	1:01	according to the secret word he also has a copy of.	
	1:05	Now imagine a code breaker, Eve, intercepts a series of messages	Eve
	1:09	and calculates the letter frequencies.	
17	1:13	She will find a flatter distribution, or a lighter	Flatter
	1:17	fingerprint.	
	1:18	So how could she break this?	
	1:22	Remember, code breakers look for information leak	Leak
	1:26	the same as finding a partial fingerprint.	
	1:29	Any time there is a differential in letter frequencies	
	1:32	a leak of information occurs.	
	1:36	This difference is caused by repetition	Repitition
	1:38	in the encrypted message.	
	1:41	In this case, Alice's cipher contains a repeating code word.	
18	1:46	To break the encryption, Eve would first	Length
	1:49	need to determine the length of this shift	
	1:52	word used, not the word itself.	
	1:55	She will need to go through and check the frequency	
	1:57	distribution of different intervals.	
	2:00	When she checks the frequency distribution	
	2:02	of every fifth letter, the fingerprint will reveal itself.	Reveal
	2:07	The problem now is to break five Cesar Ciphers	5x
	2:09	in a repeating sequence.	

	2:12	Individually this is a trivial task, as we have seen before.	
	2:16	The added strength of this cipher	
	2:18	is the time taken to determine the length of the shift	
	2:21	word used.	
	2:22	The longer the shift word, the stronger the cipher.	Longer = Stronger
19	0:00	[4][The one-time pad][Text Heavy]	Cryptography
20	0:04	For over 400 years, the problem remained.	Hides
	0:07	How could Alice design a cipher that hides her fingerprint	
	0:11	thus stopping the leak of information?	
	0:14	The answer is randomness.	Randomness
	0:18	Imagine Alice rolled a 26-sided die	
21	0:20	to generate a long list of random shifts	[long list of shifts example]
	0:23	and shared this with Bob instead of a code word.	
	0:26	Now, to encrypt her message, Alice	
	0:28	uses the list of random shifts instead.	
	0:31	It is important that this list of shifts	
	0:34	be as long as the message, as to avoid any repetition.	
	0:38	Then she sends it to Bob, who decrypts the message using	[example continues]
	0:41	the same list of random shifts she had given him.	
	0:46	Now Eve will have a problem, because the resulting	
	0:49	encrypted message will have two powerful properties.	
22	0:53	One, the shifts never fall into a repetitive pattern.	1. Never Repeat
	0:59	And two, the encrypted message will have a uniform frequency	2. Uniform
	1:02	distribution.	
23	1:04	Because there is no frequency differential and therefore	Alice --> Bob | Eve
	1:07	no leak, it is now impossible for Eve	[X through the line to Eve]
	1:09	to break the encryption.	
24	1:14	This is the strongest possible method of encryption	Strongest
	1:18	and it emerged towards the end of the 19th century.	
	1:21	It is now known as the one-time pad.	One Tim Pad
	1:25	In order to visualize the strength of the one-time pad	
	1:28	we must understand the combinatorial explosion	
	1:32	which takes place.	
	1:34	For example, the Caesar Cipher shifted every letter	
25	1:37	by the same shift, which was some number between 1 and 26.	1-26
	1:42	So if Alice was to encrypt her name	
	1:44	it would result in one of 26 possible encryptions.	
	1:48	A small number of possibilities, easy to check them all	
	1:52	known as brute force search.	Brute force search
	1:55	Compare this to the one-time pad, where each letter would	
	1:58	be shifted by a different number between 1 and 26.	
	2:01	Now think about the number of possible encryptions.	
26	2:04	It's going to be 26 multiplied by itself five times, which	26 x 26 x 26x 26 x 26
	2:08	is almost 12 million.	12 million
	2:10	Sometimes it's hard to visualize	
	2:13	so imagine she wrote her name on a single page	

	2:15	and on top of it stacked every possible encryption.	
	2:20	How high do you think this would be?	
	2:24	With almost 12 million possible five-letter sequences	
	2:28	this stack of paper would be enormous	
	2:32	over one kilometer high.	1 kilometer high
	2:35	When Alice encrypts her name using the one-time pad	
	2:38	it is the same as picking one of these pages at random.	
	2:42	From the perspective of Eve, the code breaker	
	2:44	every five-letter encrypted word she	
	2:46	has is equally likely to be any word in this stack.	Equally likely
	2:51	So this is perfect secrecy in action.	
	0:00	[5][Frequency stability property][Diagram heavy]	Cryptography
28	0:04	Consider the following.	Line
	0:06	Imagine two rooms.	Two marks
	0:08	Inside each room is a switch.	
	0:13	In one room, there is a man who flips his switch according	
	0:16	to a coin flip.	Coin flip
	0:17	If he lands heads, the switch is on.	
	0:19	If he lands tails, the switch is off.	
	0:22	In the other room, a woman switches her light	
	0:24	based on a blind guess.	Blind guess
	0:26	She tries to simulate randomness without a coin.	
	0:29	Then we start a clock, and they make their switches in unison.	[0 & 1 stacks]
	0:39	Can you determine which light bulb	
	0:41	is being switched by a coin flip?	
	0:48	The answer is yes, but how?	
	0:59	And the trick is to think about properties of each sequence	
	1:02	rather than looking for any specific patterns.	
	1:05	For example, first, we may try to count	[mark off 1's]
	1:07	the number of 1's and 0's which occur in each sequence.	
	1:11	This is close, but not enough since they	
	1:13	will both seem fairly even.	
	1:16	The answer is to count sequences of numbers, such as runs	[box around runs of 3]
	1:20	of three consecutive switches.	
	1:22	A true random sequence will be equally	
	1:25	likely to contain every sequence of any length.	
29	1:28	This is called the frequency stability property	Frequency Stability
	1:31	and is demonstrated by this uniform graph.	[uniform graph]
	1:35	The forgery is now obvious.	
	1:37	Humans favor certain sequences when they make guesses	[uneven graph]
	1:40	resulting in uneven patterns such as we see here.	
	1:43	One reason this happens is because we	[overlay of 0's & 1's]
	1:45	make the mistake of thinking certain outcomes	
	1:47	are less random than others.	
30	1:49	But realize, there is no such thing as a lucky number.	[second line] Lucky Number
	1:53	There is no such thing as a lucky sequence.	Luck Sequence [then cross outs]

	1:57	If we flip a coin 10 times, it is	
	1:59	equally likely to come up all heads, all tails	Equally likely
	2:02	or any other sequence you can think of.	
		TOTAL NARRATION WORD COUNT = 1572	TOTAL KEY WORD = 50

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PUBLICATIONS

Kaplowitz, H. (2016). Encouraging engagement by adding job like elements to a course. *The Teaching Professor*, 30(8).

Kaplowitz, J. & **Kaplowitz, H.** (2011). Creating the online learner-centered experience and Creating the blended learner-centered experience, in *Transforming Information Literacy Instruction Using Learner-Centered Teaching.* Neal-Schuman, New York.

SELECTED CONFERENCE PRESENTATIONS

Kaplowitz, H., & Watson, G. (2017, November). Learners' perceptions of animated text in multimedia lessons: "Chalk Talk" revisited. Presented at the Association for Education Communication and Technology (AECT) Convention, Jacksonville, Florida.

Ghaznavi, J., **Kaplowitz, H**., Narayanamurti, K., Silvers, J. & Luna, H. (2017, November). A longitudinal assessment of faculty self-efficacy as a measure of impact in eLearning interventions. Presented at the AECT Convention, Jacksonville, Florida.

Kaplowitz, H. (2015, November) You know it! Knowledge surveys help instructors calibrate online instructional strategies. Presented at the AECT Convention, Indianapolis, Indiana.

Watson, G., **Kaplowitz, H**., Resig, J., Wilson, T., & Stefaniak, J. (2014, November). Great expectations: An examination of the alignment of graduate students' expectations with their professional experiences. Presented at the AECT Convention, Jacksonville, Florida.