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EFFECTS OF HEADINGS ON PROCESSING OF AUDIO TEXTS

Hung-Tao Chen
University of Kentucky, hungtaoc@gmail.com

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Hung-Tao Chen, Student

Dr. Robert F. Lorch, Major Professor

Dr. David T. R. Berry, Director of Graduate Studies

EFFECTS OF HEADINGS ON PROCESSING OF AUDIO TEXTS

DISSERTATION

A dissertation submitted in partial fulfillment of the
requirements for the degree of Doctor of Philosophy in the
College of Arts and Science at the University of Kentucky

By Hung-Tao Chen

Lexington, Kentucky

Director: Dr. Robert F. Lorch, Chair and Professor of Psychology Department

Lexington, Kentucky

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ABSTRACT OF DISSERTATION

EFFECTS OF HEADINGS ON PROCESSING OF AUDIO TEXTS

Text-to-speech devices often do a poor job of translating signals such as headings from visual into audio mode. Previous research studies have attempted to address this problem but these studies have mainly used heading detection tasks. The current study seeks to investigate 1) whether listeners find the presence of audio headings useful in natural learning tasks, and 2) the type of heading rendering that is most useful in natural learning tasks. The three learning tasks in this study include note-taking, cued recall, and knowledge transfer. Results from this study reveal that listeners find audio headings useful in the note-taking task. It is less clear how audio headings affect cued recall and knowledge transfer, but there is some evidence that a rendering strategy which conveys audio contrast plus other types of signaling information seems to facilitate cued recall performance.

Keywords: Text-to-Speech, TTS, synthetic speech, signal, heading, distance learning

Hung-Tao Chen
Student's Signature

May 5, 2015
Date

EFFECTS OF HEADINGS ON PROCESSING OF AUDIO TEXTS

By

Hung-Tao Chen

Robert F. Lorch, Ph. D.
Director of Dissertation

David T. R. Berry, Ph. D.
Director of Graduate Studies

May 5, 2015

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter One

Introduction

Text-to-Speech, also known as speech synthesis, is the automated process of converting text into speech using a computer program (Fellbaum & Kouroupetroglou, 2008; Taylor, 2009). Text-to-Speech (TTS) technology has been widely used for education purposes, to assist readers with visual impairment, and in mobile electronic devices (Argyropoulos, Sideridis, Kouroupetroglou & Xydas, 2009; Dutoit, 1997; Fellbaum & Kouroupetroglou, 2008; Xydas & Kouroupetroglou, 2001). Some examples of TTS devices include *Dragon* screen reader, *JAWS* screen reader, Apple's *Siri* and Amazon's *Kindle*. The majority of the efforts in improving TTS programs has been focused on making the speech sound more human-like; relatively less effort has been made to translate nonverbal information in the text (Lorch, Chen & Lemarié, 2012; Lorch & Lemarié, 2013). A few examples of nonverbal information include the amount of white space between sections of text, indentations at the beginning of paragraphs, bold font, italics, underlined information, and so on. These types of nonverbal information often convey important structural information about the text and also an author's intended usage of a particular word or phrase (Lemarié, Lorch, Eyrolle & Virbel 2008; Lorch, Lemarié & Grant, 2011a; 2011b). Failure to communicate nonverbal textual information often results in listeners missing important topics in an audio text (Lorch, Chen & Lemarié, 2012).

The problem with translating nonverbal information from print to speech is that most electronic texts are not coded in such a way that allows the TTS program to interpret nonverbal information in the text (Kouroupetroglou, 2013; Lorch, Chen &

Lemarié, 2012; Lorch & Lemarié, 2013). Even when an electronic text is coded in a format that does convey nonverbal information, many TTS programs still do not interpret the nonverbal information correctly (Tsonos, Xydas & Kouroupetroglou, 2007). Recently, a series of studies has been conducted to demonstrate that failure to communicate nonverbal information in audio texts could have detrimental effects on the listener (Lorch et al, 2012; Lorch, Chen, Jawahil & Lemarié, 2015 unpublished study). These studies used audio headings to investigate the effects of translating nonverbal information from printed text to audio text (Lorch et al., 2012; Lorch et al., 2015 unpublished study). More specifically, participants in these studies were given tasks that emphasized detection of audio headings. Even though these types of tasks demonstrate a direct effect of audio heading rendering on detection accuracy, they bear little resemblance to real world learning tasks such as taking notes, recalling information, and solving problems. The tasks chosen for this experiment are considered as more “natural”, because they are tasks that are often encountered in a classroom setting. The present study investigates whether listeners find audio headings useful in natural learning tasks and how different types of TTS rendering strategies affect the performance of these natural learning tasks. The learning tasks in this study include note-taking, cued recall, and knowledge transfer.

Headings are labels that appear at the beginning of a section of the text and they serve several purposes. First, headings often provide the main topics in a text, and they are often highlighted via typographical contrast (Lorch, 1989). Second, headings divide different sections of the text and allow readers to navigate sections of the text more easily (Lorch, 1989; Lorch, Lemarié & Grant, 2011b). Third, authors often use systems of headings and hierarchically label the main topics to make the organization of the text more explicit (Lorch, Lemarié & Grant, 2011a). Readers who utilize headings in their reading strategy can remember more structure and content information from the text (Mayer, Brandt & Bluth, 1980; Sanchez, Lorch & Lorch, 2001; Meyer & Ray, 2011). Headings are a good type of textual device for studying TTS rendering strategies because they convey several types of nonverbal information that are often missed in the TTS rendering process. An example of nonverbal information conveyed by headings would be "emphasis", which is often conveyed in the form of bold-font, italicized, or underlined words. Many TTS programs do not convey this type of emphasis information properly and this often leads to listeners missing a bold-font heading entirely (Lorch et al., 2012). Finding one or several accurate and efficient rendering strategies for audio headings is therefore an important question for designers of TTS programs.

This paper is divided as follows. The introduction is made up of five sections. The first section of the introduction describes the cognitive mechanisms behind heading processing and the effects that headings have on reading. Headings are known to have positive effects on a reader's text processing strategy, recall, and understanding of a text's structure and content information (Sanchez et al., 2001; Lorch, Lorch & Inman, 1993; Lorch & Lorch 1996a; 1996b; Lorch, Lemarié & Grant, 2011a). A good audio heading rendering strategy, therefore, should also have positive effects in audio text processing even if the effects might not be identical to the findings from reading research.

The second section is about signaling devices and the nonverbal information they convey (Lemarié et al., 2008). Headings are just one type of signaling device but there are other types of signaling devices that share similar types of nonverbal information. In order to understand the effects of headings and the nonverbal information they carry, one needs to look at the broader category of signaling devices as a whole. It has been proposed that signaling devices could convey up to seven types of nonverbal information, and the effect of a single signaling device is the result of multiple types of nonverbal information conveyed by the signal (Lemarié et al., 2008). This section on signaling devices provides the theoretical background for us to know the type of nonverbal information that is missing from the current TTS system.

The third section of the introduction describes four types of audio rendering strategies for nonverbal textual information that have been proposed within the MOTELS model (Maurel, Lemarié & Vigouroux, 2003; Maurel, 2004; Lorch & Lemarié, 2013). This section provides the rationale for why we had chosen the particular types of heading rendering strategies to investigate audio text processing. There are four types of audio heading rendering strategies but only two of the four strategies are considered to be suitable and accessible when communicating nonverbal heading information.

The fourth section of the introduction provides an overview of the current state of research concerning the effects of headings on the processing of audio text. This section summarizes the existing literature on audio signals and establishes the relevance of this study with the existing literature. The fifth section of the introduction provides the rationale for the three audio text processing tasks and why these tasks are suitable in investigating how audio headings affect listeners. The introduction is followed by two experiments. Recommendations for rendering audio headings and the implications on audio text processing are discussed in the general discussion section at the end.

The effect of headings on text processing in reading

Before one can decide on a rendering strategy for audio headings, one needs to first look at the effects of headings on reading. Headings have been found to have positive effects on reading and therefore it is important to investigate if some of these positive effects could be replicated with audio headings. The effects of headings on reading are informative in the design of audio headings.

Headings affect readers' attention (Gaddy, Sung & van den Broek, 2001; Lorch et al., 2011b). Headings are often highlighted and distinguished from the rest of the text by use of typographical contrast (Lorch, 1989). Typographical contrasts such as bold font or underlining allow readers to focus their attention and cause slower processing for the signaled information (Lorch, Lorch & Klusewitz, 1995). Because most headings are highlighted by typographical contrast, it is possible that at least part of headings' effect is due to this highlighting property. Indeed, one of the many types of information conveyed by headings is "emphasis", which is often brought about by typographical contrast (Lemarié et al, 2008). Headings' contrast-induced emphasis information directs readers' attention and allows them to focus on the relevant information faster (Lorch et al., 2001b) Besides allowing readers to capture the signaled information, headings also facilitate the processing of topical information that follows immediately after the heading (Hyönä & Lorch, 2004). This is because a heading already conveys the important topic for a section of the text and thereby alleviates the reader's reliance on the subsequent topic sentence.

Headings also affect a reader's text processing strategy (Lemarié, et al., 2008; Lorch et al., 2011a; Lorch et al., 2011b; Meyer, Brandt & Bluth, 1980). Past research using eye-tracking techniques has shown that when readers process expository texts that do not contain headings, they tend to follow a linear processing strategy without strategically attributing more attention to important topical information (Hyönä, Lorch & Kaakinen, 2002). When headings are present in a text, readers are more likely to switch from a linear processing strategy to a structure strategy (Lorch & Lorch, 1995).

Headings allow readers to employ a structure strategy during encoding and sometimes in the retrieval process. Structure strategy refers to a reading scheme that captures the top-level topics in a text, and uses these top-level topics to form a hierarchical representation of the structure of the text (Meyer, et al., 1980). Accordingly, readers who adopt a structure strategy look for propositional patterns that tie the text together (Meyer et al., 1980). The presence of headings promotes the adoption of a structure strategy mainly in two ways. First, headings' typographical contrast could attract readers' attention to the top level topics that are useful in building a structural representation of the text. Second, headings provide hierarchical and sequential information that is useful in distinguishing different levels of main topics and in building a mental structure for the text (Lemarié et al., 2008; Lorch, Lemarié & Grant, 2011a; Lorch et al., 2012). Headings do not always promote structure strategy during information retrieval but the presence of headings helps the retrieval process if readers are primed to use a structure retrieval strategy in recall tasks such as cued recall (Sanchez et al., 2001). Besides the effect on recall, the structure strategy also facilitates the summarization process (Lorch & Lorch, 1996a; Lorch, Lorch, Ritchey, McGovern & Coleman, 2001). The presence of headings allows readers to include more important topics in their summaries and create a better structural representation of the text (Lorch et al., 2001).

Headings increase the likelihood that readers will adopt a structure strategy during reading and consequently have better memory for the texts (Lorch & Lorch, 1995; Lorch et al., 1996a; Lorch et al., 1996b). Readers who are given texts with headings perform better on cued recall tasks (Lorch & Lorch, 1995). The effects on free recall are more complicated. Studies have shown that headings do not affect free recall when the structure of the text is simple (Lorch & Lorch, 1996b). However, when readers are asked to recall a complex text with 20 topics in three different levels, the presence of headings causes readers to recall more topics (Lorch, Lemarié & Chen, 2013). Headings also affect the reader's structural representation of the text order. Readers who are presented with texts that contain headings are more likely to organize their recall according to the order of the topics presented in the text (Lorch & Lorch, 1996b; Lorch et al., 2013).

Besides the effect on recall and summarization, the presence of headings also facilitates information transfer for readers (Mautone & Mayer, 2001). Knowledge transfer refers to a reader's ability to apply acquired information to a novel problem (Loman & Mayer, 1983; Mautone & Mayer, 2001; Mayer, 2003). Readers who received a text with signals generated more plausible solutions to a novel problem than did readers who received a text without signaling information (Mautone & Mayer, 2001).

Studies have shown that headings have positive effects on the reader's memory and information transfer. The problem with many of the past studies that investigated the effects of headings on memory was that they did not distinguish the different types of information that a single heading could convey. For example, a heading that reads "**Introduction**" conveys both emphasis and also indicates that the purpose of the next section is to provide some background information. The effect on memory by this heading could be due to the typographical contrast or its purpose indication. In order to get a more comprehensive view on the effect of headings, one would need to individually analyze the different types of information that could be conveyed by a single heading.

Nonverbal Information Conveyed by Signals

Headings belong to a class of textual devices called signals (Lorch, 1989; Mayer, Dyck & Cook, 1984). Examples of signaling devices include headings, preview sentences, summaries, typographical contrasts within the text, and so on. Signaling devices highlight important parts of the text and they often convey organizational information that could be used by the reader for purposes of search, recall, and general understanding (Lorch, 1989; Lorch et al., 2011a; Lorch et al., 2011b). An individual signaling device could convey several types of information. According to SARA, a signaling device theory, seven types of information could be conveyed by signals (Lemarié et al., 2008). These seven types of information include:

1. Demarcation: signals may serve as boundary markers that separate sections in a text. For example, white space may be used to mark the separation of different sections or the beginning of a new section of text.
2. Hierarchical organization: signals could distinguish major text sections and minor sections contained within major sections. For example, this section on signaling devices is a minor section contained within the introduction section of the paper.
3. Sequential organization: signals may indicate the order of information and this is often achieved either by enumeration or simply by the order of appearance from top to bottom in a text.

4. Labeling: signals may serve as unique identifiers for different text sections. For example, the heading for this section serves as a label that is useful for a reader when navigating through the text or when a reader is searching for a particular section of the text.
5. Emphasis: signals may be used to highlight specific text content. This is commonly accomplished by the use of visual contrast such as font change, bold font, italics, or underlining.
6. Topic identification: signals often indicate the main point of a section of the text. Titles and headings are good examples of the topic identification properties of signaling devices.
7. Function identification: signals may indicate the purpose of a section of the text without revealing the actual content of the section. For example, the heading "Abstract" does not reveal the content of the abstract section but merely indicates that it will provide a summary and background information for this paper.

A series of headings could convey several of the seven types of signaling information. Take the heading "**Introduction Section 2: Nonverbal Information Conveyed by Headings**" for example. This heading demarcates the beginning of a new text section by white space and typographical contrast. It conveys hierarchical information by indicating that a minor section is contained within the introduction section of the paper. The heading also conveys sequential information using enumeration. The topic of the section is identified by the heading and readers could use the heading as a label for the purpose of navigation or search. Bold font typographical contrast indicates emphasis. Lastly, the heading labels a section and also provides the function that the section serves.

Of the types of signaling information conveyed by headings, most TTS programs have difficulty conveying demarcation, hierarchical organization, and emphasis because these three pieces of information are often conveyed in nonverbal forms (Kouroupetroglou, 2013; Lorch, Chen & Lemarié, 2012; Lorch & Lemarié, 2013; Tsonos & Kouroupetroglou, 2011). As mentioned earlier, some TTS programs are capable of pausing the audio rendering according to the amount of white space between two sections depending on the coding format of the source text file. Other programs, such as the Amazon Kindle's TTS, do not pause the audio production unless a punctuation mark is encountered (Lorch et al., 2012). Because most authors do not include any type of punctuation mark immediately after a heading, these TTS programs do not pause between a heading and the first sentence of the content paragraph. The absence of pauses equates to the absence of demarcation information and as a result, listeners have more difficulty in differentiating a heading from other un-signaled content (Lorch et al., 2012). This would cause listeners to miss important headings altogether or it could cause listeners to build an incorrect mental structure of the text. It has been found that readers rely more on demarcation than content information to differentiate between sections in a text (Lorch et al., 2011b). If demarcation is not conveyed properly in a TTS generated audio text, listeners could have an incorrect understanding of the text based on inadequate structural information.

Besides demarcation, TTS programs also have difficulty conveying hierarchical organization information accurately. The hierarchical organization for the particular heading in the example given above is conveyed verbally. Most TTS programs can process this type of hierarchical information accurately since the rendering process is not different than other un-signaled content information. However, hierarchical organization is often communicated through nonverbal form, often by varying the amount of indentation before a heading or by the typographical contrast of headings. For example, the title of a text could be in bold font, font size 18, and centered. The main sections of the text could be in italics, font size 16, and left justified without indentation. The minor sections within each main section of the text could be underlined, font size 14, left justified with one inch indentation from the left. TTS programs do not differentiate and convey the hierarchical levels of the headings when the levels are distinguished using only indentation and typographical contrasts. This causes listeners to misrepresent the hierarchical level of headings and could also lead to the impairment of a listener's ability to understand the structure of a text correctly (Lorch, et al., 2012; Lorch et al., 2015, unpublished study). Readers often resort to a one-level sequential way of representing a text when hierarchical information is not properly conveyed (Lorch, Lemarié & Grant, 2011a). Similar results have been observed when people listen to TTS-generated audio texts that have improperly rendered hierarchical heading information (Lorch, et al., 2012).

Lastly, TTS programs have difficulty conveying emphasis information that is usually brought about by typographical contrast. The typographical contrast could include font size change, font type change, bold, italics, or underlining. For printed material, emphasis provided by a signaling device causes a reader to pay more attention to the signaled information (Lorch, Lorch & Klusewitz, 1995) and this results in better memory for the signaled content (Cashen & Leicht, 1970; Crouse & Idstein, 1972; Fowler & Barker, 1974). When a TTS program fails to provide emphasis information, listeners are more likely to miss some of the headings while listening to an audio text (Lorch, et al., 2012; Lorch et al., 2015 unpublished study). If a listener misses multiple headings in an audio text, this could affect the listener's ability to understand or recall information presented in the text.

TTS programs do not convey demarcation, emphasis, and hierarchical organization correctly but they can convey the other four types of signaling information accurately. This is because these types of signaling information can be effectively communicated in verbal form. For example, a TTS program can accurately convey sequential organization and topical information as long as the information is presented in a top-to-bottom order and the topical heading is rendered clearly. Therefore, it might be a good solution for the design of TTS if demarcation, hierarchical organization, and emphasis information could all be conveyed verbally. However, there might be limitations and drawbacks to translating all nonverbal visual information to verbal audio information. The next section will explore the four possible methods of rendering and describe the advantages and disadvantages of each method. Regardless of the method of rendering, a good TTS system should not miss or disregard any of the signaling information communicated by a heading.

Four Types of Rendering Strategies

In the previous sections, seven types of signaling information have been identified. TTS programs have difficulty in conveying three of the seven types of signaling information. The challenge with TTS is not just in conveying signaling information but to do it in such a way that makes the information efficient and accessible to the listener (Lemarié et al., 2008). Although one of the main purposes of this study is to investigate different types of audio rendering for headings in particular, other forms of in-text signals such as underlining and italics will also be taken into consideration. In this section, four signal rendering strategies will be discussed. The four rendering strategies are derived from “Modèle d’Oralisation des Textes Écrits pour être Lus Silencieusement” or “MOTELS” (Lemarié, Eyrolle & Cellier, 2006; Lorch & Lemarié, 2013; Maurel, Lemarié & Vigouroux, 2003; Maurel, 2004). The advantages and disadvantages of each rendering strategy will be discussed in this section.

The first rendering strategy is the descriptive strategy. The descriptive strategy translates both verbal and non-verbal signal information into oral form. More specifically, non-verbal visual information would be given oral description of its visual properties. For example, the heading “**Methods of Rendering**” would be rendered as “Methods of rendering; the words methods of rendering are in bold font”. The content of the signaled information is translated orally and the physical appearance of the signal is also translated orally. The potential advantage of this type of rendering is that it allows listeners to create a visual image of the heading. The possible disadvantage of this type of rendering is that it could be disruptive and confusing, because the audio recording would switch constantly between content information and description of the physical properties of headings. Also, this type of rendering does not make any attempt to interpret the author’s intention. For example, the author may simply want to convey emphasis when a word is in bold; it is not clear if saying “the word is in bold” actually conveys emphasis.

In terms of efficiency and auditory contrast, this type of rendering requires the longest duration but at the same time provides low auditory distinction to the un-signaled information. This type of rendering could be useful for situations where an author's intention for a particular signal is not clear. For example, authors could use italics to indicate that the word should have a different meaning or that it is part of an utterance and the speaker is simply stressing the word. The descriptive strategy would thus describe the physical appearance of the signal accurately and let the listener deduce the correct interpretation based on the context of the text. In general, however, this strategy is probably too inefficient and not accessible to be considered as a good rendering strategy for audio headings (Lorch & Lemarié, 2013).

The second rendering strategy is the discursive strategy. The discursive strategy translates verbal and non-verbal information into oral form and also attempts to interpret the intention of the author. The heading "**Methods of Rendering**" would be rendered as "Methods of rendering is emphasized" or "The author emphasizes methods of rendering" under this strategy. One of the advantages with this type of rendering is that TTS programs are often written in XML and the XML style tags could serve as guidance for the rendering process (Tsonos, Xydas, Kouroupetroglou, 2007). For example, XML style tags such as "<Heading1>" and "<Heading2>" could be translated into "Level 1 Heading" and "Level 2 Heading" to convey the hierarchical levels of headings. The translation of "Level 1 Heading" captures some of the physical properties and interprets the author's intention for the signal without the need for manual processing by a human agent. A disadvantage of this type of rendering is that although XML style tags could convey authors' intentions, authors do not always use pre-set style tags to convey headings. For example, an author could use bold font to convey first level of heading, underlining for the second level of heading, and italics for the third level of heading. Since most TTS software are not programmed with the type of artificial intelligence to deduce the author's correct intention based on the context, the TTS program would probably have difficulty in mapping the different types of signaling to the correct hierarchical heading level. In terms of efficiency, this type of rendering would require less time duration than the descriptive strategy. The discursive rendering strategy is equally non-distinctive as the descriptive rendering strategy and does not have an advantage in terms of auditory distinction.

The third rendering strategy is the typo-phonic strategy. Unlike the previous two rendering strategies, the typo-phonic rendering strategy could translate both verbal and non-verbal signaling information into non-oral audio form. Typo-phonic strategy uses tones, earcons, or auditory icons to represent the information conveyed by headings. Tones are single pitch audio notes that are generally within one second of duration (Lorch et al., 2015 unpublished study). They can be used to express emphasis or hierarchical organization of a heading by varying its pitch, volume, or duration. Earcons are made up of short melodies that are digitally produced by software programs (Brewster, Wright & Edwards, 1993; Hogan, Raisamo & Brewster, 2009; McGookin & Brewster, 2004). Earcons can express emphasis or hierarchical level by changing the melody composition, pitch, tempo, or volume. Auditory icons mimic the natural sound that an action or object makes (Dingler, Lindsay & Walker, 2008; Gaver, 1986). Auditory icons are most often encountered on computer interface. For example, the action of deleting a file on the desktop of a Windows computer is accompanied by an auditory icon that resembles the sound of crushing paper. A typo-phonic rendering strategy is often used to translate only the non-verbal signaling information; however, examples such as auditory icons or earcons can also be directly associated with verbal signaling information.

The advantage of a typo-phonic rendering strategy is that it provides a high level of auditory distinction in comparison to discursive and descriptive rendering strategies. Tones, earcons and auditory icons are all effective in attracting a listener's attention and alerting listeners to the onset of headings (Brewster et al., 1993; Lorch et al., 2015, unpublished study). The disadvantage of this rendering method is that it requires listeners to be familiar with the mapping of a particular sound or melody to particular nonverbal heading information. Therefore, training is required in order for listeners to use this type of heading rendering. In terms of efficiency, tones, earcons, and auditory icons are usually less than one second long in time duration. That is shorter than descriptive and discursive rendered headings. A typo-phonic rendering strategy is also the most distinctive of the four rendering strategies. However, extreme distinctiveness could cause disruption to the flow of the text. Furthermore, typo-phonic rendering could exert high cognitive demand on the listener since listeners would need to remember the mapping between a sound and the corresponding nonverbal heading information.

The fourth rendering strategy is the prosodic rendering strategy but it should be more appropriately termed as "vocal variety strategy" since the strategy involves vocal variations and not prosodic changes. A vocal variety rendering strategy uses voice change to express non-verbal signaling information, while at the same time retaining the verbal information conveyed by the signal. The types of voice change could include pitch, tempo, volume, and accent. For example, the title of a text could be spoken with a lower pitched voice and the headings of minor topics in the same text could be spoken with a higher pitched voice. This type of rendering strategy is both efficient and accessible to the listener. First, the non-verbal and verbal signaling information are presented concurrently and does not increase the duration of the audio signal than its un-rendered form. Second, the change in pitch, volume, or tempo creates auditory contrast between signaled and un-signaled content information and allow listeners to identify signaled information accurately (Lorch et al., 2015 unpublished study).

The advantage of a vocal variety rendering strategy is that listeners receive verbal and nonverbal heading information concurrently and there is minimum interruption to the flow of a text. Another advantage of this type of rendering strategy is that it also has the potential to use XML codes like the discursive strategy to interpret the author’s intention. Although this is possible (Kouroupetroglou, 2013), there is currently no guideline to the mapping between an author’s intention and a particular vocal variety rendering. If the author’s intention is to emphasize something, the vocal variety rendering could be expressed as increased volume or higher pitch. However, these vocal variety renderings are arbitrary and do not guarantee that the listener would perceive the emphasis as intended by the author.

The disadvantage of the vocal variety strategy is similar to that of the typo-phonic strategy where listeners would need to be trained before they could use this strategy effectively. If there are three descending levels of headings, then the vocal variety rendering could be translated into three descending levels of pitch; listeners would need to be trained on the mapping between a certain level and its corresponding pitch (Lorch et al., 2015 unpublished study). A second disadvantage of the vocal variety rendering strategy is that the listener would need to be sensitive to changes of pitch, volume, tempo, or accent. The vocal variety rendering strategy would not be effective for individuals who could not detect pitch or volume variations. In terms of auditory contrast, vocal variety rendering strategy does not cause any time delay in its audio presentation and it provides better contrast between signaled and un-signaled information than descriptive or discursive rendering.

Based on the evaluations above, it appears that the vocal variety strategy, typo-phonic rendering strategy and the discursive strategy are the better heading rendering strategies. A vocal variety strategy is highly efficient because it causes minimum delay in conveying nonverbal heading messages and provides some level of auditory contrast. The discursive strategy is less efficient and provides low auditory contrast, but it is very good at translating non-verbal heading information into oral form (Lorch et al., 2012; Lorch et al., 2015 unpublished study). Also, these three strategies allow the possibility of interpreting the author's intention by usage of XML tags. All three rendering strategies have been tested previously and have proven to be useful to the listener in conveying audio headings (Lorch et al., 2015 unpublished study). A typo-phonic rendering strategy has the advantage of providing clear auditory contrast; however, its effect in alerting listeners to headings is similar to the vocal variety strategy (Lorch et al., 2015 unpublished study). The vocal variety rendering strategy has been chosen because the effect that vocal variety rendering has on audio text processing would likely be similar to the typo-phonic strategy (Lorch et al., 2015 unpublished study). A descriptive strategy has not been chosen because it is the least efficient and causes the greatest delay in delivery.

The Current State of Audio Signal Research

Several studies have attempted to translate signaling devices from printed form into audio form. Some of the audio signaling studies translated printed signals to audio based on listeners' emotional state (Kouroupetroglou & Tsonos, 2008; Tsonos & Kouroupetroglou, 2011); another line of study translated signals based on signaling analysis theory (Lorch et al., 2012; Lorch et al., 2015 unpublished study). The current study follows the latter research approach and uses signaling theory as the basis for audio heading translation (Lemarié et al., 2008). It has already been shown that listeners can detect headings more accurately when non-verbal information is restored to audio headings (Lorch et al., 2012; Lorch et al., 2015 unpublished study). Although it is useful to understand how different rendering strategies affect audio heading detection, a listener's ability to detect headings does not necessarily generalize to other forms of text processing such as recall or comprehension. This section will discuss how previous research studies have rendered audio headings and how specific types of rendering might affect other forms of text processing.

Headings in printed text are often highlighted and distinguished from the rest of the text by use of typographical contrast (Lorch, 1989). Typographical contrast such as bold font or underlining provides emphasis and attracts more attention from the reader; selective attention, in turn, contributes to the usage of a structure processing strategy and results in an increase in the recall of signaled information (Lorch et al., 1995; Crouse & Idstein, 1972; Fowler & Barker, 1974). Past studies have expressed this typographical contrast by use of tones or pitch change (Lorch et al., 2015 unpublished study). The presence of tones before headings allowed the listener to detect headings faster and more accurately than headings with no audio contrast (Lorch et al., 2015 unpublished study). There is currently no study that investigates the effect of audio contrast on memory but it is possible that auditory contrast could affect listeners' attention to the signaled information and consequently affect the recall of signaled information.

Headings also provide hierarchical and sequential information in a text. A system of headings can convey hierarchical and sequential information through indentation, different typographical contrasts, or enumeration (Klusewitz & Lorch, 2000; Lorch, 1989; Lorch, Lemarié & Grant, 2011a). The hierarchical and sequential information provided by headings allow readers to construct more accurate outlines during text processing (Lorch, Lemarié & Grant, 2011a). The hierarchical and sequential information of headings also help novice readers in navigating a text (Dee-Lucas & Larkin, 1986; 1988), increases recall for unfamiliar topics (Lorch & Lorch, 1996), and helps readers understand texts with poor or complex organization (Lorch & Lorch, 1985; Lorch, Lorch & Matthews, 1985). Hierarchical and sequential heading information is able to facilitate the reading process because they help readers in forming an accurate mental outline of the main topics in a text and thus promotes the adoption of the structure processing strategy. Past studies have rendered hierarchical and sequential information using discursive rendering, typo-phonic, and vocal variety rendering strategies (Lorch et al., 2015, unpublished study). It has been shown that a discursive rendering methodology is most effective in conveying hierarchical information, whereas typo-phonic and vocal variety strategies are less effective (Lorch et al., 2015 unpublished study). It is not clear, however, how this might affect a listener's note-taking strategy, memory or comprehension.

Besides emphasis, hierarchical information and sequential information, headings also provide demarcation information (Lemarié et al., 2008). Headings' demarcation information allows readers to accurately identify headings from un-signaled information and separate major sections of the text from minor sections of the text (Lorch et al., 2011b). In terms of audio text processing, demarcation usually translates into pauses in the audio recording (Lorch et al., 2012; Lorch et al., 2015 unpublished study). The silence before and after a heading allows listeners to detect headings faster and produce fewer false alarms in heading detection (Lorch, et al., 2012; Lorch et al., 2015, unpublished study). Demarcation is important in audio text processing because it allows listeners to detect, encode, and process the signaled information.

Three Tasks That Investigate Audio Text Processing

The current literature on audio heading rendering focuses on heading detection (Lorch et al., 2012; Lorch et al., 2015 unpublished study). This study focuses on other forms of text processing tasks that better represent audio comprehension than heading detection. This section describes three different text processing tasks including note-taking, cued recall, and knowledge transfer.

Note-Taking Task

One of the tasks that is relevant in studying the effect of audio text processing is note-taking. Notes are defined as the written or typed condensation of source material from listening, reading, or observing (Piolat, Olive & Kellog, 2005). Note-taking, therefore, is the process of generating this condensed material. Note-taking provides a physical record of the encoding process during listening comprehension (Kiewra, 1989). This function of note-taking allows us to investigate how different heading rendering strategies affect listeners' structural representation of the audio text and their selection of specific content to be included in their notes.

There are several ways in which note-taking reflects the encoding of audio information. First, note-taking reflects the listener's ability to select important and relevant information from an audio presentation (Einstein et al., 1985; Kiewra & Benton, 1988; Titsworth & Kiewra, 2004). The selection process is more cognitively involved than merely copying down random information (Piloat, Olive & Kellog, 2005). The normal rate of speech delivery is two to three words per second while the rate of writing is 0.2 to 0.3 words per second (Piolat et al., 2005). Under this constraint, note-takers are forced to be selective with the information that they have been given. Note takers are constantly processing information and writing down only the information that they deem as more important. Because audio headings are effective in signaling important topic information in an audio text (Lorch et al., 2012; Lorch & Lemarié, 2013), a note-taking task should be sensitive to listeners' ability to capture important topics using audio headings. Secondly, notes could reflect the organization of a listener's mental representation of the text. Past research has shown that note-takers recorded different proportions of topic information according to their hierarchical level of importance in the text (Kiewra, Benton & Lewis, 1987; Einstein et al., 1985; Kiewra & Benton, 1988; Titsworth & Kiewra, 2004). Because note-takers were sensitive to the hierarchical importance of topics within a text, they could express this hierarchical sensitivity in their notes. No current research investigates the effect of audio headings on listeners' ability to select important information and organize this information into a hierarchical structure. It is possible that audio headings that make the hierarchical information of a text more accessible could induce listeners to select the headings and construct their notes in a hierarchical manner.

Audio headings may affect note-taking in several ways. One way in which different audio heading renderings could affect a listener's note-taking is with the listener's information selection strategy. As mentioned earlier, note-takers are constrained by their rate of writing and therefore need to identify and record the topics that the note taker has subjectively deemed as more important. The ideal notes should include all of the important topics presented, and the topic organization would reflect the structure of the text. Past studies have shown that students are generally good at selecting the topics that they believe to be important and include them with relatively higher proportion (Einstein et al., 1985; Kiewra & Benton, 1988). According to these studies, it seems that students have a strategy of selecting the topics which they subjectively deemed as most important, and then select the topics of lower importance as permitted by the constraint of writing speed. It is not clear, however, that the topics which students subjectively deemed as more important are in agreement with the author's intended main topics. A more recent study has shown that students only record 15% of the important topical information as indicated by the author when no explicit cues are given (Kiewra et al., 2004). In contrast, students recorded 54% of the topic information when they were highlighted by cues such as emphasis and enumeration. Two things are apparent from these results. First, most students have a strategy of writing down the most important topical information. Second, students are not very good at identifying the important topics in the absence of explicit verbal cues. If spoken cues in lectures are effective in helping listeners to identify the most important topical information, then headings in audio texts should have similar effects assuming that listeners utilize audio headings as cues for important topical information.

Different types of audio heading renderings could have different effects on a listener's information selection strategy. Discursive and vocal variety renderings are both effective in conveying topical heading information when listeners are explicitly instructed to detect headings (Lorch et al., 2015, unpublished study). It is possible that both discursive and voice change heading renderings would cause listeners to include more heading information in their notes (Titsworth & Kiewra, 2004). This is because the audio signals guide listeners' information selection process and allow listeners to select the most important information; this is assuming that listeners are not constantly taking notes but only select the information that they deem as important and relevant. The results should replicate the findings of Titsworth & Kiewra (2004) but with the use of TTS instead of an actual human lecturer.

Another way in which different audio heading renderings could affect note-taking is with the hierarchical presentation of the notes. Different types of audio heading renderings should affect the visual presentation of notes. Previous studies have shown that discursively rendered headings convey hierarchical information more saliently than voice change rendered headings (Lorch et al., 2015, unpublished study). If listeners use headings as cues to guide the organization of their notes, then their notes should reflect the saliency of this hierarchical information. However, it is not clear if listeners actually know how to use the salient hierarchical structure information and represent the information accordingly in their notes. It might be that the salient and somewhat unnatural hierarchical level information conveyed by the discursive rendering strategy would be more distracting than useful.

Cued Recall

Recall measures a person's ability to retrieve information that has been encoded and stored. Signals such as headings have been shown to affect recall of signaled information (Lorch, Lorch & Inman, 1993; Lorch & Lorch, 1995; Sanchez, Lorch & Lorch, 2001). The effects of headings on recall, however, appears to be mediated by a reader's encoding and retrieval strategy (Sanchez et al., 2001). In order for headings to have an effect on recall, the reader would need to adopt a structure strategy not just during encoding but also during the retrieval process (Lorch & Lorch, 1995). That is the reason why the effects of headings on recall are sometimes not observed in a free recall task (Lorch & Lorch, 1995). Because of this, a cued recall task has been chosen to investigate the effects of audio headings on memory since it is a more sensitive measure for recall of heading information.

There are two cognitive mechanisms through which headings could affect recall. First, in the presence of headings, readers are more likely to switch their processing strategy from a temporally organized list strategy to a structure strategy (Lorch & Lorch, 1995). This switch in strategy does not directly cause better recall; rather, the reader would also need to adopt a structure strategy during retrieval in order for the effects of headings on recall to be observable. Once adopted, the structure strategy has been hypothesized to serve as a guide in the reader's retrieval scheme (Meyer, Brandt & Bluth, 1980). This is especially true when the text is structurally complex (Lorch & Lorch, 1996). Headings are useful in the structure strategy reading scheme, because headings provide sequential and hierarchical structure information and they demarcate the boundaries among various sections of the text (Lorch, Lemarié & Grant, 2011a; 2011b). Second, readers exhibit slower processing for information that has been signaled by typographical contrast, and it has been hypothesized that this slower reading is indicative of more attention allocated to the signaled information (Lorch, Lorch & Klusewitz, 1995). Because headings also use typographical contrast, it is possible that headings would also attract more attention from the reader.

Based on these past studies, it appears that the effects of headings on recall could be attributed to two main mechanisms: 1) headings encourage readers to adopt a structure strategy through the structural information they provide, and 2) nonverbal information conveyed by headings have the potential to promote selective attention to signaled information. The two mechanisms seem to be related and complement each other. In order to successfully adopt a structure strategy, the person processing the text would need to select information that is important (Meyer et al., 1980; Titsworth & Kiewra, 2004). Although it is possible that readers might attend to other types of content cues in the text, headings are generally distinct and provide the most comprehensive structural information. Perceptually distinctive headings should therefore aid the selective attention process and allow readers to adopt a structure strategy using headings.

The two cognitive mechanisms related to headings in printed text could also be observed in audio texts. Past studies have shown that both discursive and vocal variety rendering strategies convey structural information effectively, with discursive rendering conveying hierarchical information more effectively (Lorch et al., 2012; Lorch et al., 2015, unpublished study). The hierarchical advantage of discursive rendering is evident from previous studies (Lorch et al., 2012; Lorch et al., 2015, unpublished study). On the other hand, varying the pitch of a speaking voice seems like a more natural way to convey hierarchical information than saying “Level 1 Heading”. Nevertheless, based on existing data with audio heading detection, a discursive rendering strategy should lead to the best cued recall results because it conveys clear hierarchical information and allows listeners to detect headings with high degree of accuracy (Lorch et al., 2015 unpublished study).

Even though a discursive rendering strategy appears to be the best rendering strategy in promoting cued recall, it is also possible that a vocal variety rendering strategy would lead to better cued recall. Previous studies have shown that discursive rendering allows listeners to construct the most accurate structural representation using headings (Lorch et al., 2012; Lorch et al., 2015 unpublished study). It is not clear, however, how different types of heading renderings and the nonverbal information they convey affect selective attention. Past studies use tasks that ask listeners to attend to the headings (Lorch et al., 2012; Lorch et al., 2015 unpublished study). Because the tasks in this experiment do not explicitly ask listeners to attend to the headings, variations in pitch and volume might have a larger effect on selective attention than a discursive rendering strategy. The selective attention effect on recall produced by signaling is the result of both increased processing time for the signaled information and also the contrast between signaled and un-signaled information (Lorch, Lorch & Klusewitz, 1995). However, this slower processing is not likely to occur with audio text processing because listeners of audio texts have relatively more difficulty in controlling the rate of audio presentation compared to reading, and actually listeners do not have any control of the rate of audio presentation in this study. The effect of selective attention would therefore be mostly attributed by audio contrast that facilitates the selection process of main topic information (Lorch, Lorch & Klusewitz, 1995; Lorch & Lorch, 1996; Hyönä & Lorch, 2004). Comparing discursive and vocal variety rendering strategies, vocal variety rendering provides greater contrast between signaled and un-signaled content information (Lemarié & Lorch, 2008). If listeners are induced to use structure strategy in both encoding and retrieval, then it is more likely to produce better recall performance from participants who heard headings that had greater contrast compared to un-signaled information.

Besides the hypothesized effect that headings have on selective attention, specific heading rendering could also cause a break in the local cohesion of the audio text. The discursive type of heading rendering switches between describing the visual hierarchical level of a heading and the semantic content information. There is only tangential evidence for this hypothesis; however, previous studies have shown that adding sound, background music, or irrelevant video clips to a narration would disrupt the cohesion of the audio text and leads to poorer recall and knowledge transfer (Mayer, Heiser & Lonn, 2001; Moreno & Mayer, 2000; Mayer 2003). It is possible that a similar disruption effect would be observed with the discursive type of heading rendering that verbally describes the hierarchical information of headings. This hypothesized effect is mostly dependent on whether listeners find the description of hierarchical level information relevant and useful. If listeners find the hierarchical level information useful in a cued recall task, then this information would be less likely to disrupt local cohesion. On the other hand, if listeners find the hierarchical information irrelevant within the cued recall task, it becomes more likely that the hierarchical information would serve as a distraction and disrupts local cohesion of the audio text. Vocal variety rendering presents the hierarchical level information and the semantic content information simultaneously and should cause less break in the overall textual cohesion and lead to better recall performance.

Knowledge Transfer

Knowledge transfer is a test for understanding, where listeners are required to solve a novel problem by applying existing knowledge (Loman & Mayer, 1983; Mautone & Mayer, 2001; Mayer, 2003). The note-taking task investigates primarily the encoding process of information acquisition, and the cued recall task investigates the retrieval process of stored information. The transfer test investigates listeners' ability to integrate new and old information to creatively use the integrated information to solve a new problem (Mayer, 2003). Successful transfer seems to be dependent on a listener's ability to build a mental model of the situation described in the text (Loman & Mayer, 1983; Moreno & Mayer, 2000). But beyond a coherent structure, the listener would need to link the learned information to pre-existing knowledge, and then create a solution to the novel problem. For example, the text used in this study describes how an airplane's engine achieves thrust by igniting air in the combustion chamber. One of the transfer questions asks participants to describe how the engine of a rocket might be different than that of a jet engine. In order to answer this question correctly, participants must first realize that there is no air in space. This pre-existing knowledge needs to be retrieved and integrated with the learned information that a jet engine's function is entirely dependent on air combustion—hence a rocket's engine needs to either carry an oxygen tank or use an alternative energy source. The knowledge transfer test investigates listeners' ability to integrate pre-existing knowledge with the learned information.

Past studies have shown that the presence of headings improves transfer test performance in reading situations (Loman & Mayer, 1983; Mautone & Mayer, 2001; Mayer, 2003). According to Mautone and Mayer (2001), successful knowledge transfer is the result of selecting relevant information, organizing this information into a coherent structure, and integrating it with existing knowledge. It is possible that headings facilitate knowledge transfer by alleviating cognitive load in the selection, organization, and integration processes (Mautone & Mayer, 2001). This explanation coincides with previous findings concerning the effects of headings on attention and the usage of the structure strategy (Lorch et al., 1995; Sanchez et al., 2001). No test has directly investigated the effects of TTS generated audio headings on knowledge transfer. However, one previous study had examined the effect of audio headings on recall and transfer where the audio was generated by a human narrator and the headings were read with a deeper voice (Mautone & Mayer, 2001). In the situation where a human narrator generated the audio text and heading, participants in the headings condition had significantly better recall and transfer performance than participants in the no headings condition (Mautone & Mayer, 2001). Mautone & Mayer (2001) had hypothesized that better recall and transfer performance was due to the alleviation of cognitive load, because audio headings facilitated the selection and organization phase of knowledge acquisition. This alleviation of cognitive load frees more cognitive resources for knowledge integration and consequently better knowledge transfer. While the result from this past study is promising, it does not guarantee that similar effects would be observed with a TTS generated audio text that is four times as long and more complex structurally.

Chapter Two

Experiments

The main purpose of this study was to 1) investigate if listeners find audio headings useful in natural learning tasks, and 2) examine the effects of different audio heading renderings on learning tasks other than heading detection. Previous studies have already shown that a discursive rendering strategy and a vocal variety rendering strategy are both effective in alerting listeners to audio headings, with discursive rendering doing a better job in conveying hierarchical level information (Lorch et al., 2012; Lorch et al., 2015 unpublished study). However, audio text comprehension generally involves other processes besides heading detection. This study seeks to investigate the effects of different types of heading rendering on listener's note-taking, cued recall, and knowledge transfer performance.

Four between-subjects heading rendering conditions were created and they were identical for both Experiment 1 and Experiment 2. These four audio heading rendering conditions included: None, Headings Only, Label, and Voice Change. The None condition did not include any audio headings. The Headings Only condition included audio headings that were produced directly by the TTS engine with pauses before and after; no other special rendering was included in this condition. The Label condition corresponded to the discursive rendering strategy. Each topical heading had a verbal description of "Level 1 Heading", "Level 2 Heading", or "Level 3 Heading" before the topical heading information. The Voice Change condition included headings that had lower pitch, slower tempo, and higher volume. The variations in pitch, tempo, and volume corresponded to the different hierarchical heading levels. The variations in pitch, tempo, and volume in the Voice Change condition were distinctive to listeners based on results of a previous study (Lorch et al., 2015 unpublished study). These four conditions allowed comparisons of the presence of headings versus the absence of headings and also the effect of three different types of heading rendering strategies on natural learning tasks.

Two experiments were designed to test the effects of audio headings on a listener's ability to mentally represent, recall, and comprehend information from the text. The first experiment used a note-taking task, a cued recall task, and a knowledge transfer task to investigate listener's ability to represent, retrieve, and apply information from the audio text. The second experiment used cued-recall and knowledge transfer tasks only. The two experiment were identical with the exception that participants were asked to take notes in Experiment 1 but were not allowed to take notes in Experiment 2. Although the note-taking task was separate from the recall and transfer task in Experiment 1, and participants were not allowed to use their notes to answer either recall or transfer questions, it was possible that participants' note-taking performance could affect the subsequent recall and transfer tasks. Because the note-taking task might cause listeners to pay attention to headings more and consequently affect cued recall and knowledge transfer performance, it was necessary to conduct a second experiment. The second experiment was designed to gauge the direct effect of different heading rendering strategies on recall and transfer without possible mediating effects from the note-taking task.

A note-taking task was selected to gauge participants' ability to represent the information encoded while listening to the audio text (Kiewra, 1989). Participants were instructed to take notes while listening to the audio text recording and they were allowed to pause the recording as many times as they would like while taking notes. No instruction was given to participants on how to take notes or to include headings in their notes. Participants' notes were scored and the number of pauses made by individual participants was recorded.

A cued recall task was selected to determine the extent to which listeners organized their text representations around the headings of the text. . The cued recall task in the two experiments was constructed in such a way that participants would use higher level headings as cues to recall lower level heading information. If listeners use headings to construct a structural representation of the text during encoding, then higher level recall cues should facilitate the retrieval of lower level information (Tulving & Thomson, 1973).

The knowledge transfer task gauged listeners' abilities to apply acquired knowledge to a novel task. According to a past study, the presence of headings should alleviate cognitive load during the information encoding processing, and thus allows the listener to have more processing resources for the information integration process (Mautone & Mayer, 2001). Hypothetically, acquired knowledge that is better integrated with existing background knowledge should allow the listener to solve novel problems more effectively. Participants were asked to apply knowledge acquired from the text to a novel question in the knowledge transfer task. For example, the text explained how an airplane's curved upper surface allowed it to achieve lift. A transfer question would ask participants to explain how a helicopter's top rotor was designed to help the helicopter achieve lift force. Other than spinning to create airflow, participants had to apply the knowledge of curved upper wing surface to the design of a helicopter's rotor to successfully answer this question.

Besides note-taking, cued recall, and knowledge transfer, information concerning participants' prior knowledge and user experience was also collected. Prior knowledge and user experience were both factors that could affect participants' performance for the three learning tasks. While no specific hypotheses were developed for these factors, they were analyzed for possible interaction effects.

The results from these two experiments should provide useful information in determining how different types of audio heading rendering affect various aspects of audio text processing.

Experiment 1: The effects of different audio heading renderings on note-taking, cued recall, and knowledge transfer.

The presence of headings may affect listeners' abilities to form a structural representation of the text and this representation can be investigated using a note-taking task (Kiewra & Benton, 1988). Listeners who produce better notes with a hierarchical outline structure should attain better learning outcomes such as recall and knowledge transfer (Kiewra, Dubois, Christian, McShane, Meyerhoffer & Roskelly, 1991; Kiewra, Benton, Risch & Christensen, 1995; Titsworth & Kiewra, 2004). Participants in Experiment 1 completed three learning tasks including note-taking, recall, and knowledge transfer. Note-taking was used to investigate the quality and structure of information encoded by listeners and how listeners represented and transcribed this information; cued recall was used to measure listeners' retrieval ability of encoded information, and knowledge transfer was used to measure listeners' ability to solve novel problems using acquired information.

Three hypotheses were proposed for the note-taking task. First, listeners who listened to texts that included audio headings should include more main ideas in their notes than listeners without headings (Titsworth & Kiewra, 2004). The main ideas in a text were higher level topical information signaled by the headings. The notes were scored for main ideas signaled by headings instead of verbatim headings because listeners often abbreviate information in their notes (Carrel, 2007). Previous studies have already shown that listeners in the Headings Only, Label, and Voice Change rendering conditions were better at detecting the headings and consequently should produce notes that captured more main topics (Lorch et al., 2012; Lorch et al., 2015 unpublished study).

Second, listeners in the Label and Voice Change rendering conditions should construct notes with more accurate hierarchical level relationships than listeners in the Headings Only rendering condition because these two rendering conditions provided more salient hierarchical and emphasis information (Lorch et al., 2015; unpublished study). Along with this, participants in the Label and Voice Change rendering conditions should make more pauses while listening to the audio recording than participants in the None and Headings Only conditions. This is because participants in the Label and Voice Change condition would need to make more pauses to write down important topic information in their notes. Past studies have indicated that participants in these two conditions do make more pauses and capture more headings than the participants in a

Headings Only condition in a heading detection task (Lorch et al., 2015 unpublished study).

Third, listeners who constructed more hierarchically accurate notes and included more main topics should also perform better in the subsequent recall and knowledge transfer tasks. According to previous studies, performance of cued recall depends on successful adoption of a structure processing strategy during the encoding and retrieval process (Sanchez et al., 2001). Notes that include more main ideas with accurate hierarchical structure should imply that the listener encoded information structurally; consequently, the accurate structural information should promote better cued recall and knowledge transfer performance.

Participants who listened to texts with Label and Voice Change rendering should produce more structurally accurate notes and should also produce better recall and transfer of knowledge. Hypothetically, better notes with all of the main topics in their correct hierarchical structure reflect a more accurate structural representation of the text (Einstein, Morris & Smith, 1985; Titsworth & Kiewra, 2004). More accurate structural representation of the text promotes recall (Kintsch, 1994; Meyer, Brandt & Bluth, 1980; Meyer & Poon, 2001; Van den Broek, Virtue, Everson, Tzeng & Sung, 2002) and also knowledge transfer (Mautone & Mayer, 2001). In other words, there should be a high correlation in the performance of the three tasks. If participants within a certain rendering condition perform better on the note-taking task, then the same group of participants should also perform better on the cued recall and knowledge transfer task. This would be the case if the performance for all three audio text processing tasks depends on a listener's ability to select relevant information and use this information to construct a structural representation of the text. Previous studies suggest that discursive heading rendering strategy is most effective in conveying topical and hierarchical heading information and produces the best performance in a heading detection task (Lorch et al., 2015 unpublished study). One possible outcome of Experiment 1 is that listeners in the Label condition would have the best performance across all three tasks. However, it is not clear if the superior heading detection performance would translate to note-taking, recall, and knowledge transfer performance. Alternatively, it is also possible that the advantage for heading detection in the Label condition does not translate into actual note-taking performance or structural representation. Instead, participants might benefit more from a heading rendering condition, such as Voice Change, that provides greater audio contrast between headings and non-heading information. One past study that looked at the effect of audio headings on recall and knowledge transfer found that headings spoken with a deeper voice produced better recall and transfer performance than an audio text that was spoken without headings (Mautone & Mayer, 2001). Audio contrast, when combined with topical and hierarchical heading information, might be more useful to listeners. If the alternative is true, then we should observe instead that participants in the Voice Change rendering condition have better note-taking, cued recall, and transfer performance, possibly because Voice Change provides greater audio contrast between heading and non-heading information.

Method

Participants. 206 students from the Psychology subject pool at the University of Kentucky participated in Experiment 1. Participants were primarily undergraduate students between the ages of 18 and 25 from introductory level psychology courses. All participants received one research credit for their participation.

Materials. The text used in this experiment was adopted from Mautone & Mayer's experiment (2001) and was different than the texts used in previous related experiments (Lorch, Chen & Lemarié, 2012; Lorch et al., 2015 unpublished). This was done because the new text had a clear causal structure that was more suitable for the knowledge transfer task. The new text explained airplane flight by describing four aerodynamic principles that were utilized in the design of airplanes. Structure wise, the text had 16 headings in three hierarchical levels. The text had two highest level headings, each containing two second level headings, followed by 10 third level headings; each second level heading had two to three third level headings. The experiment text on airplane flight can be found in the Appendix section.

Four audio heading rendering conditions were created, including None, Headings Only, Label, and Voice Change. The None condition did not include any audio headings. This condition measured baseline performance without any heading information. The None condition was used to gauge if listeners find audio headings useful in natural learning situations. The Headings Only condition identified heading topics but there was no special rendering beyond the topical information. This condition had a pause to indicate demarcation information before and after a heading. The Label condition included a discursive expression of hierarchical level before the heading. For example, the recording would say "Level 1 Heading, Energy Problems" to indicate both the hierarchical level and topic of the heading. The Voice Change rendering condition corresponded to the vocal variety rendering strategy. Voice Change rendering used variations in pitch, volume, and tempo to express the hierarchical information of headings. The specific pitch frequency, volume and tempo of the headings in the Voice Change condition were identical to those in Lorch et al.'s (2015 unpublished) study. Each heading level differed by two semi-tones in pitch, 2-5 percent tempo variation, and 2-10 decibel volume variation.

The audio recordings were created by Amazon Kindle Fire's TTS program and the voice change modification was made in Audacity. The specifications of the recordings such as frequency and tempo of the text were identical to those used in Lorch et al.'s study (2015, unpublished study). The new text's content was different than the texts used in Lorch et al. (2015) study, but the new text's hierarchical structure and nonverbal information rendering were similar.

The recall questions were given in the form of cued recall. Recall questions were created that assessed participants' recall performance of second level and third level main topics that were signaled by their corresponding headings. The text is divided into two main sections that described how aerodynamic forces aid or resist airplane flight. Two of these forces, weight and drag, are forces that resist flight and the other two forces, lift and thrust, are forces that aid flight. The first two questions in the cued recall task used top level headings (forces that aid or resist flight) as cues for participants to recall second level main topic information that included the force of lift, thrust, weight, and drag. Since the second level headings were the answers to the first two recall questions, they were not used as cues for third level main topic information recall. Instead, the cues were physical parts of the plane instead of the aerodynamic forces. For example, the section on the force of thrust talked about various parts of the engine and how thrust was generated. The third level main topics in this section included *compressor, combustion chamber,* and *exhaust*, which were parts of an airplane's engine. The relevant recall question asks participants to list the main compartments of an airplane's engine and describe each compartment's function. In this way, even though the cues are not second level headings, participants should understand the specific section of the text that a question is addressing. Four questions were included that gauged participants' recall of third level main topic information; the four questions correspond to the four aerodynamic forces described in the text. The list of cued recall questions can be found in the Appendix section.

The knowledge transfer questions were adopted from Mautone & Mayer's study (2001) and they focused on applying the knowledge given in the text to a novel problem. For example, the text described the design of airplane's wings as having more curved upper surface than bottom surface. This caused air to flow faster cross the top of the wing than the bottom. The faster airflow led to lower air pressure and lower net air pressure above the wing resulted in the generation of an upward lift force. One of the transfer questions asked participants to describe how helicopters achieved lift. Essentially, participants would need to make the connection that helicopters' top rotor has a similar surface curvature design as airplane wings that led to lower air pressure above the rotor. Successful knowledge transfer depends on participants' ability to integrate learned knowledge with existing knowledge (Mautone & Mayer, 2001). In this case, participants would need to have the background knowledge that helicopters achieve lift mostly through its top rotor, and then make the connection that the rotors are probably shaped similar as airplane wings. The instructions for the transfer task also encouraged participants to use information from the audio text to answer the questions. The complete list of transfer questions can be found in the Appendices section.

Besides note-taking, recall, and knowledge transfer tasks, participants were also given a self-reflective questionnaire at the end that asked participants to gauge their prior knowledge and their cognitive load while completing the task. The measures for cognitive load was adopted from NASA-TLX questionnaire (Hart & Staveland, 1988). There were a total of four questions that asked participants to rate their experience on a scale of 0-100. These questions include 1) self-perceived mental demand, 2) self-perceived performance on the three tasks, 3) difficulty of the tasks, and 4) level of irritation and annoyance while completing the tasks. There were a total of six questions that asked participants to self-report relevant prior knowledge. These questions include 1) number of physics courses taken, 2) number of engineering courses taken, 3) interest level in machine mechanics, 4) knowledge about airplane mechanics, 5) knowledge about engines, and 6) number of times on an airplane. The complete questionnaire is included in the Appendices section.

Procedure. Participants were given two blank sheets of notebook paper with horizontal lines and a pen to take notes with. Participants took part in the experiment in groups of four. Participants were told that they would be listening to a TTS generated audio texts. Their task was to take notes during the audio recording and they would receive a test that gauged their understanding after the recording had finished playing.

Participants first listened to a TTS generated sample text. The exact same sample text was played across the four heading rendering conditions with the exception of specific heading renderings. There were two reasons for creating the sample texts. First, the sample text gave participants a general idea of what it meant to have a text with three hierarchical levels. Secondly, participants could use this opportunity to familiarize themselves with the audio presentation. The audio sample text first repeated the instruction concerning the note-taking task and subsequent test. The sample text then briefly described what headings were and how the headings were rendered in the text. After hearing the instructions, participants heard a short text with three hierarchical levels on the topic of energy production. A transcription of this short audio text was provided for participants so that participants could have a visual representation of the three hierarchical level structure of the text. The audio and visual instruction for participants in the None (no heading) condition was modified so that participants were shown a three hierarchical level text without headings. Also, participants in the None condition did not receive any descriptions about headings in the instruction and the short text on energy production did not include any headings.

Participants were allowed to pause the audio recording as many times as they would like. Participants had to press the left arrow key to pause the recording and press the right arrow key to resume playing. Participants were not allowed to rewind the audio recording.

Once the sample text had finished playing, participants listened to the experimental text while taking notes. Participants were told that there was a test at the end of the recording that would gauge their understanding of the text. No instruction on the method of note-taking was given to participants to ensure that the results of note-taking were only affected by the different types of heading rendering conditions.

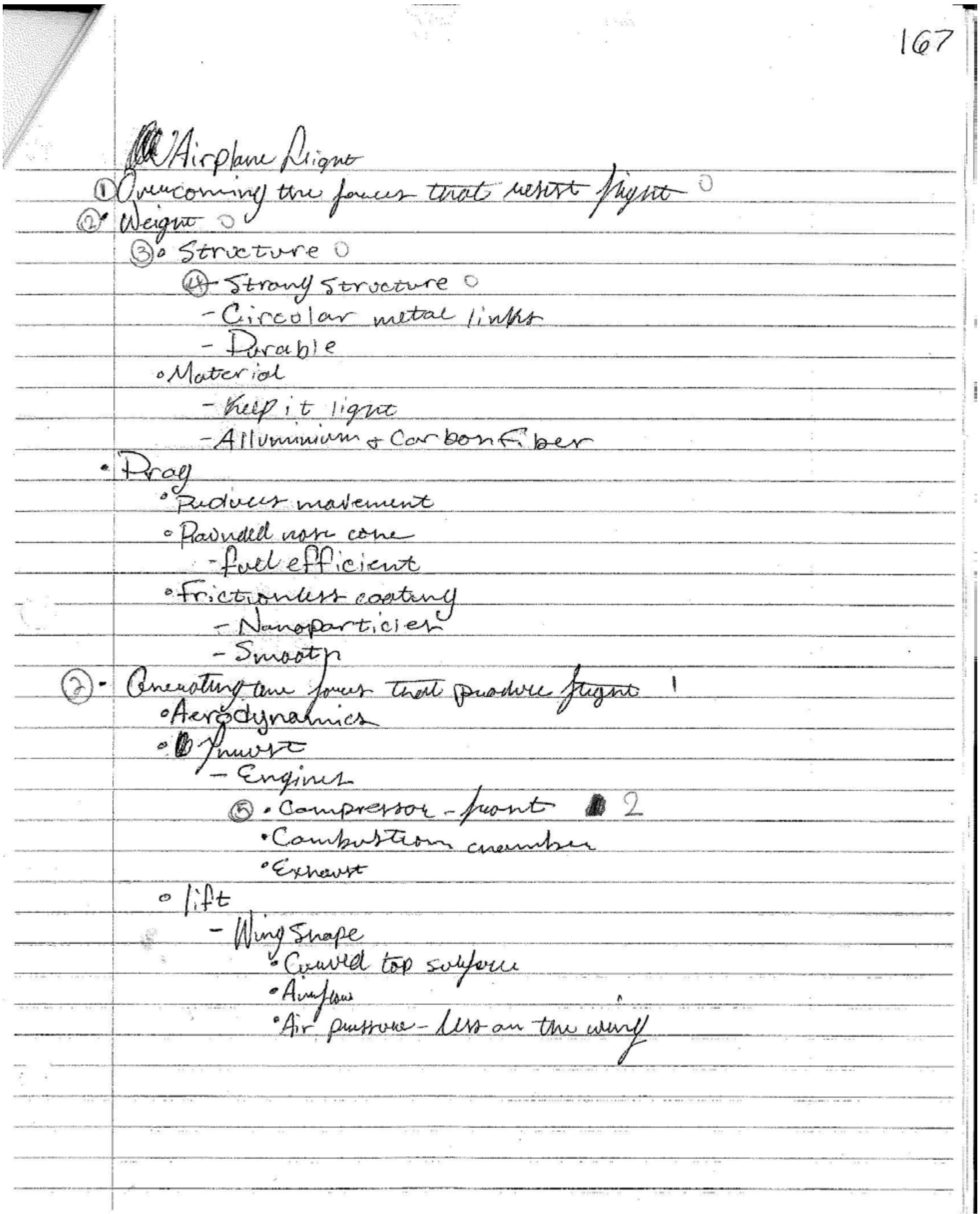
After participants had finished listening to the audio text, they were given the recall test followed by the transfer test. Participants were told to seal their notes in an empty envelope provided for them and then click on an icon on the computer's desktop that led them to the recall and transfer tests. The tests were hosted on Qualtrics, an online survey tool. Participants transitioned immediately from the note-taking task to the cued recall task without any chance to review their notes. This was done because individual participants may have different levels of efficiency in acquiring information from their notes. If review time was allowed, it could potentially contribute to variability in recall and transfer performance. Past studies have shown that rehearsal of notes does affect participants' subsequent learning task performance (Kiewra, 1989). Participants were always presented with the cued recall test first and then proceeded to the transfer test. Once the recall test was completed and a participant proceeded to the transfer test, the person could not go back to the recall test. This was done to ensure that the questions given in the knowledge transfer test were not used as retrieval cues for the recall test.

Design. The between-subjects variable in this study was heading rendering strategies. Four conditions were created within this variable, including None, Headings Only, Label, and Voice Change. Participants were randomly assigned to each of the four conditions with approximately equal number of participants in each condition (i.e. 51±1 participants per condition).

Scoring. The notes taken by participants were scored by two independent scorers who were unaware of the manipulation assigned to each participant. The percentage agreement was 80.30%. Participants' notes were scored for 1) total number of main ideas as expressed by headings, 2) the average hierarchical level deviation for the main ideas expressed, 3) the ratio of words used to expressed these main ideas versus the total number of words included in the notes. A strict heading scoring criteria was not used because note-takers often use abbreviations and paraphrase in their notes (Carrell 2007). The notes scoring procedure was adopted from Lorch et al.'s (2012) outline scoring procedure and also Carrell's (2007) notes scoring criteria.

The number of main ideas recorded in notes was scored by identifying main topic ideas that matched the ideas signaled by headings. If a participant's notes expressed an idea that was judged to be similar in meaning to the ideas expressed by headings, the participants was given credit for the particular main idea. The total number of main ideas captured by listeners is similar to a heading detection measure without telling participants to attend to the audio headings. This measure gauges participants' selection strategy of important topics from the audio text.

The main ideas expressed in notes were analyzed for their average level deviations. Hierarchical level deviations were scored by judging the relative visual relationship between two ideas. Varying levels of bulleting, numbering, and indentation helped to indicate the hierarchical relationship between two propositions. For example, if the topic "Energy Solutions" was labeled as "2" with no indentation, and the topic "Conservation of Natural Resources" was labeled as "a" with indentation immediate below Energy Solutions, then this would be a correct hierarchical level relation. The usage of lined notebook papers facilitated the scoring process of hierarchical information. Average level deviation was calculated by first subtracting the correct level from the expressed level for individual topics expressed, and the differences were summed for each participant. Any negative value was converted to an absolute value for the final summation. The notes-taken shown in Figure 1 serves as an example of the level scoring process. In Figure 1, topics such as “Overcoming forces that resist flight” and “weight” received zero level deviation because the expressed level and the correct level are the same. However, for the topic “Generating the forces that produce flight” should be a Level 1 topic but is expressed as a Level 2 topic. The topic therefore receives one deviation point. Similarly, “compressor” should be a Level 3 topic but is expressed as a Level 5 topic. Therefore, the topic receives two deviation point. A participant’s average deviation is calculated by taking the summed deviation points and divide by the total number of main ideas expressed. The average deviation point is a measure of how far each main idea expressed in the notes is from the correct level on average. Previous studies have shown that Label rendering is better than Voice Change and Headings Only renderings in communicating hierarchical level information (Lorch et al., 2015 unpublished study). However, it is not clear if the advantage in detecting heading level translates to a situation where listeners need to represent the hierarchical level information in their notes. Level deviation is important because it gauges whether participants accurately captured and represented hierarchical structure information of the audio text. Hypothetically, participants who did not recognize the text’s structure would have poorer recall and knowledge transfer performance.



167

Airplane flight
① Overcoming the forces that resist flight 0
② • Weight 0
③ • Structure 0
④ Strong structure 0
- Circular metal links
- Durable
• Material
- Keep it light
- Allumminum & Carbon Fiber
• Drag
• Reduces movement
• Rounded nose cone
- fuel efficient
• Frictionless coating
- Nanoparticles
- Smooth
② • Generating the forces that produce flight 1
• Aerodynamics
• Thrust
- Engines
⑤ • Compressor - front 2
• Combustion chamber
• Exhaust
• lift
- Wing Shape
• Curved top surface
• Airflow
• Air pressure - less on the wing

Figure 1. Sample level scoring

The ratio of topic words versus the total number of words was calculated by dividing the number of main idea words by the total number of words included in the notes. Main ideas words were calculated by first counting the number of words that expressed a particular main idea, and then summing these numbers to obtain the total number of main idea words. This calculation provides a more direct measure of participants' selectiveness in attending to main topic information as signaled by headings. A higher ratio would mean that participants focused more attention on heading information and recorded that information into their notes; a low ratio would mean that participants did not have a strategy of focusing only on the audio headings. Since participants were not explicitly told to attend to headings in the instructions, we wanted to see if any one type of the rendering manipulation affect participants' note-taking strategy and selective attention.

The scoring for recall and knowledge transfer questions was done by four independent scorers who were unaware of the manipulated conditions. The percentage agreement for the recall task and the transfer task were 84% and 79% respectively. Recall performance was judged by the similarity of participants' answers to the second and third level headings provided in the text. Answers for the knowledge transfer task were compared to a list of plausible answers according to the scoring rubric adopted from Mautone & Mayer's study (2001). The scoring rubrics for the note-taking task, recall task, and knowledge transfer task are provided in the Appendix section.

Results & Discussion

An ANOVA test was used to analyze the effect of heading rendering on every dependent variable. If a significant effect was observed for the heading manipulation, a Tukey's honestly significant difference test (HSD) was used to determine the pair of heading rendering conditions that had significant difference. The adopted significance level for all reported result is 0.05 unless noted otherwise.

Note-Taking Task

A total of 203 notes from 206 participants were scored; one participant did not take any notes and two participants terminated the recall and transfer test early. The number of main ideas captured by participants while listening to the audio recording was analyzed. The main ideas were information signaled by the headings; however, the scorer did not adopt a verbatim heading scoring procedure and therefore individual main idea may not include a complete heading. The maximum number of main ideas that could be expressed in participants' notes was 16. A summary of the mean number of main ideas expressed in notes is shown in Figure 2. Error bars indicate standard error. There was a main effect of heading rendering manipulation on the number of main ideas included in notes $F(3, 202)=30.75$, partial $\eta^2=0.32$. Participants in the three heading conditions recorded significantly more main ideas in their notes; however, there was no reliable difference in performance across Headings Only, Label, and Voice Change. Results indicate that participants found the presence of audio headings useful and were able to capture more main ideas when audio headings were present. However, participants did not find special heading renderings (Label and Voice Change) more useful than generic heading rendering (Headings Only).

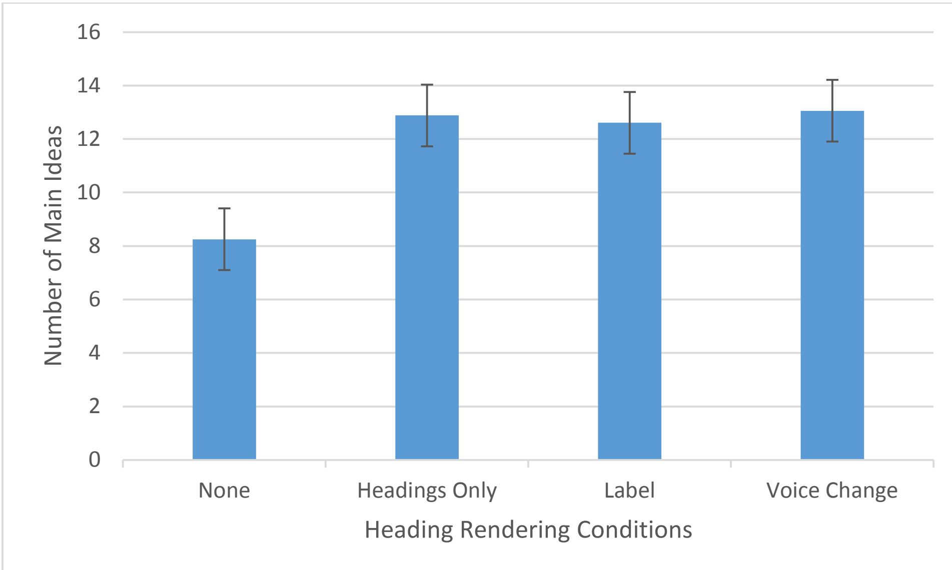


Figure 2. Number of main ideas included in notes

The average level deviation of individual main ideas included in the notes was analyzed. This measure reflects, on average, the difference between an expressed level and the correct level. There was no main effect of rendering strategy on the average level deviation; $F(3, 202)=2.06$, $p=0.106$, partial $\eta^2 =0.03$. Although hierarchical level information was conveyed by both the Label condition and Voice Chance condition, participants did not use this information when constructing their notes. The null effect could be due to the lack of a training session or the inability to organize audio hierarchical information into written hierarchical information.

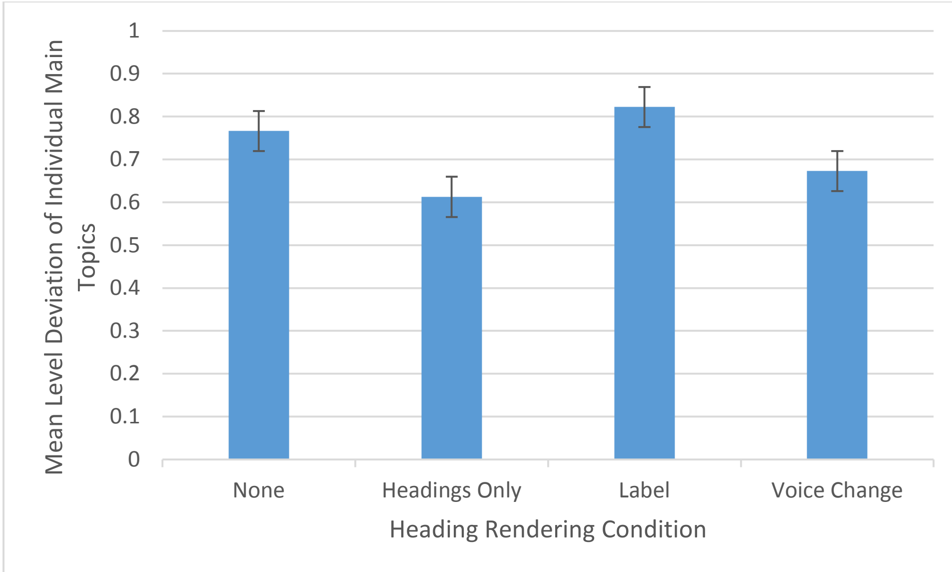


Figure 3. Average level deviation of main topics included in the note-taking task

Next, the ratio of topic words versus the total number of words included in the notes was analyzed. This ratio expresses listeners' note-taking strategy and indicates whether listeners selectively attended to headings or if listeners included equal amount of heading and non-heading information. A higher ratio meant a higher proportion of main ideas captured versus minor or unrelated ideas. For example, the ratio for participants in the None condition was 0.3145. This meant that participants in the None condition took notes that comprised of 31.45% main idea words and 68.55% minor or un-related idea words. There was a main effect of heading rendering on the proportion of main idea words included; $F(3, 202)=6.64$, partial $\eta^2=0.09$. There was a reliable difference between None and the three other heading conditions but there was no reliable difference across Headings Only, Label and Voice Change. A summary of the results for the ratio of main ideas versus minor or unrelated ideas is shown in Figure 4. Results indicate that the presence of audio headings allowed participants to focus more on main ideas highlighted by headings. However, additional rendering in the Label and Voice Change conditions did not have an effect participants' selective attention.

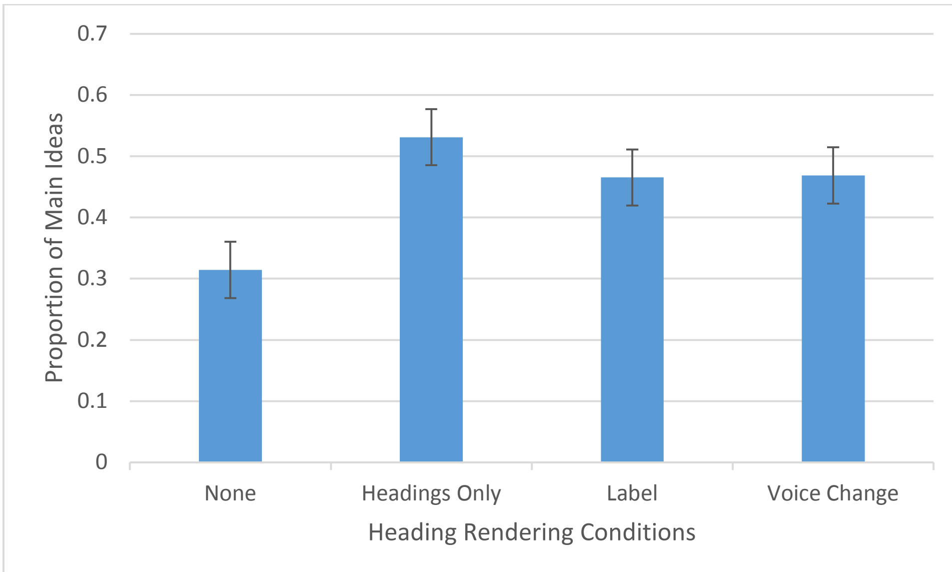


Figure 4. Proportion of main ideas versus minor or unrelated ideas

The number of pauses made by participants while listening to the audio text and taking notes was analyzed. According to our initial hypothesis, participants in the Label and Voice Change conditions should make more pauses. This was because the headings in these two conditions were more salient and allowed listeners to capture more of the headings. A summary of the average number of pauses across the four heading rendering conditions is presented in Figure 5. There was a main effect of heading rendering on the number of pauses made; $F(3,202)=2.549$, partial $\eta^2 =0.037$. Participants in the Voice Change condition made 5.73 pauses on average; this was significantly lower than participants in the Headings Only condition (12.48 pauses) and also the Label (13.27

pauses) conditions. Participants in the Voice Change condition were able to achieve similar level of note-taking accuracy despite having fewer number of pauses. Participants in the Label condition had the highest number of pauses and was the only group that had significantly more pauses than participants in the None condition (7.15 pauses). This indicates that participants in the Label condition had to make more pauses, but the notes produced were not significantly better than the ones from Headings Only and Voice Change. There was no reliable difference in the number of pauses made between participants in the Label condition and Headings Only condition.

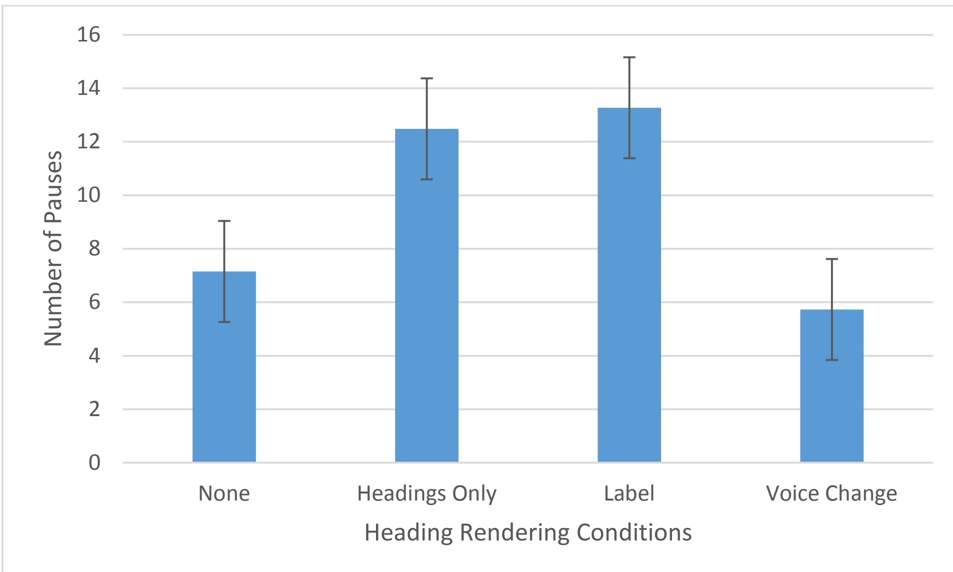


Figure 5. Number of pauses made while listening to audio text

Recall Task

A total of 203 recall tasks were recorded and scored. One of the 206 participants did not take any notes. Two other participants terminated the online Qualtrics test prior to completion and no data was recorded for these two participants. The remaining participants' recall performance was analyzed for 1) total number of main topics recalled, 2) number of second level main topics recalled, and 3) number of third level main topics recalled. Participants did not have to recall the first level main topics because they were used as cues for the recall of second level and third level main topics. There were four second level main topics and 10 third level main topics. Two recall questions were created for the second level main topics. The first question asked participants to list the four main aerodynamic forces mentioned in the text and the second question asked participants to categorize the forces listed from the previous question into forces that aid flight and forces that resist flight. Participants could score up to eight points from the first two questions. The remaining four questions asked participants to recall the third level main ideas. Each main idea has two components. For example, a third level main idea is "compressor: air is pressurized by the compressor". One point is awarded to participants who could recall the idea "compressor". A second point is award for recalling the compressor's function of pressurizing air. A third point is awarded if the two ideas mentioned are correctly related. That is, a participant could mention that an engine contains a compressor and air is pressurized by the engine but fails to link "compressor" with "pressurizing air" directly. Because each third level main idea could potentially be awarded three points, participants could score up to 30 points for the recall of third level topics, making the maximum possible recall score 38 for any participant. The recall scoring rubric can be found in the Appendix section.

The total number of main ideas recalled was analyzed. The means of total recall indicated that participants in the three headings condition recalled more information than participants in the no heading condition, with participants in the Voice Change condition performing best. However, heading rendering manipulation had no reliable effect on total recall; $F(3, 202)=1.734$, $p=0.161$, partial $\eta^2=0.03$. A summary of the results for total number of main ideas recalled is shown in Figure 6.

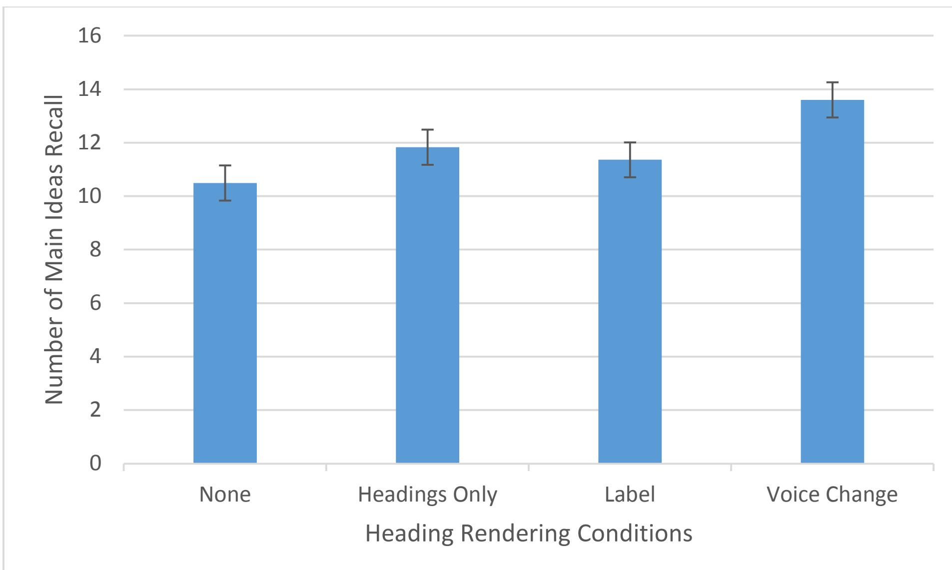


Figure 6. Total number of main ideas recalled

The recall performance for second level main ideas also yielded no main effect for the heading rendering manipulation; $F(3, 202)<1$. The null effect of the total number of main ideas recalled was probably contributed by the similarity in the recall performance across all conditions for the second level main topics. A summary of results for the recall of second level main ideas is shown in Figure 7.

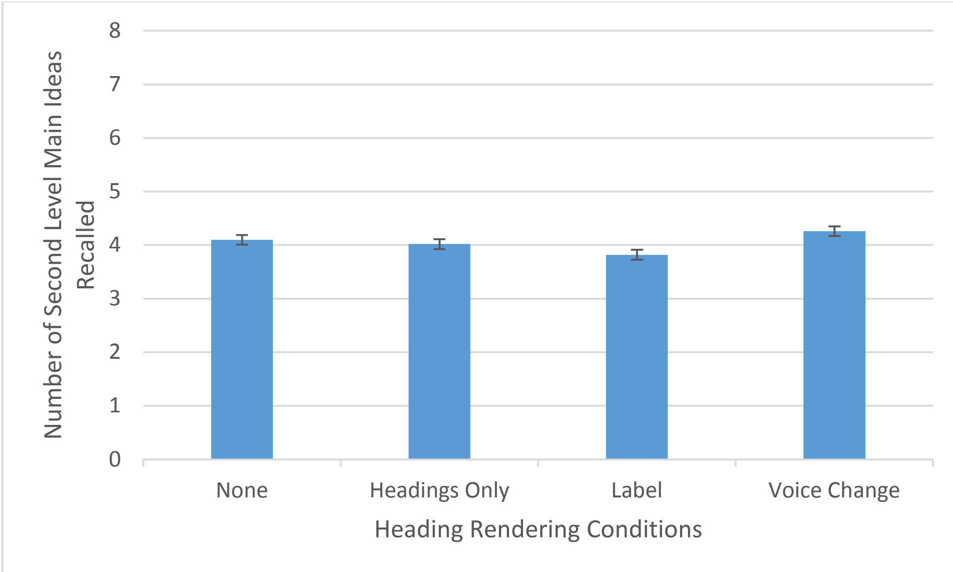


Figure 7. Recall of second level main ideas

The heading rendering manipulation had a main effect on the recall of third level main topics $F(3,202)=2.809$, partial $\eta^2=0.041$. A summary of the recall performance for third level main ideas is shown in Figure 8. Participants in the Voice Change condition had better third level recall performance than participants in the None condition. There was no reliable difference across None, Headings Only, and Label. There was also no reliable difference across Headings Only, Label, and Voice Change. It is possible that audio contrast conveyed by pitch, volume, and tempo variation in the Voice Change condition facilitated the processing of other signaling information. In other words, no single signaling information was sufficient in producing reliable difference in third level recall performance. Only the combination of several types of signaling information, including audio contrast, was able to produce a reliable increase in third level recall performance. The pattern of recall results will be discussed in greater detail in the General Discussion section.

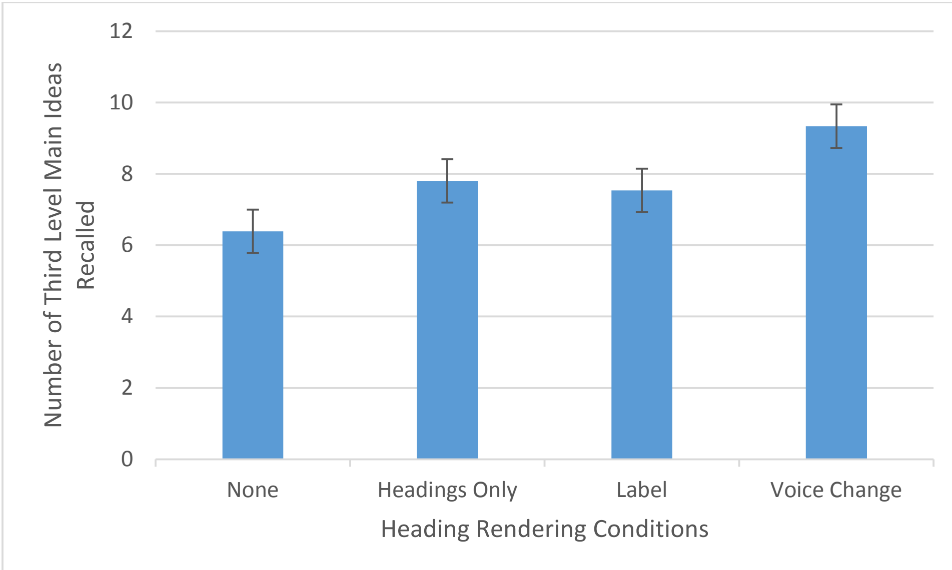


Figure 8. Number of third level main ideas recalled

Knowledge Transfer Task

A total of 203 transfer task protocols were recorded and scored. The same three participants that were excluded from the recall analysis were also excluded from the transfer test. Participants could score up to 10 points on the transfer task, one point per question. Performance for the transfer task was poor, with no main effect for the heading rendering manipulation $F(3, 202) < 1$. A summary of the transfer results is shown in Figure 9. Factors that could have contributed to the null result include the type of text used, length of the text, and the type of questions used. A more detailed analysis is provided in the General Discussion section.

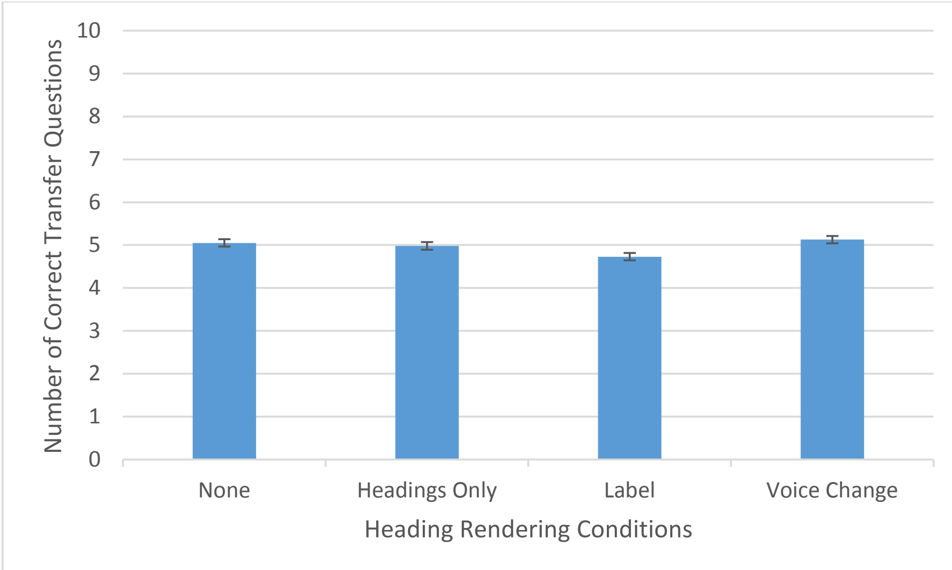


Figure 9. Number of correct transfer questions

User Experience

Besides the results from notes, recall, and knowledge transfer, user experience information was also collected from participants after the recall and transfer tasks. These user experience measures included: 1) perceived mental demand, 2) perceived effort, 3) perceived stress, and 4) self-evaluation of performance on the recall and transfer tasks. These measures were adopted from the NASA-TLX (Task Load Index) questionnaire (Hart & Staveland, 1988). A MANOVA analysis showed that heading rendering manipulation did not have an effect on any of the user experience measures. That is, participants did not perceive significantly more or less mental demand, effort, or stress in any of the heading rendering conditions nor did participants in any condition feel like they did significantly better on the three learning tasks. There is probably high variability due to the self-reporting nature of these questions. The general trend of means, however, indicates that participants in the Voice Change condition perceived less mental demand, stress, and effort. Figure 10 through 13 provide summary of means for the four user experience measures.

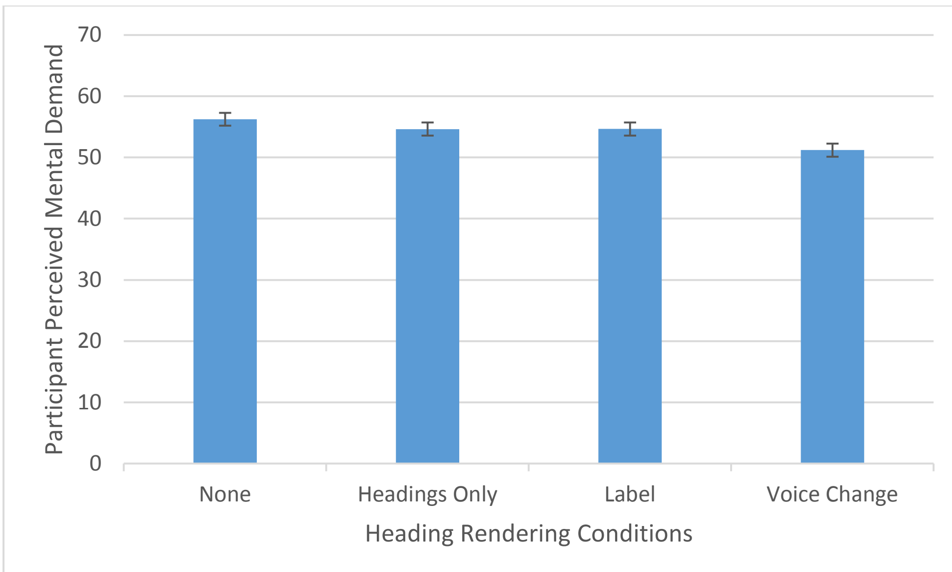


Figure 10. Participants' self-perceived mental demand for the three learning tasks (lower number indicates lower mental demand).

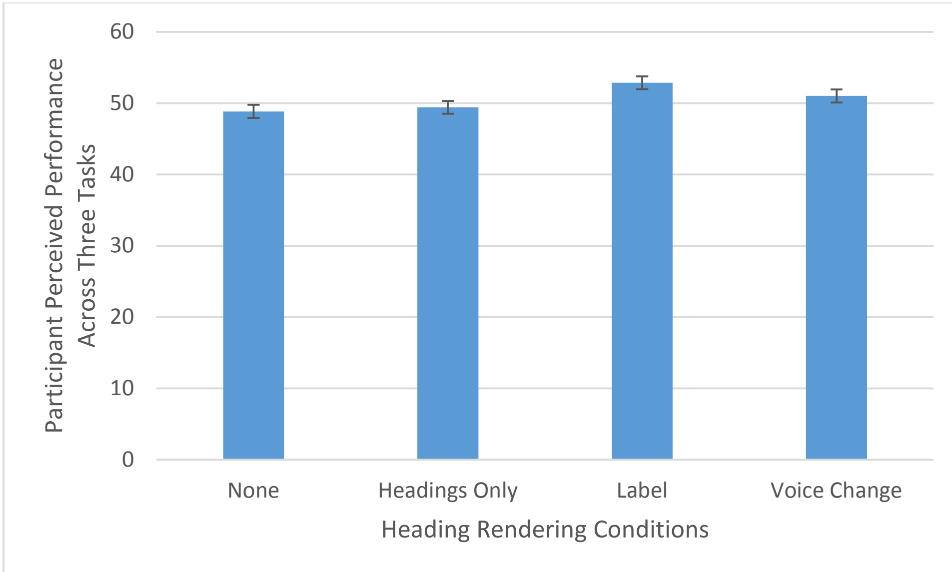


Figure 11. Participants' self-perceived performance level for the three learning tasks (lower number indicates lower performance level).

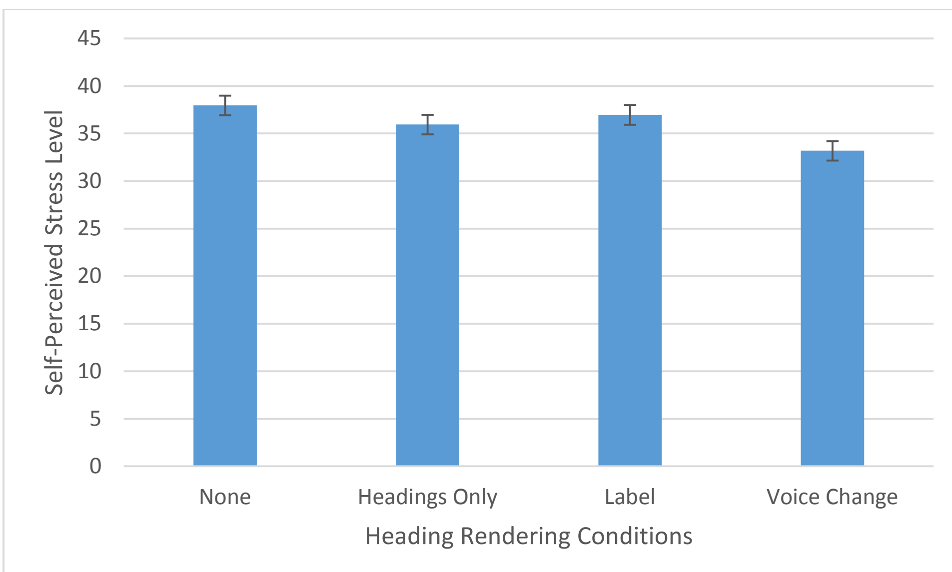


Figure 12. Participants' self-perceived stress level for the three learning tasks (lower number indicates lower stress level).

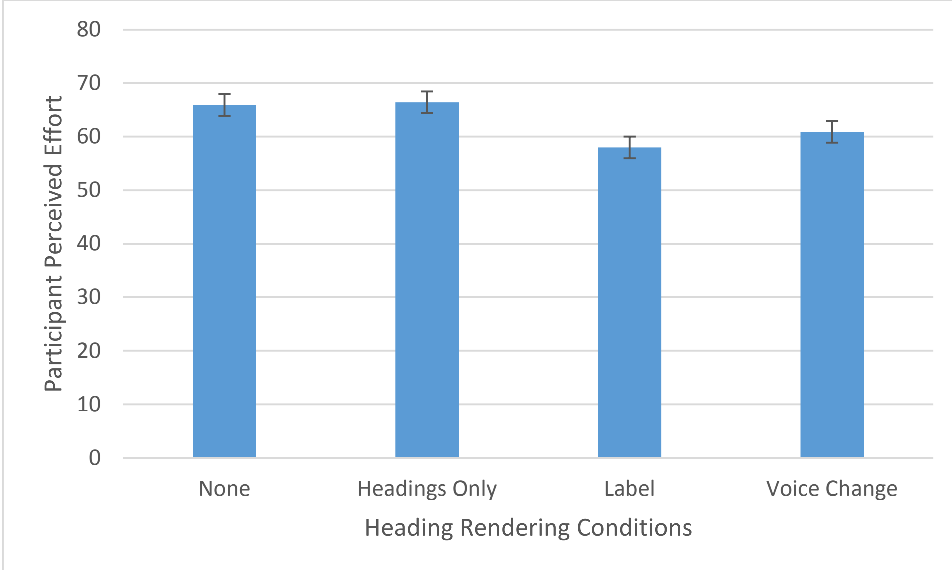


Figure 13. Participants' self-perceived effort for the three learning tasks (lower number indicates lower perceived effort).

Prior Knowledge

The last set of measures included in the experiment is prior knowledge. This set of measures include: 1) number of times a participant had been on a plane, 2) level of personal interest in airplanes, 3) prior knowledge of airplanes, 4) prior knowledge of engines, 5) prior knowledge of airplanes, 6) number of physics courses taken, and 7) number of engineering courses taken. Since most of the participants were first or second year undergraduate students in lower level Psychology courses, it was assumed that most of them did not have strong physics or engineering backgrounds. A MANOVA analysis revealed that the number of physics courses taken was the only variable that had a significant relation to total recall, where participants who had taken one physics course had better total recall performance than participants who had not taken any physics course. None of the other prior knowledge variables had any relation to note-taking performance, recall, or knowledge transfer.

Correlation across the performance of note-taking, recall, and transfer

It was hypothesized that performance on the note-taking task would correlate with performance on recall and knowledge transfer because accuracy of encoded information as expressed in the notes might affect the subsequent retrieval and integration processes. A summary of the Pearson's correlations across measures of the three tasks is shown in Table 1. All correlations were positive with the exception of *average level deviation* where the correlation was negative. Therefore, participants who recorded notes with higher average level deviation tended to record fewer main ideas and had poorer recall and transfer performance. All correlations were significant at 0.05 level except the correlation between *average level deviation* and *ratio of main idea words versus non-main idea words*. The correlation results indicate that participants who are able to encode audio information more accurately in their notes are also better at retrieving and integrating audio information. While this is not direct evidence to support the notion that notes quality affects recall and knowledge transfer performance, it does provide motivation for conducting a second experiment that excludes the note-taking task in order to examine the direct effect of heading rendering on cued recall and knowledge transfer performance.

Table 1.
Correlation across measures of note-taking performance, recall performance, and knowledge transfer performance

	1	2	3	4	5	6
Notes Total Ideas						
Notes Level Deviation	-.293**					
Notes Ideas Ratio	.452**	-.054				
Total Recall	.333**	-.405**	.264**			
Second Level Recall	.242**	-.399**	.161*	.805**		
Third Level Recall	.331**	-.349**	.278**	.953**	.588**	
Total Transfer	.214**	-.267**	.143*	.568**	.465**	.537**

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

In summary, it appears that participants do find heading information useful and attend to heading information provided by audio text in note-taking task. Results for recall and transfer are more complex but they seem to indicate that a heading rendering type which includes audio contrast produces the best third level recall performance.

Chapter Three

Experiment 2: Effects of different heading renderings on recall and knowledge transfer

Experiment 1 explored the effect of different audio heading renderings on note-taking and the subsequent learning outcome. The tasks used to gauge learning outcomes in Experiment 1 included a cued recall task and a knowledge transfer task. Participants' performance on these two tasks were probably affected by the notes that they took (Lai et al., 2000; Kiewra, Benton, Risch & Christensen, 1995; Mautone & Kiewra, 2004). That is, the cued recall effect observed for third level main ideas in Experiment 1 could have been affected by note-taking performance. The strong correlations between note-taking performance and the other two tasks from Experiment 1 provides some evidence for this possibility. It is therefore important to investigate the effect of heading renderings on cued recall and knowledge transfer directly without any possible mediating influence of note-taking. Experiment 2 focused on the effect that different types of audio heading renderings have on cued recall and knowledge transfer.

Method

Participants. A total of 200 undergraduate students from the Psychology subject pool participated in the experiment. One of the participants was given the wrong audio file and another three participants terminated the recall and transfer tests earlier than they should. Therefore, data was recorded only for 196 participants. All participants received one research credit for their participation.

Material. The audio recordings used were the same as those described in Experiment 1. The sample text also remained the same with the exception that participants were not allowed to take any notes while listening to the audio text. The text, questions for cued recall, and transfer test were identical to the ones used in Experiment 1.

Design. The design of Experiment 2 was the same as Experiment 1, with one between-subjects variable that had four conditions including None, Headings Only, Label, and Voice Change.

Procedure. Subjects participated in the experiment in groups of four. Participants were told that they would be listening to a short text about airplane flight and factors that affected airplane flight. After the recording had finished playing, participants were given a test that gauged their memory and comprehension at the end of the recording. Participants were not allowed to take notes in any form during the listening phase. The recording was only be played once and participants were allowed to pause the recording as many times as they wanted.

Participants first listened to the sample text and then listened to the experiment text. The recall and transfer questions were delivered via Qualtrics. Participants were given unlimited time to complete the two tests at their own pace.

Scoring. Recall and transfer results were scored by three independent scorers who were unaware of the experimental manipulation. The procedure and scoring criteria were identical to Experiment 1. Percentage agreement for the recall task was 84% and the percentage agreement for the transfer task was 79%.

Results & Discussion

An ANOVA test was used to analyze the effect of heading rendering on every dependent variable similar to Experiment 1. No post-hoc analysis was conducted because no heading rendering effect was found in either of the two learning tasks. The adopted significance level for all reported result is 0.05 unless noted otherwise.

Recall Task

There was no main effect of heading rendering manipulation on total recall; $F(3, 195)<1$. There was also no effect of heading rendering manipulation on the recall of second level main topics; $F(3,195)<1$. There was no effect of heading rendering on the recall of third level main topics; $F(3,195)=1.392$, $p=0.246$, partial $\eta^2=0.021$. Figures 14-16 provide summaries for the total number of main topics recalled, number of second level main topics recalled, and number of third level main topics recalled.

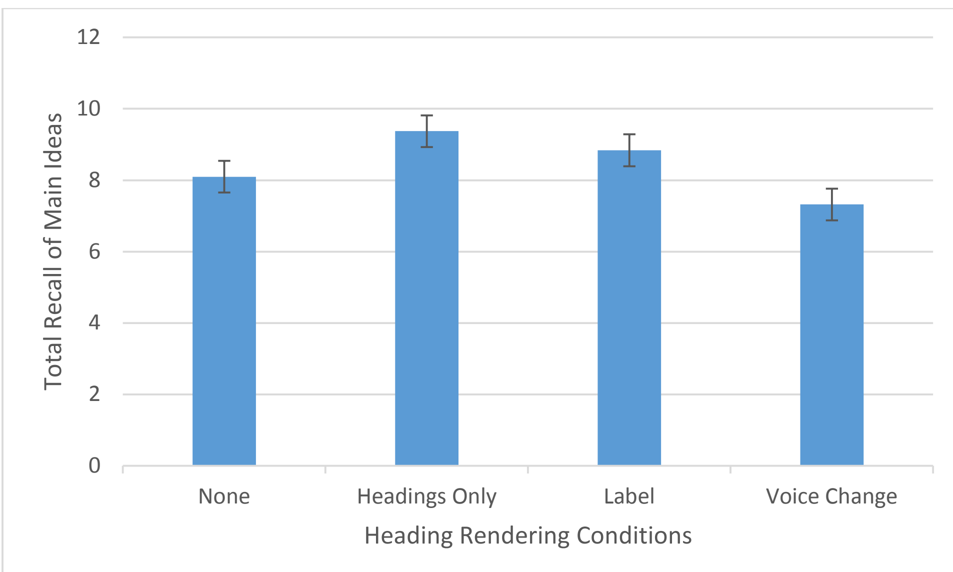


Figure 14. Total number of main topics recalled

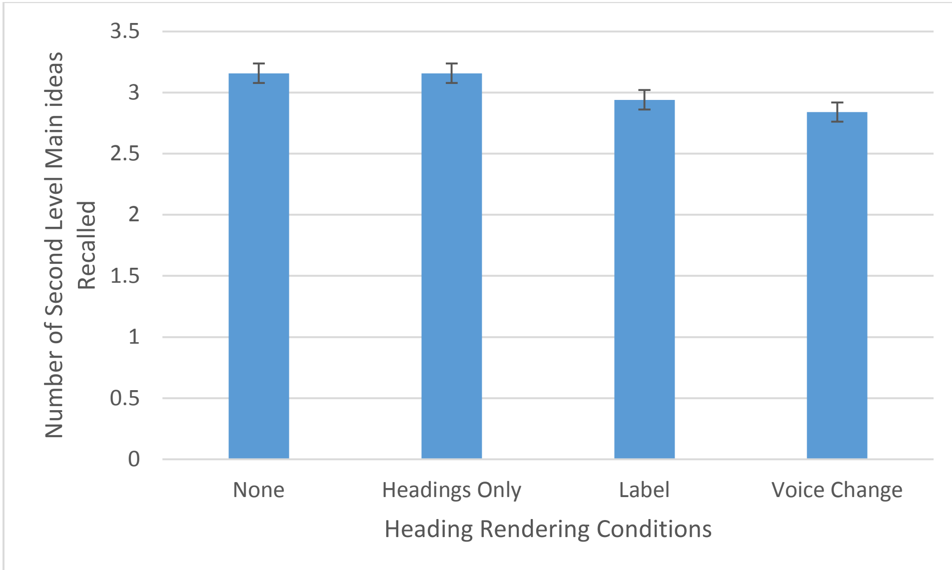


Figure 15. Number of second level main topics recalled

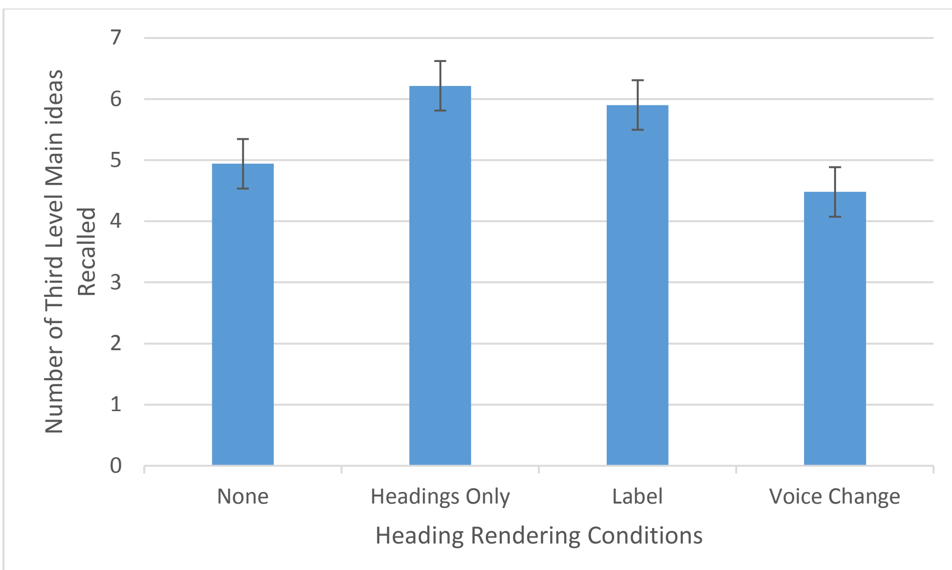


Figure 16. Number of third level main ideas recalled

Transfer Task

There was no main effect of heading rendering manipulation on transfer performance; $F(3,195)<1$. Figure 17 provides a summary for the mean transfer performance in each condition.

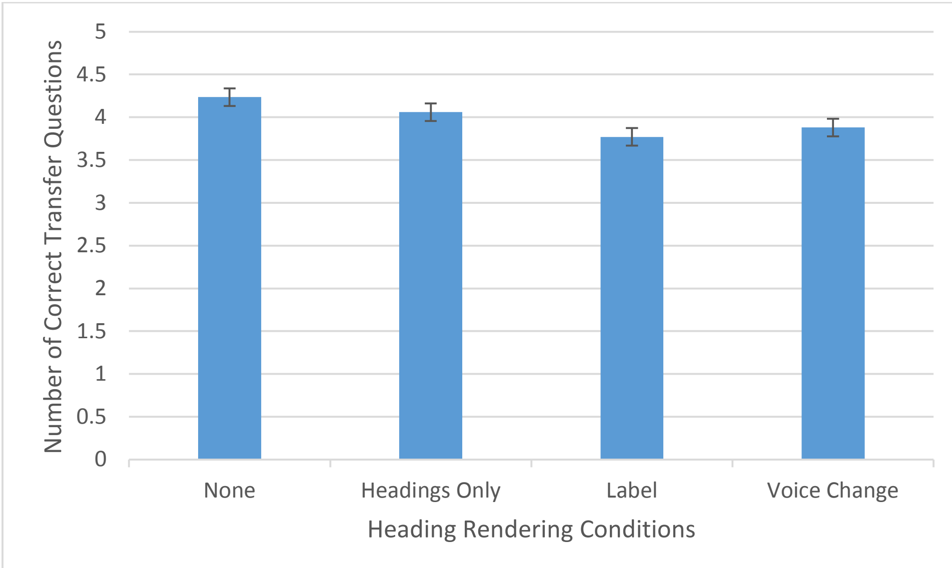


Figure 17. Number of transfer questions correctly answered

There was no effect of heading rendering on recall or knowledge transfer performance in Experiment 2. This was contrary to the initial prediction that different types of heading renderings would have a direct effect on listeners' recall and transfer performance. Comparing recall and transfer results between Experiment 1 and 2, participant performed much worse when they were not allowed to take notes while listening to the audio text.

One past study shows that note-taking does improve participants' comprehension of synthetic speech (Lai et al., 2000). Without taking notes, participants' recall performance dropped from an average of recalling 11.82 main ideas across the four heading conditions in Experiment 1 to 8.41 main ideas in Experiment 2. The only heading rendering effect on cued recall from Experiment 1 was found on the recall of third level main ideas. Participants in the None (no heading) condition in Experiment 1 recalled 6.39 third level main ideas; participants in Experiment 2 recalled an average of 5.38 third level main ideas across all conditions with no reliable difference between any two conditions. That is, participants' third level recall in Experiment 2 in any of the conditions with headings was worse than those in the no heading condition from Experiment 1. It is possible that participants in Experiment 2 did not utilize audio headings at all to guide their listening process.

One possible explanation for the poor recall performance in all levels for Experiment 2 is that participants might have failed to adopt a structure strategy during the encoding process. Participants might not have selectively attended to important topic information and attempted to build a coherent structural representation of the text. Past studies have shown that the presence of headings does not necessarily promote the adoption of a structure strategy during text processing (Sanchez et al., 2001). It is possible that without a note-taking task, participants resorted to a linear processing strategy and did not use audio headings during the encoding process.

Another possible explanation for the poor performance in Experiment 2 was that participants listened passively and did not attempt to pause and rehearse any information while listening to the audio text. Results from the number of pauses made while listening to the audio text indicate that many of the participants did not pause the audio recording at all. Although participants were allowed to pause the audio recording while listening to the text, only 9% of the participants paused the audio recording at least once while listening to the audio recording. This was a drastic decrease compared to Experiment 1, where 60% of the participants paused the audio recording at least once. Since the only difference between Experiment 1 and Experiment 2 was the presence of the note-taking task, the note-taking task was probably the main factor that contributed to the difference in the number of pauses that participants made. Participants who were not required to take notes probably did not find pausing the audio recording necessary because they did not need to spend time to write down any information. However, failure to pause the audio recording probably forced participants to process more information in a shorter amount of time, and all this information would have to be retained in the working memory. Without pausing, participants' recall performance was probably limited by individuals' working memory capacity.

Chapter Four

General Discussion

The purpose of this study was to investigate 1) whether listeners find audio headings useful in natural learning tasks, and 2) the type of heading rendering that is most useful in natural learning tasks. Past studies have provided evidence that participants can detect audio headings with the right rendering, and different rendering strategies affect listeners' heading detection accuracy (Lorch et al., 2012; Lorch et al., 2015 unpublished study). However, priming listeners to use headings in an outline task or explicitly asking listeners to detect headings are not naturally occurring learning tasks in a classroom setting. This study therefore compared four types of heading conditions across three learning tasks including note-taking, cued recall, and knowledge transfer. These three learning tasks resembled more realistic learning situations without priming participants to focus on the audio headings.

According to the results from Experiment 1, participants found audio heading information useful and guided their note-taking strategy using headings. Participants in the three conditions with headings (Headings Only, Label & Voice Change) captured more main ideas and also had proportionately higher main idea words compared to minor or un-related idea words. However, participants did not find any one of the three types of heading renderings more useful for any of the three learning tasks. Audio headings are useful, but is not clear if any one type of the rendering strategies is the best.

Based on previous studies (Lorch et al., 2012; Lorch et al., 2015 unpublished study), we had expected to find that participants in the Label and Voice Change conditions would have better note-taking performance than participants in the Headings

Only condition. The results of Experiment 1 did not support this hypothesis. Instead, participants had similar note-taking performance across Headings Only, Label, and Voice Change in all measures of note-taking. Previous studies had indicated that Label and Voice Change conditions provide very salient emphasis and hierarchical information, and allow listeners to detect headings and produce outlines better than participants in the Headings Only condition (Lorch et al., 2012; Lorch et al., 2015 unpublished study). The Label condition, according to previous studies, is especially effective in communicating hierarchical level information (Lorch et al., 2015 unpublished study), but no reliable difference is found in the average level deviation measure for the note-taking task.

One of the possible explanations for the discrepancy between the results observed from previous studies and the current study is the amount of practice given to participants before the experiment. One of the previous TTS studies allowed participants to go through 20 practice trials with feedback before the actual heading detection task (Lorch et al., 2015 unpublished study). The current study only provided participants with a short sample text that included three headings and participants were not told to focus on headings. It is likely that participants in the Label and Voice Change conditions could have produced better notes if they were more familiar with the type of information conveyed by these two rendering strategies (Lai, Wood & Considine, 2000).

A second likely cause for the difference between findings from previous studies and the current study is in the instructions given to the participants. Previous studies either specifically instructed participants to listen for headings (Lorch et al., 2015 unpublished study) or showed participants a sample outline consisted of heading-like main topics (Lorch et al., 2012). The instruction for the current study did not specifically tell listeners to detect or use headings in their note-taking task. The sample text included in the instruction was also very short, providing only three headings along with the relevant content information. It was likely that participants did not adopt a note-taking strategy that took advantage of the hierarchical level information provided by the Label and Voice Change conditions. Similarly, participants may also have ignored some of the emphasis information if they did not adopt a note-taking strategy that selectively attend to the information that was emphasized. The original intention of the study was to try and mimic a natural learning situation that was different from a heading detection task in order to investigate whether participants would use audio headings in such a situation. Results from Experiment 1 seem to indicate that listeners do find audio headings useful when taking notes, but they do not find extra heading rendering more useful when they are not primed to use headings.

A third possibility that could have contributed to the difference in previous findings and the current finding is the structure of the texts used. The text used in previous studies lacked a clear causal structure. Minor sections were grouped under major sections but each section was largely independent from another. The text used in this study had a clear causal structure for both the major and minor sections. Participants could have adopted a listening strategy that focused only on the causal coherence of information using just the topical information provided by headings (Trabasso, Secco & van den Broek, 1982; Trabasso & van den Broek, 1985). If listeners were able to build a coherent representation of the text using just causal inference from topical information, listeners might be less reliant on hierarchical and emphasis information provided by Label and Voice Change. The initial motivation for changing the text from one that lacked causal relation to one with strong causal relation was to promote knowledge transfer for the third learning task. Perhaps a difference would have been observed across the three heading rendering conditions if different texts were used for the different learning tasks in Experiment 1.

Although there was no difference in the performance of the note-taking task across the three heading rendering conditions, it was still possible that some type of signaling information conveyed by Voice Change rendering had an effect on participant's note-taking process. The number of pauses that participants made while taking notes provided some evidence. For the Voice Change condition, participants made significantly fewer pauses than participants in the Headings Only condition but participants in both conditions produced similarly accurate notes. Voice Change heading rendering used variations in pitch, volume, and tempo. Audio variations in these three dimensions have been widely used in the design of warning systems for airplanes and cars because these variations cause information to be very salient (Edworthy, Hellier & Rivers, 2003; Simpson & Marchionda, 1984; Zobel, 1998). It is possible that audio contrast produced by pitch, volume, and tempo variations could have served as an additional type of signaling information. The hypothesis is that this audio contrast facilitated other types of heading information in the note-taking task through the alleviation of cognitive load. There is no direct evidence that audio contrast causes cognitive load alleviation, but there is some indirect evidence from the measures of user experience. Measures of user experience show a non-significant general trend that listeners perceived lower effort, stress, and mental demand in the Voice Change condition than the Headings Only condition. Because these are self-reported measures, variability across participants could have contributed to the null effect. However, the general trend of the means is in the direction that cognitive load is lower for the Voice Change condition. Therefore, participants did not pause as many times in the Voice Change condition while listening to the audio text possibly because they had more cognitive resources to continue to listen while writing down the main ideas signaled by the headings. Participants in the Headings Only condition made 12.48 pauses on average, and this number corresponds to the 12.88 main ideas recorded in the notes. Participants in the Voice Change condition only paused 5.73 times but recorded just as many main ideas as participants in the Headings Only condition.

It is not entirely clear how audio contrast would contribute to alleviation of cognitive load. Audio contrasts in the form of pitch, volume, and tempo variations often occur in natural speech (Frazier, Carlson & Clifton, 2006). For example, a question generally ends with an increase in pitch. People of different age and gender have different voice pitch. Volume and tempo increase is often associated with mood variations in speech. This familiarity with audio contrast in everyday speech might have allowed audio contrast to require less cognitive resources when it is used to facilitate the mapping of a particular nonverbal information to a heading. In other words, audio contrast facilitates the processing of topical, demarcation, hierarchical, and emphasis heading information and consequently alleviates cognitive load.

Another possible explanation is that audio contrast increases the discriminability of heading information and thereby help focus listeners' attention. Audio contrast is often linked to the occurrence of some type of warning information, signifying importance (Edworthy, Hellier & Rivers, 2003; Simpson & Marchionda, 1984; Zobel, 1998).

Previous studies have shown that listeners in the Voice Change condition are much quicker at detecting headings and have fewer false alarm responses (Lorch et al., 2015 unpublished study). Because participants in the note-taking task were constantly making decisions about what main ideas to include in the notes, audio contrast could help disambiguate main ideas from minor ideas. Therefore, audio contrast did not necessarily helped alleviate cognitive load; rather, audio contrast helped focus participants' attention and facilitated the decision of whether to include a particular heading information or not. Audio contrast's possible effect on facilitating the processing of other types of signaling information can also be observed in participants' recall performance.

Heading rendering manipulation did not have any effect on total recall and recall of second level main ideas. The null effect for total recall is most likely contributed by the recall performance for the second level main ideas where participants' performance was virtually the same across all four conditions. There was no heading rendering effect on recall of second level main ideas possibly because there were only four main ideas at this level, and the text was probably not complex enough for headings to have any effect. Past studies have shown that headings are only useful for texts with more complex structure (Meyer, Brandt & Bluth, 1980).

Although there was no main effect for total recall and second level recall, there was a main effect for the recall of third level main ideas. There were a total of 10 third level main ideas with two or three ideas in four different sections. The complexity of the text at this level probably contributed to the main effect of heading manipulation on recall. There was a reliable difference between Voice Change and None conditions, but there was no reliable difference across None, Headings Only, and Label conditions.

There was also no reliable difference across Headings Only, Label, and Voice Change conditions. The most probable explanation for this result is that there are multiple types of nonverbal signal information that affected third level recall performance; none of the signaling information by itself was sufficient to cause better recall performance. That is, the better recall performance found between Voice Change and None conditions was caused by a combination of five types of signaling information. According to signal theory, a heading could convey several pieces of information (Lemarié et al., 2008). The Headings Only condition conveyed topical information by stating the main idea and also demarcation information by including pauses. The Label condition conveyed both pieces of information from Headings Only condition plus emphasis and hierarchical information. The Voice Change condition conveyed all four pieces of information plus it provided audio contrast in the form of pitch, volume, and tempo variation. Although audio contrast probably falls within the “emphasis” classification of signaling theory, it may communicate emphasis more effectively than a label (i.e., provide more accessible emphasis in the language of SARA). According to our hypothesis, audio contrast probably facilitated the processing of other types of signaling information either by alleviated cognitive load or focusing listeners’ attention. However, audio contrast by itself was evidently not sufficient to produce better recall because there was no difference across Voice Change, Label, and Headings Only. Topical information, demarcation, hierarchical information, and emphasis together were also not sufficient to produce better recall because there was no difference across None, Headings Only, and Label. It was only when the four types of information were conveyed in conjunction with audio contrast did we observe a reliable difference between Voice Change rendering and the None condition.

No effect of the heading rendering manipulation was observed for the knowledge transfer task. The most probable cause for this null effect is the length of the text and the scoring procedure. Unlike the text used in previous studies that contained only one section on the aerodynamic force of lift (Mautone & Mayer, 2001), the text used in Experiment 1 had a total of four sections, each with two or three minor sections. The four aerodynamic forces included in Experiment 1 were lift, thrust, weight, and drag and these four aerodynamic forces were expressed as second level headings. We had already observed, from the cued recall task, that no reliable difference was found across the four heading conditions for the recall of second level heading information. The main problem with Experiment 1's transfer task was that participants could use second level heading information to answer many of the questions. For example, one of the transfer questions asked participants to explain how ice formation on airplane's wings would affect airplane flight. In the previous study (Mautone & Mayer, 2001), participants had to answer this question by inferring that ice formation changed the curvature of the top surface of the wings because the text only contained information on the aerodynamic force of lift. However, in the current study, participants could simply answer this question by using a second level heading information. Therefore, many of the participants gave the answer that ice formation would increase the weight of the airplane, which was correct but it only showed a superficial understanding of the text that was likely not affected by the presence of headings. Just like the null effect observed for the cued recall of second level main ideas, answering the transfer questions mainly with second level heading information instead of third level heading information probably led to the null effect for the transfer task. The transfer questions should have probably been re-phrased as: “Ice formation on an airplane’s wings increased weight and drag; how does ice formation also affect the aerodynamic force of lift?” Therefore, the question should be phrased in such a way that limits the responses only to third level main ideas. Future study design should probably separate the recall and transfer tasks, and use a longer, more complex text for the recall task and a shorter, simpler text for the transfer task.

Results from Experiment 1 indicate that a combination of topical heading information, demarcation heading information, emphasis heading information, and hierarchical heading information do not produce better recall performance. It is necessary to combine audio contrast with these four types of heading information to produce a recall effect for third level main ideas. Previous studies have already shown that multiple redundant rendering types (Label + Voice Change) produce near ceiling performance in heading detection task (Lorch et al., 2015 unpublished study). It was, however, not clear if it was necessary to provide this type of redundant heading rendering because performance for Label alone and Voice Change alone was also close to ceiling. If audio contrast does serve to facilitate the processing of signaling information, then a heading rendering type that combines both Label and Voice Change should produce even better recall performance than Voice Change alone. Future research should investigate this possibility and compare recall performance across Headings Only, Label, Voice Change, and Label + Voice Change.

No effect of heading rendering was found for either of the two tasks in Experiment 2. This was most likely because participants did not adopt a listening strategy that utilized audio headings. Participants in Experiment 2 were not required to take notes, and consequently only 9% of the participants in Experiment 2 made any pauses while listening to the audio text. Future study design should provide instructions on pausing the audio text for rehearsal purposes and also provide a training session on pausing and rehearsing prior to the actual experiment.

In summary, two experiments were designed to investigate whether listeners find audio headings useful and which type of audio heading rendering is the most useful. The first experiment compared four heading rendering conditions across three learning tasks. Because previous studies suggested that note-taking could affect subsequent comprehension (Lai et al., 2000), a second experiment was designed to test the direct effect of heading manipulation on cued recall and knowledge transfer. Results from Experiment 1 showed that the presence of audio headings improved note-taking performance, but it was less clear how different types of heading rendering affected note-taking. There was some evidence indicating that audio contrast provided by Voice Change rendering led to an alleviation of cognitive load, resulting in participants making half as many pauses but produced equally accurate notes as participants in the Headings Only and Label conditions. There was not a main effect of heading manipulation on overall recall performance but there was a significant effect on the recall of third level main ideas. The effect on recall of third level main ideas was likely caused by a combination of several types of signaling information, including topic, demarcation, hierarchical organization, emphasis, and audio contrast. No effect for heading manipulation was found for the knowledge transfer task in Experiment 1. No effect for heading manipulation was found for either of the tasks in Experiment 2.

Results from this study provide evidence that audio headings are useful even in classroom-like learning situations without the need to provide much instruction or training on audio headings. It is less clear whether any type of audio heading rendering strategy is superior, but the results from this experiment does provide some evidence that heading renderings that combine two or more rendering strategies would probably yield better learning results than any single rendering strategy.

It is not always necessary for a Text-to-Speech program to provide special heading rendering. Comparing our findings across Experiment 1 and Experiment 2, it seems that listeners do not find audio headings useful when they are not actively engaged in an activity such as a note-taking task while listening to the audio text. This finding could have a few implications. First, it is probably not necessary for a TTS program to provide special heading rendering if a user is listening to a TTS generated audio text while driving a car or doing exercises. In these situations, the user is only allocating a percentage of his or her cognitive processing ability to the listening task and is much less likely to be actively building a structural representation of the text. Second, individuals enrolled in a distance learning course who take notes while studying could benefit greatly from headings that are rendered using two or more rendering strategies. The presence of audio headings in this situation could allow learners to construct a more coherent and accurate structure of the information presented.

There are three design improvements that could make the study better if the study is to be replicated in the future. These design improvements are based on the results from previous studies and the current study. First, the three learning tasks should be separated into three different experiments. This is to avoid any possible carryover or mediating effects from one learning task to the next. Second, different texts should be used for the different learning tasks. Past studies that examined audio headings had used complex texts that did not have a clear causal structure. The current study used a relatively simpler text with clear causal structure; this change in text could have accounted for much of the discrepancies between the findings from previous studies and the findings from the current study. Third, this study has already established that the presence of headings is useful at least in a note-taking task. Future studies should investigate the effect of audio headings that combine two or more rendering strategies.

The current study focuses only on the rendering of headings but there are other types of in-text signaling devices that are worth considering. An example of these would be italicized words in a paragraph. It is often not clear whether the purpose for italicizing a word is just to provide emphasis or because the author is using the word in an unconventional way. Future studies could investigate the effect of different rendering strategies for these in-text signaling devices.

APPENDICES

Appendix A: Experiment Text

<u>The Title of This Article Is: "Airplane Flight"</u>

The airplane is one of the most significant achievements of modern science. Human beings have long aspired to fly like birds. Although airplanes have dramatically changed since the time of the Wright brothers, the principles that allow airplanes to fly have not changed. In this article, we will discuss the forces that allow airplanes to fly and the ways that engineers have designed airplanes to conquer the principles of flight.

OVERCOMING THE FORCES THAT RESIST FLIGHT

Let's begin by considering the forces that make it difficult for airplanes to achieve flight.

How To Overcome The Force Of Weight

The most obvious force that must be overcome to achieve flight is the weight of the airplane itself. Modern commercial aircraft weigh hundreds of tons. Yet the weight of a well-designed airplane is kept to a minimum in two main ways.

<u>Structure: Use A Strong Skeletal Structure For The Body</u>

Engineers build the body of an aircraft in several steps that are designed to create a structure that is hollow and light yet durable. First, a series of circular metal rings linked by long metal rods are installed along the length of the body. This skeletal structure is then covered by a sheet of metal skin to protect the skeletal structure. This construction allows the airplane's body to be durable while using minimum amount of material.

<u>Material: Use Body Material That Is Light</u>

The first airplanes were built with a relatively heavy wooden skeletal structure. Modern airplanes are built with a combination of aluminum alloy and carbon fiber. These materials are lighter than wood but much more durable.

How To Overcome The Force of Drag

The Earth's atmosphere has a density that resists the movement of objects through it. This resistance is called "drag" and it is the other force that engineers must keep in mind. A well-designed airplane will include design details that minimize drag.

<u>Nose Cone Design: Use A Rounded Nose Cone That Directs Air Flow</u>

Most commercial airplanes have a rounded nose cone attached to its cylindrical body. The rounded nose cone keeps the air flow attached to the plane. Having air flow attached to the plane reduces drag and leads to a more fuel efficient flight.

Outer Coating: Use A Nanoparticle Coating That Reduces Surface Friction

The smoother a surface, the less friction that occurs when air passes over it so engineers do all that they can to make the surface of an airplane as smooth as possible. Most modern airplanes are coated with a special type of paint that contains nanoparticles. These nanoparticles are able to fill even the tiniest uneven part of the surface and prevent adherence of dirt and other contaminants. This nanoparticle coating allows the exterior of the plane to remain extremely smooth and thereby reduces surface friction.

GENERATING THE FORCES THAT SUPPORT FLIGHT

Having considered the forces that must be overcome to achieve flight, let's turn to a consideration of the aerodynamic forces that support flight.

How To Generate The Force of Thrust

Thrust is the force that opposes drag. In order for a plane to move forward, the net thrust generated by the plane's engines must be greater than the drag on the plane. To understand how an airplane's engine achieves forward thrust, you need to focus on the different parts of an airplane's engine.

Compressor: Air Is Pressurized By The Compressor

The first step in generating an airplane's thrust is achieved by the compressor located at the front of each engine on the plane's wing. The compressor consists of a cone-shaped cylinder of blades that are designed to suck air into the engine compartment. The compressor sucks in so much air at such a rapid rate that it squeezes a tremendous amount of air into the relatively small space of the engine compartment. This results in highly pressurized air that is highly combustible.

Combustion Chamber: Fuel Is Injected Into The Combustion Chamber To Create Combustion

Behind the compressor in the middle part of the engine is a ring of fuel injectors that send a steady stream of fuel to the pressurized air. This causes the pressurized air to ignite. The heated air and fuel creates even more pressure inside the engine.

Exhaust: The Flaming Air Passes Through The Turbine And Nozzle

Finally, the ignited gas in the combustion chamber is expelled out the back of the engine compartment. As the ignited gas exits the engine compartment, it spins a set of turbines located at the back of the jet engine. The set of turbines converts the heat and pressure from the ignited gas into energy. The flaming air exits through nozzles that are designed to squeeze the fuel mixture still further. This causes air to accelerate even faster as it exits the engine. Because the air exiting the plane's engine is moving much faster than the air entering the engines, tremendous thrust is generated and the plane moves forward.

How To Generate The Force of Lift

Of course, an airplane must do more than move forward. It must elevate into the air. The aerodynamic principle of "lift" explains how a plane overcomes its weight to become airborne. To understand how lift works, you need to understand the design of an airplane's wing.

Wing Shape: Curved Upper Surface is Longer

All wings share a common, critical property: The upper surface of the wing is curved more than the bottom surface. Because it is curved, the top surface of the wing is longer than the bottom surface of the wing. This property is essential to achieving lift.

Air Flow: Air Moves Faster Across Top of the Wing

When an airplane is in flight, air hitting the front of the wing separates. Some air flows over the wing and some flows under the wing. The air flowing over the top of the wing has a longer distance to travel in the same amount of time. Because of the curvature of the wing, air traveling over the curved top of the wing flows faster than the air that flows under the bottom of the wing.

Air Pressure: Pressure is Less on the Top of the Wing

Because the air flowing over the top of the wing is moving faster than the air flowing under the wing, it gets more "spread out." This means that the top surface of the wing has less pressure exerted against it than the bottom surface of the wing. Or to say it the other way around: There is more upwards force on the bottom surface of the wing than there is downwards force on the top surface of the wing. As a result, there is a net upward force on the wing, thus creating a lift.

We speak of "the miracle of flight" but, in fact, we understand how the miracle works.

THE END

Appendix B: Recall Scoring Rubric

1. List all the aerodynamic forces discussed in this article that allow airplanes to achieve flight? (4 points)
- Thrust, lift, drag, and weight (verbatim answers are required)

2. Which of the forces mentioned above aid the flight process and which of the forces resist the flight process? (2 points)
- Thrust and lift aid flight
- Drag and weight inhibit flight

3. List all of the main compartments of an airplane AND briefly describe the function of each main compartment of the airplane's engine. (6 points)
- **Compressor** pressurizes the air
- **Combustion chamber** ignites the air to create hot flaming air
- **Exhaust** expels the hot flaming air through turbine and nozzle to create thrust force

4. List and explain all the ways in of the airplane's wings allow for the airplane to fly? (3 points)
- The upper surface of an airplane's wing is curved
- Air flows faster across the top of wings compared to the bottom of the wings
- Air pressure on the top of wings is less compared to the bottom of the wings.

5. Briefly describe how each difference in the airplane's wings helps an airplane fly. (3 points)
- The curved upper surface is longer than the bottom surface of the wing
- Since the upper surface is longer, air has to travel faster at the top compared to the bottom of the surface.
- The air at the top of surface moves faster and the air moles get more spread out. This results in lower pressure at the top of the wings.

6. How do engineers decrease the overall gravitational force exerted on the plane's body? (4 points)
- By constructing the fuselage/body of the airplane using a skeletal frame (metal ring formers and stringers), and then cover it with a layer of thin metal (skin).
- The material used in construction of airplane should be light, usually aluminum alloy or carbon fiber.

7. How do aircraft designers decrease any force that opposes thrust? (4 points)
- By focusing on the geometry of the body and having a cone-shaped nose.
- By coating the surface of the plane using paint that contains nanoparticles.

Appendix C: Transfer Scoring Rubric

1. How could an airplane be designed to achieve lift more rapidly?
- Curve the top surface of the wing more (also, increase the surface area of the top of wing, or make the top of the wing longer),
- Flatten the bottom of the wing more (also, decrease the surface area of the bottom of the wing, or make the bottom of the wing shorter)
- Increase the air speed over the top of wing
- Decrease the airspeed under the bottom of wing
- Lower the pressure on the top of the wing
- Increase the pressure under the wing
- Increase the dispersion of air above the wing
- Concentrate more air under the bottom of the wing.

2. How could an airplane be designed to fly faster?
- Use fuel that could generate more combustion
- Try to increase the temperature within the combustion chamber
- Decrease nozzle size so that air flows out of the exhaust faster
- Use more efficient turbines that could convert air flow into thrust more efficiently
- Use a compressor that pressurizes the inlet air more than existing engine
- Use a bigger engine (with bigger inlet) that takes in more air

3. Suppose ice forms on the wing of an airplane. How does that affect its ability to achieve lift?"
- It increases curvature (or surface area, or length) of the bottom surface of the wing, or decreases it for the top of the wing.
- It slows down the air on top or increases speed on the bottom of the wing.

4. Supposed that a new type of fuel is used that causes much greater combustion than the traditional fuel. How would this affect an airplane's engine and the airplane's velocity?
- The greater combustion will increase the temperature in the combustion chamber
- The greater combustion will increase the pressure in the combustion chamber
- Higher temperature and pressure in the combustion chamber could reduce engine lifespan
- Higher temperature and pressure could also generate greater thrust force and airplane velocity

5. Pretend that beings on another planet have seen our version of an airplane and decide to try to design one themselves. They are able to get the plane to taxi down a runway, but it doesn't take off. What are some reasons to explain why the plane doesn't leave the ground?
- Not enough lift is generated because
  i. the top surface was too short or the bottom surface too long
  ii. the pressure on the top was too great or the pressure on the bottom was not great enough.

6. Pretend that beings on another planet have seen our version of an airplane and decide to try to design one themselves. They are able to get the planes to fly but they fly at extremely slow speed. What are some reasons why the plane is slow?

- Not enough thrust force is generated because

i. They used a type of fuel that doesn't create enough combustion
ii. Their atmosphere is really thick and causes a lot of drag
iii. They forgot to design the engine so that the nozzle is smaller than the inlet and air doesn't accelerate through the engine
iv. The compressor does not create enough air pressure

7. Using what you've learned about how airplanes achieve lift, explain how helicopters achieve lift

- Helicopters' main rotor has blades that are shaped similar to commercial planes to achieve lift

i. The top surface of the blade is more curved or the bottom is flatter than the top
ii. The air over the top of the blades flows faster than the air under the blades

8. What are some critical differences between the design of a rocket engine (that will fly into space) and a jet engine?

- A rocket engine will need to fly into space where there is a lack of oxygen. Therefore

i. A rocket engine might need to carry its own oxygen to create combustion
ii. A rocket engine could use a different type of energy source (solar or nuclear?) to generate thrust force
iii. It might not be necessary to have an inlet compressor since there will be no inlet air.

9. Ailerons are flaps on the rear edge of an airplane wing which the pilot can move up or down. Explain how ailerons affect a plane's altitude.

- Ailerons affect a plane's altitude mainly by controlling the pressure difference between the top and bottom of the wing. This is achieved by:

i. Changes in the shape/length of the top or bottom of the wing
ii. Ailerons causes the air traveling faster or slower above or below the wing
iii. Ailerons causes increased pressure above the wing, or decreased pressure below the wing. or vice versa (depending on the position of the aileron).

10. For an airplane flying at constant speed, is the air blowing out of the engines moving faster, slower, or at the same speed as the plane itself?

- The air blowing out of the engine is moving faster than the plane itself. The net thrust force will need to be greater than the drag force in order for the plane to move forward at all.

Appendix D: Notes Scoring Rubric

OVERCOMING THE FORCES THAT RESIST FLIGHT Y / N
Heading Level _______
Number of words used to express the heading idea ________

How To Overcome The Force Of Weight Y / N
Heading Level _______
Number of words ________

Structure: Use A Strong Skeletal Structure For The Body Y / N
Heading Level _______
Number of words ________

Material: Use Body Material That Is Light Y / N
Heading Level _______
Number of words ________

How To Overcome The Force of Drag Y / N
Heading Level _______
Number of words ________

Nose Cone Design: Use A Rounded Nose Cone That Directs Air Flow Y / N
Heading Level _______
Number of words ________

Outer Coating: Use A Nanoparticle Coating That Reduces Surface Friction Y / N
Heading Level _______
Number of words ________

GENERATING THE FORCES THAT SUPPORT FLIGHT Y / N
Heading Level _______
Number of words ________

How To Generate The Force of Thrust Y / N
Heading Level _______
Number of words ________

Compressor: Air Is Pressurized By The Compressor Y / N
Heading Level _______
Number of words ________

Combustion Chamber: Fuel Is Injected Into The Combustion Chamber To Create Combustion Y / N
Heading Level _______
Number of words ________

Exhaust: The Flaming Air Passes Through The Turbine And Nozzle Y / N
Heading Level _______
Number of words ________

How To Generate The Force of Lift Y / N
Heading Level _______
Number of words ________

Wing Shape: Curved Upper Surface is Longer Y / N
Heading Level _______
Number of words ________

Air Flow: Air Moves Faster Across Top of the Wing Y / N
Heading Level _______
Number of words ________

Air Pressure: Pressure is Less on the Top of the Wing Y / N
Heading Level _______
Number of words ________

Total number of words in notes _______

Number of diagrams _______

Appendix E: Questionnaire on User Experience and Prior Knowledge

1. How mentally demanding was the listening task?

   0=Not at all
   100= Extremely demanding

2. How do you think you did?

   0=Extremely poorly
   100=Extremely well

3. How hard did you feel like you had to work to achieve this level of performance?

   0=Did not have to work hard at all
   100=Had to work extremely hard

4. How irritated, annoyed, or stressed were you while listening to the text?
   0=I felt really calm and peaceful
   100=I was extremely frustrated and stressed

5. How many Physics courses have you taken, either in college or high school?

6. How many Engineering courses have you taken, either in college of high school?

7. Are you generally interested in machine mechanics before this experiment?

8. What is your level of knowledge (before listening to this text) about the mechanics of airplane flight? (None, Little, Some, A Lot, Expert)

9. What is your level of knowledge (before listening to this text) about engines in general? (None, Little, Some, A Lot, Expert)

10. Approximately how many times have you been on an airplane? (Never, 1-5, 6-10, 11-20, 20

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H-T. Michael Chen

Curriculum Vitae

EDUCATION

2015 Ph. D. Experimental (Cognitive) Psychology, University of Kentucky (expected)
Dissertation: Effects of Text-to-Speech Rendering Strategies on Learning
Advisor: Robert F. Lorch, Ph. D.

2011 M.S. Experimental Psychology, University of Kentucky
Thesis: Reader's Knowledge of Functional Devices
Advisor: Robert F. Lorch, Ph. D.

2006 B.A. Biology, Berea College
Cum Laude

CERTIFICATES

2013 Applied Statistics

2011 College Teaching and Learning (Preparing Future Faculty)

TEACHING EXPERIENCE

Spring 2015 Teaching Assistant, Department of Psychology, University of Kentucky
General Psychology (Online lab design)

Fall 2014 Teaching Assistant, Department of Psychology, University of Kentucky
Research Methods

Summer 2014 Instructor, Department of Psychology, University of Kentucky
Learning and Cognition (Online)

Summer 2014 Course Developer, College of Arts & Science, University of Kentucky
Research Method Tools (Online)

Fall 2013	Instructor, Department of Psychology, Eastern Kentucky University General Psychology (2 sections)
Summer 2012	Teaching Assistant, Department of Psychology, University of Kentucky Learning and Cognition (Online)
Fall 2011	Instructor, Department of Psychology, Berea College General Psychology
Fall 2011	Teaching Assistant, Department of Psychology, University of Kentucky General Psychology (Online)
Fall & Spring 2009	Teaching Assistant, Department of Psychology, University of Kentucky Statistics

PUBLICATIONS

Lorch, R. F., Lemarié, J. & Chen, H-T. (2013). Signaling topic structure via headings or preview sentences. *Psicologia Educativa 19*, 59-66.

Lorch, R. F., Chen, H-T. & Lemarié, J. (2012). Communicating headings and preview sentences in text and speech. *Journal of Experimental Psychology: Applied, 18*(3), 265.

MANUSCRIPTS IN PREPARATION

Lorch, R. F., Chen, H-T. & Lemarié, J. (2015). Communicating Printed Heading Information to the Ear. [Manuscript submitted for publication]

Chen, H-T. & Lorch, R.F. Readers' knowledge and use of functional devices during reading.

Chen, H-T. Superstructure and its effect on reading.

CONFERENCE PRESENTATIONS

Chen, H.-T., Lorch, R. F. (2014, May). Communication of Headings by Text-to-Speech Software. Poster session presented at the *2014 Conference on Language, Discourse, and Cognition*, Taipei, Taiwan.

Chen, H.-T., Lorch, R. F., Chow, J., Carter, N., Crispin, R. (2011, March). Effects of Signals on Outlining. Poster session presented at the *2011 Kentucky Psychological Association Foundation Spring Academic Conference*, Frankfort, KY.

Chen, H.-T., Lorch, R. F., Chow, J., Carter, N., Crispin, R. (2011, May). Effects of Signals on Outlining. Poster session presented at the *2011 Midwestern Psychology Association Annual Conference*, Chicago, IL.

Lorch R., Chen H.-T., Chow J., Carter N., Crispin R. (2011, July). Effects on Outlining of Signaling Topics in Printed and Spoken Texts. Poster session presented at the *Annual Meeting of the Society for Text & Discourse*, Poitiers, France.

Freer, B., Dunlap E. E., Koslaski, J. S., Chen, H.-T., Calderhead W., Lorch, E. P., Lorch, R.F., (2011, April) Very Long-Term Effects of Teaching the Control of Variables Strategy in High and Low Achieving 4th Grade Classrooms. Poster session presented at the *Biennial Meeting of the Society for Research in Child Development*, Montreal, Quebec, Canada.

Koslaski, J. S., Chen, H.-T., Freer, B., Dunlap E. E., Calderhead W., Lorch, E. P., Lorch, R.F., (2011, April) Effects of Variable Complexity and Planning Support on 4th Graders' Acquisition of the Control of Variables Strategy. Poster session presented at the *Biennial Meeting of the Society for Research in Child Development*, Montreal, Quebec, Canada.

RESEARCH EXPERIENCE

2010-Present Project and Research Lab Manager, Department of Psychology, University of Kentucky
Signal rendering in Text-to-Speech programs.
Supervisor: Dr. Robert F. Lorch, Ph.D.

2011-Present Research Assistant, Department of Psychology, University of Kentucky
Eye Movements in Reading (Eye-Tracking)
Supervisor: Dr. Robert F. Lorch, Ph.D.

2009-2011	Research Assistant, Department of Psychology, University of Kentucky Control Variable Strategy for Fourth Grade Science Education Supervisor: Dr. Robert F. Lorch, Ph.D.

PROFESSIONAL EXPERIENCE

Summer 2014	Instructional Designer, College of Arts & Science, University of Kentucky
Summer 2011-2012	Instructional Designer, College of Arts & Science, University of Kentucky
Spring 2012	Visiting Scholar, Université de Toulouse II - Le Mirail
2007-2009	Civil Service, Ministry of Education, Taiwan National Distinguished Civil Serviceman

AWARDS & FUNDING

2015	Make A Difference Award, University of Kentucky Psychology Department
2014	Student Travel Support Award, University of Kentucky Graduate School
2011	Student Travel Support Award, University of Kentucky Graduate School
2004	Phi Kappa Phi, Berea College

DEPARTMENTAL SERVICE

2014-2015	Graduate student executive committee representative
2012-2013	Student representative in departmental faculty meeting

LANGUAGES

English	Bilingual fluency in speaking, reading, and writing
Chinese	Bilingual fluency in speaking, reading, and writing

PROFESSIONAL MEMBERSHIPS

Human Factors and Ergonomics Society
Society for the Teaching of Psychology