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# Learning from science lectures : students remember more and make better inferences when they complete skeletal outlines compared to other guided notes.

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# LEARNING FROM SCIENCE LECTURES: STUDENTS REMEMBER MORE AND MAKE BETTER INFERENCES WHEN THEY COMPLETE SKELETAL OUTLINES COMPARED TO OTHER GUIDED NOTES

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July 14, 2016

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DEDICATION

"The good life is one inspired by love and guided by knowledge." – Bertrand Russell

I pursued a Ph.D. because I had a thirst for acquiring and producing knowledge. Without question, this knowledge has helped shape me into the person I am today – arguably a better version of myself relative to when I began this journey. While knowledge is important, close relationships are paramount. The love, support, and encouragement of my family and friends made the entire Ph.D. journey a much more meaningful and fulfilling experience.

To my best friend and beautiful wife, Maggie, I am humbled by your extraordinary commitment to think of me before yourself. Thank you for uprooting your life to Kentucky, allowing me to work long hours even when it was inconvenient for you, and patiently listening to my "nerd rants" regarding my research projects. To my courageous son, Henry, you approach every day as an adventure full of learning opportunities. Thank you for inspiring me to continually improve both as a person and a professional. Everything is better when both of you are a part of it and I am delighted to dedicate this dissertation to you. Thank you for being part of my "good life."

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ABSTRACT

LEARNING FROM SCIENCE LECTURES: STUDENTS REMEMBER MORE AND MAKE BETTER INFERENCES WHEN THEY COMPLETE SKELETAL OUTLINES COMPARED TO OTHER GUIDED NOTES

David Bradley Bellinger

July 14, 2016

It is common for students to take notes during lectures, but the accuracy and completeness of these notes is highly questionable. Therefore, instructors must make an important decision – should they provide their students with lecture notes? If so, how complete should the notes be and in what format? The present experiments examined how note format and degree of support impacted the encoding benefit of note-taking. In Experiment 1, undergraduate students listened to brief audio-recorded science lectures (Human blood, $N = 42$; Human ear, $N = 36$) and completed skeletal outlines (requiring students to conceptually organize the information using the structure indicated by the notes) or cloze notes (requiring students to record key words that were deleted from the notes). In Experiment 2, students ($N = 120$) completed outlines or cloze notes with varying degrees of support, thus providing students with more or less complete notes. Both experiments found that, compared to other guided notes, completing skeletal outlines (i.e., outlines with minimal support) led to the highest cognitive load and the least complete notes, but also the most accurate free recall and inference responses.

Consistent with the material appropriate processing framework, the mnemonic benefits derived from completing guided notes were constrained to notes that induce a type of semantic processing which complements that afforded by the lecture.

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# CHAPTER I

# INTRODUCTION

Lecturing is perhaps the oldest and most frequently used teaching method in higher education (Svinicki & McKeachie, 2011). A survey administered by the National Center for Education Statistics revealed that 83% of undergraduate faculty used "lecture/discussion" as their primary instructional method (Chen, 2002). As a result, many students choose to take notes in their classes (Van Meter, Yokoi, & Pressley, 1994), even without being instructed to do so (Williams & Eggert, 2002), because they believe it will help them learn the information (Dunkel & Davy, 1989). Unfortunately, despite the prevalent use of both lecture and note-taking, research examining the learning benefits of lecture note-taking has produced inconsistent results.

The goal of this project was to examine factors that may help explain the mnemonic benefits of lecture note-taking. The two explanatory mechanisms of interest were the format of the notes and the degree of support provided by the notes. The effects of these mechanisms on students' cognitive load, metacognitive ratings, free recall, and short answer accuracy were examined.

## How does lecture note-taking impact learning?

It is generally accepted that note-taking can facilitate learning at two time points: while initially taking the notes (encoding benefit) and while reviewing the notes at a later time (external storage benefit; DiVesta & Gray, 1972). The current project focused on the former; strategies for the latter (e.g., spaced retrieval practice) are well documented (e.g., Karpicke & Roediger, 2010). Given the ubiquitous use of note-taking as a learning strategy, it is surprising that systematic reviews find that the benefits of note-taking are minimal. One meta-analysis revealed that note-taking only produced a slight encoding benefit relative to no note-taking ($d = .26$; Kobayashi, 2005), whereas another review revealed a clear lack of consensus for the encoding benefit of note-taking (Kiewra, 1985a). Specifically, an encoding benefit was found in 33 out of 56 studies (59%), meaning that a sizable number of studies found no differences (21 studies; 37%) or a detrimental effect (2 studies; 4%) of note-taking.

To account for these inconsistent results, it may be necessary to examine the cognitive processes that note-taking induces more closely. Note-taking can be conceptualized as a generative learning activity that influences the way in which the information is encoded in memory (Peper & Mayer, 1978). In fact, several authors have posited that the act of taking notes stimulates the learner to actively process the information being presented (e.g., Bretzing & Kulhavy, 1979; Einstein, Morris, & Smith, 1985; Peper & Mayer, 1978). Although active processing is typically viewed as beneficial to learning, this description only provides a general, high-level explanation for the mnemonic benefits of note-taking. The active processing view is too simplistic and incomplete, because some studies examining students' notes have established that students commonly attempt to take verbatim notes (e.g., Bretzing & Kulhavy, 1981; Kiewra, 1985a) and thus bypass some aspects of active processing (e.g., organization or elaboration).

In the context of learning from a lecture, the active-passive continuum may be characterized with the active end represented by note-taking in various forms, and the passive end represented by simply listening to the lecture without mentally elaborating on the information. The active end may then be further classified according to the type of processing induced by the note-taking format, meaning that active processing can take multiple forms (e.g., item-specific versus relational processing; Einstein & Hunt, 1980). This more nuanced view of active processing may partially account for the inconsistent effects of note-taking on test performance. If different note-taking formats induce qualitatively different cognitive processes, then demonstrating the benefits of note-taking will depend upon interactions with other variables. The current project investigated two variables in the context of a descriptive lecture (i.e., the to-be-learned material), based on Jenkins' (1979) tetrahedral model of memory experiments: the encoding task (i.e., note-taking format) and the amount of support provided during the encoding task (i.e., less or more). The effects of these factors were examined on several memory measures (i.e., free recall, verbatim short answer questions, and inference short answer questions).

**Guiding theoretical principles**

There is no agreed upon theory to explain the mnemonic benefits of note-taking. However, a few theoretical principles from cognitive and educational psychology appear promising to help explain when note-taking will and will not facilitate memory of lecture content. First, as explained by the generation effect (Slamecka & Graf, 1978), self-generated information is better remembered than being provided (via reading or listening) the same information. This principle implies that students should benefit more from creating their own lecture notes compared to simply listening to a lecture or receiving complete notes (which they can passively read) from a peer or the instructor. Importantly, the act of generating the notes increases the difficulty of initial learning, but this difficulty appears to facilitate the retention of the to-be-learned information and thus can be labeled a "desirable difficulty" (Bjork & Bjork, 2011).

Second, as proposed by cognitive load theory (e.g., Chandler & Sweller, 1991), students' limited working memory resources should be allocated to relevant processing that promotes learning. If the student's cognitive resources are overloaded, learning is hindered. Note-taking is a complex cognitive task, which is highly demanding of working memory resources (Bui & Myerson, 2014; Bui, Myerson, & Hale, 2013; Piolat, Olive, & Kellogg, 2005). Because the act of taking notes requires students to hold onto information in memory while recording other information, the student is essentially multi-tasking, which is highly dependent upon working memory resources (Engle, Tuholski, Laughlin, & Conway, 1999).

Third, extracting meaning via semantic processing is enhanced when multiple aspects of the information are encoded compared to encoding a single aspect of the information (encoding variability; Estes, 1950; Huff & Bodner, 2014; Martin, 1968). Building on the levels-of-processing framework (Craik & Lockhart, 1972; Craik & Tulving, 1975), it is assumed that we automatically process incoming information on a variety of levels, and our attention can be intentionally directed toward the different levels. Hunt and Einstein (1981) distinguished between two types of semantic ("deep") processing: item-specific and relational processing. Item-specific processing focuses on distinctive features of the information, whereas relational processing focuses on information that organizes and connects the various ideas. Importantly, the information that is encoded in memory corresponds to the type of processing (i.e., item-specific or relational) in which the student engages and, according to encoding variability, memory is optimized when the student encodes multiple aspects of the information. Building on this early work, Hunt (2003, 2013) developed a theory of distinctive processing to explain memory performance, which is achieved by processing both item-specific and relational information.

In the laboratory, two popular encoding tasks used to learn prose are letter insertion and sentence sorting. The letter insertion task involves providing learners with a passage in which some letters have been deleted and replaced with blanks, and learners are asked to write a letter above each blank to complete the words as they read. This task is thought to induce the learner to focus on individual words, propositions, or ideas (Einstein, McDaniel, Bowers, & Stevens, 1984). In support of this idea, research using word lists (Einstein & Hunt, 1980; Hunt & Einstein, 1981) demonstrated that letter insertion improved recognition of target words among distractor words (i.e., a measure of item-specific processing).

In contrast, the sentence sorting task involves providing learners with a passage in which the sentences have been randomly scrambled, and learners are asked to reorder the sentences so that the passage makes sense. The sentence sorting task has been likened to a category sorting task that is often used with word lists (McDaniel & Einstein, 2005). The category sorting task has been shown to lead to higher clustering scores (i.e., a measure of relational processing) during recall of unrelated word lists (Einstein & Hunt, 1980; Hunt & Einstein, 1981). Thus, it is assumed that the sentence sorting task also induces the learner to focus on the relationships between sentences, propositions, or ideas

(Einstein et al., 1984). Consistent with the encoding variability principle, when students completed both item-specific and relational processing tasks while learning a list of related words, free recall was enhanced relative to performing either type of task twice (Hunt & Einstein, 1981).

Similar to how different encoding tasks induce qualitatively different types of semantic processing, the type of prose being learned differs in the degree to which the material affords item-specific or relational processing. Two commonly studied types of prose are descriptive (e.g., expository) and narrative (e.g., fairy tale) texts. Descriptive passages typically present independent facts, and readers often remain unaware of the underlying structure of the text (Cook & Mayer, 1988). Importantly, because students do not use the underlying structure of the passage as an organizational framework for understanding the information, they tend to treat the to-be-learned information as a list of independent facts (Mayer, 1985, 1987; as cited in Cook & Mayer, 1988). In fact, studies utilizing unrelated word lists have found that when the learner is not aware of any underlying relationship between the words, the learner's individual word recognition scores (i.e., a measure of item-specific processing) are much higher relative to their clustering scores (i.e., a measure of relational processing) (Einstein & Hunt, 1980; Hunt & Einstein, 1981). On the other hand, narratives present a series of interdependent ideas that are linked together, thus providing a more explicit underlying structure. This awareness of the text structure helps the learner build a mental representation (schema) of how the individual ideas relate to one another. Similarly, when the relationships between items in a word list are clear, clustering scores are enhanced (Einstein & Hunt, 1980; Hunt & Einstein, 1981).

To add clarity regarding specific processing mechanisms underlying encoding variability, two appropriate processing frameworks may be considered: material appropriate processing (MAP; McDaniel & Einstein, 1989) and transfer appropriate processing (TAP; Morris, Bransford, & Franks, 1977). According to MAP, memory is enhanced when the type of processing induced by the encoding task complements the type of processing afforded by the learning material. Applying this idea to text passages, if narratives (which afford relational processing) are encoded using a letter insertion task (which induces item-specific processing) and descriptive texts (which afford item-specific processing) are encoded using a sentence sorting task (which induces relational processing), then memory performance will be maximized. According to TAP, memory is enhanced when the type of processing induced by the encoding task is congruent with the type of processing required by a retrieval event (e.g., on a test). For example, item-specific processing is required to answer test questions that target independent facts from a text passage. Therefore, performance on these test questions is enhanced if the encoding task orients the student toward item-specific processing (e.g., letter insertion). Critically, achieving MAP supports the goal of encoding variability and simultaneously increases the likelihood of TAP, because both item-specific and relational processing has occurred (Bellinger & DeCaro, 2015).

The MAP and TAP principles were established using basic laboratory materials (i.e., word lists; e.g., Einstein & Hunt, 1980; Morris et al., 1977) and have subsequently been applied to more educationally relevant materials (i.e., text passages; e.g., Einstein et al., 1984; Einstein, McDaniel, Owen, & Cote, 1990; McDaniel, Einstein, Dunay, & Cobb, 1986; Thomas & McDaniel, 2007). The current project further extended these principles to understand the mnemonic benefits of lecture note-taking. Based on the MAP and TAP frameworks, the note-taking strategy that will most benefit memory depends upon the type of processing afforded by the lecture and the type of information the student will need to retrieve at a later time (e.g., on a test).

In summary, three guiding principles may help explain why note-taking benefits learning. Memory is enhanced when students generate information relative to receiving the same information (generation effect) and when students encode multiple aspects of the information such as both item-specific and relational processing relative to only one aspect (encoding variability; MAP). An important moderator of memory is the amount of cognitive load experienced during encoding, such that higher levels of cognitive load can hinder learning whereas lower levels do not (cognitive load). When all three principles are considered in concert, one can make novel predictions about when lecture note-taking will benefit learning and when it will not.

**Mapping guiding principles onto popular note-taking formats and manipulations**

Traditionally, science instructors deliver informationally-dense lectures, and students are responsible for taking notes in their preferred format. Regardless of the format, student-generated lecture notes are thought to induce high cognitive load and may hinder learning due to the unavailability of working memory resources (Bui & Myerson, 2014; Bui et al., 2013; Piolat et al., 2005). This problem is further compounded because the lecture content typically includes a large amount of detailed information.

In an effort to minimize the cognitive load associated with note-taking, some instructors elect to provide their students with complete lecture notes to serve as a learning aid. Instructor-provided lecture notes are more accurate and complete than student-created notes, and the use of instructor-provided notes is associated with better exam performance (e.g., Armbruster, 2009; Kiewra, 1985b). By freeing students from recording the lecture content, they are able to reallocate their working memory resources to engage in more semantic processing; students also participate more during the lecture by asking and answering questions (Austin, Lee, Thibeault, Carr, & Bailey, 2002). The downside of complete instructor-provided notes, however, is that students may be less likely to attend lectures (e.g., Cornelius & Owen-DeSchryver, 2008). Also, some students may not automatically engage in generative processing, despite the support provided by the instructor.

To counter these concerns, some instructors have adopted a modified approach: provide students with guided, but incomplete, notes. These notes typically take one of two formats: cloze notes and skeletal outlines (Boyle, 2012). Cloze notes include the majority of the lecture content, but essential words are replaced with a blank space and require students to fill in the missing words as they listen to the lecture. Skeletal outlines, on the other hand, provide students with an organizational framework for the lecture, requiring students to fill in the main and/or supporting ideas as they listen to the lecture.

These two note formats are similar in that they are both intended to reduce the cognitive load relative to students generating notes without guidance from the instructor, because the majority of the cognitive demand of recording the lecture content is offloaded to the instructor-provided notes. However, these two note formats should encourage qualitatively different types of semantic processing. Specifically, both cloze notes and a letter-insertion prose manipulation (discussed above) require the student to fill in some missing information as they learn the material, so it is likely that both of these tasks induce item-specific processing. The skeletal outline has been shown to mirror the effects of a sentence sorting prose manipulation (discussed above), so it is likely that both of these tasks induce relational processing (Einstein et al., 1990).

**Current experiments**

The current experiments examined two potential explanatory mechanisms of the encoding benefit of note-taking during a lecture: note format and degree of support. First, it is plausible that different note formats can induce qualitatively different types of semantic processing. Therefore, note-taking may be an ecologically-valid method of achieving MAP when learning from lectures. Second, when guided notes are made accessible to students, they can provide varying degrees of support based on how much information is provided to the student. Instructor-provided learning aids were created by crossing these two factors to produce four versions of guided notes (see Figure 1).

| | | **Degree of Support** | |
|---|---|---|---|
| | | Less (100% of idea units incomplete) | More (50% of idea units incomplete) |
| **Note Format** | Cloze | Less Support Cloze | More Support Cloze |
| | Outline | Less Support (Skeletal) Outline | More Support Outline |

Figure 1. Four guided note-taking conditions created by the factorial combination of the two note-taking formats and the two levels of support.

It is important to note that a couple of oversimplifications are adopted within this paper, and the MAP literature more broadly, to facilitate ease of exposition. First, science prose (e.g., text passage or lecture) can be descriptive or narrative depending on how the information is conveyed. Furthermore, a single textbook chapter or lecture can oscillate between both types of prose, suggesting that they can be fluidly combined. In laboratory research, internal validity is increased by strategically selecting learning materials that adhere to one type of prose or the other. In the current experiments, the brief lectures are predominantly descriptive in nature and thus the term science lecture is equated with descriptive prose.

Second, science prose contains both item-specific and relational information. One could speculate that the type of information students attend to likely depends on characteristics of the lecture (e.g., speed of presentation, amount of unfamiliar jargon, use of cue words to highlight the underlying structure, informational density) as well as the prior knowledge of the student. Specifically, more difficult lectures and lacking prior knowledge may encourage students to favor processing of the item-specific information, whereas easier lectures and more expertise may allow students to process the relational information or flexibly alternate between item-specific and relational information.

As mentioned earlier, Cook and Mayer (1988) listed five common underlying structures for science prose (i.e., the structure refers to the organization of the information which can be represented as an outline, thus indicating how the ideas are connected – in other words, the structure provides relational information) and found that students struggled to identify these structures. This is consistent with the preponderance of evidence in the MAP literature, which suggests that the item-specific aspect of descriptive prose tends to be more salient for novice students. As a result, the complementary relational information is obscured from being processed, and thus not learned, unless the student's attention is directed to that aspect of the information (e.g., via guided notes). Therefore, in the current experiments, science lectures are assumed to primarily afford item-specific processing even though relational information is also present. The purpose of selecting an encoding task that achieves MAP is to help students attend to information that is present within the learning material, but that they do not automatically process (McDaniel & Einstein, 1989).

As indicated above, predicting memory performance requires knowledge of the type of semantic processing required by the lecture, note-taking format, and type of memory test. Both of the current experiments employed descriptive lectures, which should afford item-specific processing. As for note format, cloze notes should induce item-specific processing, whereas outline notes should induce relational processing. Finally, three measures of memory performance were utilized: free recall as well as verbatim and inference short answer questions. Because free recall relies on both item-specific and relational processing, accuracy is enhanced when both types of processing occur during encoding (e.g., Einstein & Hunt, 1980; Einstein et al., 1984; Hunt & Einstein, 1981). Furthermore, verbatim and inference short answer questions should require item-specific and relational processing, respectively.

The interaction between the type of processing afforded by the lecture and induced by the note format determines whether MAP is absent or present. Because the lecture affords item-specific processing, MAP is achieved by completing outline notes. Therefore, students who complete cloze notes will only engage in item-specific processing because both the lecture and note format encourage it. Students who complete outline notes, however, will engage in item-specific processing due to the lecture and relational processing due to the note format. This leads to different predictions for the memory tests.

Specifically, students who complete cloze notes will perform well on verbatim short answer questions because TAP is present. Conversely, these students are not expected to perform well during free recall or on inference questions because these rely on relational processing, which these students did not experience. In contrast, students who complete outline notes will perform well on all three memory tests because they engaged in item-specific processing (i.e., achieving TAP for verbatim questions) as well as relational processing (i.e., achieving TAP for free recall and inference questions). In other words, no differences in verbatim accuracy are expected between students who complete cloze and outline notes. Importantly, because students who complete outline notes achieve MAP, they will demonstrate superior memory performance on free recall and inference questions relative to students who complete cloze notes.

Experiment 1 compared Cloze Less to Outline Less notes across two descriptive lectures. Following the logic above, it was hypothesized that students who complete Outline Less notes would remember more lecture content during free recall and produce more accurate inferences compared to students who complete Cloze Less notes. No difference in verbatim accuracy was expected. The predictions for Experiment 2, however, required an additional consideration.

Experiment 2 is designed to answer an important question: should instructors provide guided notes with more or less support, and in which format, in order to enhance their students' learning from science lectures? To answer this question, all four versions of guided notes listed in Figure 1 were compared, which provides the first empirical test of the independent and combined roles of different types of semantic processing (i.e., induced by the encoding task and learning material) and degrees of support in an educationally relevant task (i.e., lecture note-taking). Given the primary concern for achieving MAP, the two outline conditions were expected to lead to superior free recall and inference performance. However, these two conditions differ along a continuum of support. Compared to notes with more support, notes with less support will require students to generate more information, thus simultaneously increasing their active involvement in comprehending the lecture and imposing greater cognitive load.

Previous research has found supporting evidence for using instructional strategies that reduce cognitive load placed on students (e.g., cognitive load theory; Mayer & Moreno, 2003) as well as for using instructional strategies that increase the amount of semantic processing performed by students (e.g., desirable difficulty framework). In other words, the appropriate amount of support needed to strike a balance between reducing cognitive load (compared to not receiving guided notes) and encouraging semantic processing remains an open question. Both cognitive load theory and the desirable difficulty framework share a common goal and weakness. The common goal is to help students engage in the appropriate type and amount of cognitive processing. The common weakness is that the respective labels (e.g., germane or extraneous cognitive load; desirable or undesirable difficulty) are purely descriptive and applied post hoc, depending on whether performance outcomes are positive or negative. Thus, neither cognitive load theory nor the desirable difficulty framework can provide accurate a priori predictions. Instructors face a remarkably challenging task of selecting appropriate instructional strategies because their effectiveness hinges on a complex combination of factors.

In the current experiments, each of the instructor-provided learning aids (i.e., guided notes) were intended to reduce the cognitive load associated with note-taking relative to when students take notes without a learning aid. However, students were required to semantically process the lecture in order to fill in the missing information. Introducing this difficulty during the learning process can be either appropriate or inappropriate depending on (a) whether the difficulty triggers a type of semantic processing that enhances learning (i.e., achieves MAP) and (b) whether the student can overcome the amount of difficulty (e.g., successfully record lecture content using the guided notes). Potential outcomes from the perspective of cognitive load theory and the desirable difficulty framework are discussed below.

The relation between cognitive load and MAP has received limited attention, with prior research only manipulating the level of difficulty of the encoding task. For example, Einstein et al. (1990) found that moderately difficult encoding tasks increased learning relative to easy encoding tasks, but further increasing the difficulty of encoding tasks was not beneficial, even for encoding tasks that encourage MAP. A key assumption is that increasing the difficulty of an encoding manipulation (e.g., generation tasks) beyond some unknown limit (i.e., when the student is no longer able to successfully complete the processing task) would hinder recall performance (Einstein et al., 1990). Notably, the difficult encoding tasks in this prior research (i.e., inserting letters or sorting sentences) were completed while reading prose without time constraints, which may induce a relatively low amount of cognitive load (Piolat et al., 2005). Importantly, it is likely that the load induced by the encoding task combines with the load induced by the instructional method.

Cognitive load theory places the limitations of working memory at the forefront when attempting to explain learning outcomes. Specifically, the theory suggests that some difficulty (i.e., germane cognitive load) is necessary for learning to occur. However, in order to make learning more efficient, the goal is to minimize overall cognitive load and maximize memory performance (Clark, Nguyen, & Sweller, 2006). One potential cause of failing to overcome the difficulty introduced by taking outline notes is exceeding the learner's cognitive resources, particularly because both note-taking and learning from a descriptive lecture should place a high demand on students' working memory. Between the two outline conditions, Outline More notes should lead to lower cognitive load but still be beneficial to memory performance. If this were supported by the data, Outline More notes would be the most efficient learning aid. In contrast, if Outline Less notes result in a manageable amount of overall cognitive load, they could most benefit memory performance because this learning aid should maximize the amount of germane load. If Outline Less notes increase total cognitive load to the point that the student's working memory resources are exceeded, then the benefits of MAP could be attenuated and learning may be curtailed rather than enhanced (Aiken, Thomas, & Shennum, 1975; Anderson & Armbruster, 1986).

Alternatively, the desirable difficulty framework largely ignores the limitations of working memory in favor of focusing on the amount of active processing performed by the learner as the paramount concern. Generally speaking, instructional interventions that introduce a moderate amount of difficulty during encoding (i.e., force the learner to engage in cognitively demanding semantic processing by generating information) often enhance learning. One possibility is that Outline Less notes create the most appropriate balance between decreasing cognitive load due to the instructional support while facilitating semantic processing by requiring the student to generate more information. However, students may find that Outline Less notes present an insurmountable difficulty and thus learning is impeded. Outline More notes, on the other hand, provide additional support in order to minimize cognitive load and prevent this negative outcome. However, an unfortunate consequence of providing a high degree of support may be that it decreases active processing and thereby hinders learning (e.g., Bjork & Bjork, 2011).

In sum, multiple outcomes are possible and even reasonable given the complexity of predicting learning. Consistent with the predictions for Experiment 1, and given that skeletal outlines have been shown to benefit learning from science text, it was hypothesized that students who complete Outline Less notes would remember more lecture content during free recall and produce more accurate inferences compared to students who complete the other three note formats. No difference in verbatim accuracy was expected.

# CHAPTER II

# EXPERIMENT 1

Experiment 1 tested whether note-taking which encouraged MAP would improve memory performance across two descriptive lectures, and thus provide initial evidence for the generalizability of note-taking as an effective manipulation to facilitate encoding variability. The most relevant difference between the two lectures was the underlying structure of the descriptive prose (Cook & Mayer, 1988). Specifically, the human blood lecture listed and described a series of independent facts (i.e., an enumeration structure) whereas the human ear lecture described a series of connected events and steps in a process (i.e., a sequential structure). Despite the differences in the underlying structures, both lectures were descriptive in nature and should benefit most from the outline notes due to the relational processing induced by this note format.

## METHOD

Prior to data collection, all research materials and procedures were approved by the Institutional Review Board at the University of Louisville.

### Experimental Design

Students listened to two different lectures (human blood, human ear) and completed one of two different note-taking formats for each lecture (cloze, outline). To eliminate order effects, lecture topic and note format were counterbalanced. Results from the two lectures were analyzed separately, to examine the impact of the two note-taking formats across two different passages.

**Participants**

Participants were undergraduate students from the psychology participant pool (Human blood lecture: $N = 42$ [Cloze $n = 21$, Outline $n = 21$], $M$ age = 19.88 years, $SD$ = 1.67, 76.2% female, 23.8% male; Human ear lecture: $N = 36$ [Cloze $n = 23$, Outline $n$ = 13], $M$ age = 19.58 years, $SD$ = 1.38, 58.3% female, 41.7% male). The majority of students identified themselves as White (Human blood lecture: 64.3%; Human ear lecture: 66.7%), with the remaining individuals identifying themselves as Black (Human blood lecture: 23.8%; Human ear lecture: 13.9%), Asian (Human blood lecture: 2.4%; Human ear lecture: 2.8%), Hispanic or Latino (Human blood lecture: 2.4%; Human ear lecture: 2.8%), or other (Human blood lecture: 7.1%; Human ear lecture: 13.9%). Additional students were tested, but excluded from the analyses, for three reasons. First, students were excluded for not following experiment instructions: (a) completing less than 30% of the notes handout, indicating that students were not sufficiently exposed to the processing manipulation of the note-taking format (Human blood lecture, $n = 1$; Human ear lecture, $n = 14$), (b) committing 15 or more errors on the automated reading span task (Human blood lecture, $n = 6$; Human ear lecture, $n = 6$), or (c) missing data (i.e., did not complete the experiment; computer error; missing more than two responses across both reaction time tasks) (Human blood lecture, $n = 3$; Human ear lecture, $n = 4$). Second, students were excluded for self-reporting a high degree of prior knowledge (Human blood lecture, $n = 10$; Human ear lecture, $n = 2$). Finally, students were excluded for experimenter error (i.e., administered memory tests in the wrong order) (Human blood lecture, $n = 1$; Human ear lecture, $n = 1$).

**Procedure**

All students were tested individually in separate testing rooms. After providing written informed consent, students were informed that they would be listening to two different audio lectures about the human body, and that they were not allowed to rewind, fast-forward, or pause the audio recordings. Furthermore, they were instructed to take notes using the handouts provided to them in order to help them learn the information for a memory test at the end of the experiment. There was no mention of whether or not they would be able to review their notes later or use them during the memory test. Students were then asked to wear headphones and complete a baseline reaction time task (see below).

Immediately before the first lecture began, students received a handout to use to take notes, with instructions based on their assigned condition (see below). There were 10 seconds of silence at the beginning of the audio recording to allow the experimenter to leave the room after starting the recording. Students continued to perform the reaction time task during the lecture (using their non-writing hand) while simultaneously taking notes. After the lecture, the experimenter collected the notes and asked students to complete a brief questionnaire. This process was then repeated for the second lecture, which covered a different topic.

Then, students completed a working memory capacity task followed by a post-experiment questionnaire. Finally, students completed the memory tests for the lectures, in the order in which the lectures were administered. At the end of the memory tests, the students were debriefed and thanked for their participation. The experiment lasted approximately 60 minutes.

**Materials**

**Lectures.** Students listened to a two-minute hematology lecture about the components and functions of *human blood* as well as a two-minute auditory sensation lecture about the sequential steps involved in the process of hearing sounds with the *human ear* (adapted from Blunt & Karpicke, 2014, and Karpicke & Blunt, 2011). The 245-word human blood lecture was presented at an average rate of 117 words per minute and included 33 individual idea units (i.e., a small group of words that represent a single idea or fact; see Appendix A). The 255-word human ear lecture was presented at an average rate of 115 words per minute and included 29 individual idea units (see Appendix B), which were used to assess note-taking and free recall performance.

**Reaction time task.** Students were asked to wear headphones and complete a reaction time task by pressing the space bar as quickly as possible once they heard a tone. Specifically, this task was two-minutes in duration and presented six auditory tones at predetermined random intervals ranging from 15 to 30 seconds so that each student experienced the same time interval between the tones. In total, this task was completed three times during the experiment.

The first iteration of this task was intended to provide a baseline reaction time measure for each student. Importantly, the tones were presented as a single-task and the timing of each space bar press was recorded. The time intervals preceding each tone were 21s, 15s, 18s, 17.5s, 20.5s, 27.5s. The six reaction times were calculated by subtracting the onset time for each tone from the time at which the space bar was pressed.

If no response time to a tone was recorded (i.e., the student pressed the space bar before the tone was played or the student did not respond to the tone), then the missing response time was replaced with the maximum time allotted to respond to the corresponding tone. Then, the onset time for the tone was subtracted from the replaced response time to calculate the reaction time.

The second and third iterations were presented as dual-tasks in order to provide a direct measure of online cognitive load (Piolat et al., 2005). During both lectures, the primary task was to take notes and the secondary monitoring task was to respond as quickly as possible to the six auditory tones. The tones could occur within or between idea units, but they never overlapped with the presentation of a word from the lecture. The timing of the tones used during the blood lecture was consistent with those used during the baseline reaction time task whereas the timing of the tones used during the ear lecture differed slightly (i.e., 20s, 15s, 17s, 19s, 27s, 24s). The six reaction times for each lecture were calculated using the same procedure as explained for the baseline reaction times above. To quantify online cognitive load and negate the influence of outliers, a median interference in reaction time (IRT) was calculated for each student by following two steps: (1) subtract the first baseline reaction time from the first dual-task reaction time and repeat this process for each of the other five reaction times and then (2) calculate the median value of the six reaction time differences. A positive median IRT indicates an increase in reaction time (i.e., slower response) during the dual-task relative to the baseline task and may be interpreted as an increase in cognitive load induced by lecture note-taking (Piolat et al., 2005).

**Note-taking.** Appendices C-F illustrate each type of note-taking handout (cloze, outline) for each of the two lecture topics. The four note-taking handouts were designed to simulate two types of "instructor-provided" partial notes with minimal support. The two *cloze notes* handouts provided a transcription of the lectures with words that had been deleted, thus requiring students to fill in the missing words. Specifically, one word was missing from each of the idea units (human blood = 33 missing words; human ear = 29 missing words). The *outline notes* handouts identified the organizational structure of the lectures in an outline format. Specifically, the outlines emphasized the hierarchical relationships between idea units without providing the supporting information (human blood = 31 missing idea units; human ear = 29 missing idea units).

**Working memory capacity.** The automated reading span task (Redick et al., 2012) served as a distractor task between listening to the lecture and completing the memory tests. In addition, scores were used as a covariate in the analyses to allow an estimate of the effects of different note-taking strategies and cognitive load independent of the effects of working memory capacity. In this task, students were presented with a set of sentences and asked to judge whether or not each sentence was sensible. After each sentence, students were presented with a letter for recall at the end of the set. They were presented with a recall grid and asked to select the letters they saw during the trial in the correct serial order. Set sizes ranged from three to seven and included three administrations for each set size (i.e., 75 total sentence-storage pairs). The total score was calculated by summing the total number of correct responses out of 75 (Conway et al., 2005).

**Questionnaires.** Both of the post-lecture questionnaires included six questions (see Appendix I for details). The questions assessed students' metacognition regarding their comprehension of the lecture (adapted from Einstein et al., 1990), perception of how difficult (adapted from DeLeeuw & Mayer, 2008), helpful, and enjoyable the note-taking task was, how familiar students were with the lecture topic prior to the experiment, and a judgment of learning (i.e., prediction of how much information they will remember on the upcoming test; adapted from Blunt & Karpicke, 2014; Karpicke & Blunt, 2011). The familiarity question was used as an estimate of prior knowledge and, to preserve a larger sample size, only students who self-reported maximum prior knowledge (i.e., Blood: "I could list each component and their functions clearly"; Ear: "I could list each physical structure and correctly order the steps") were excluded from all analyses (see Participants section above). The post-experiment questionnaire (see Appendix J for details) asked for demographic information as well as students' note-taking preferences and experience with instructor-provided notes during their post-secondary education.

**Memory tests.** To assess learning of both lecture topics, two types of memory tests were employed: free recall and short answer. Consistent with prior research, students began with a free recall task for which they were asked to write down everything they could remember from the lecture. This task was limited to a maximum of seven minutes, which has been shown to be a sufficient amount of time for students to express their knowledge and reach asymptotic levels of recall of this information (Karpicke & Blunt, 2011, supplemental online material). The short answer tests, adopted from Blunt and Karpicke (2014, Exp. 1) and Karpicke and Blunt (2011, Exp. 2), consisted of 10 verbatim questions and four inference questions for each lecture topic (see Appendices L and M for details).

The verbatim questions (Human blood lecture, Cronbach's α = .51; Human ear lecture, Cronbach's α = .63) assessed item-specific information stated directly in the lecture and typically referred to a single idea unit (Blunt & Karpicke, 2014). For example, the question "What percentage of plasma is water?" corresponded to the idea unit "Plasma is about 90% water." In contrast, the inference questions (Human blood lecture, Cronbach's α = .46; Human ear lecture, Cronbach's α = .54) required students to connect information across multiple idea units (Blunt & Karpicke, 2014) from the lecture and use this synthesis to reason beyond the information provided in the lecture. For example, the question "What would happen to the blood flow from a wound if the body had no fibrin?" referred to the following idea units: (a) "The fibrin forms a meshwork of microscopic fibers"; (b) "These fibers trap blood cells"; (c) "and create a clot"; (d) "The clot closes off the cut or wound"; (e) "so that bleeding stops."

Students were required to spend a minimum of 15 seconds attempting to answer each short answer question. After the 15 seconds had elapsed, an arrow button appeared below the question which could be clicked to advance to the next question (adapted from Karpicke & Blunt, 2011). The total time to answer each short answer question was unlimited.

Two raters scored 20% of all memory tests and notes. Overall, Cohen's kappa coefficients indicated adequate consistency between raters (all $ps < .001$): free recall of Human blood (.96) and Human ear (.98) lectures, verbatim short answer questions for Human blood (.99) and Human ear (.79) lectures, inference short answer questions for

Human blood (1.00) and Human ear (.91) lectures, Cloze Less notes for Human blood (.95) and Human ear (1.00) lectures, and Outline Less notes for Human blood (.91) and Human ear (1.00) lectures. The remaining memory tests and notes were scored by only one of the raters.

CHAPTER III

EXPERIMENT 1 RESULTS & DISCUSSION

## Note-Taking Habits and Experiences

Before exploring the efficacy of the different note-taking formats, it is informative to identify students' note-taking habits and experiences in their post-secondary education. When asked about their note-taking habits in science courses, every student reported taking some form of notes during lectures, which reinforces the practical utility of this research. The majority of students indicated that they attempt to create outlines (Human blood, 33.3%; Human ear, 38.9%) or write a list of bullet points (Human blood, 38.1%; Human ear, 41.7%). One student noted that he or she would draw pictures to represent the information presented during the lecture (Human blood, 2.4%; Human ear, 2.8%). The remaining students indicated that they try to write down everything the instructor says (Human blood, 19.0%; Human ear, 13.9%) or use a copy of the instructor's PowerPoint slides to guide their note-taking (Human blood, 7.2%; Human ear, 2.8%), both of which suggest that students value having notes that are as complete as possible. Additionally, despite being part of the note-taking research literature, no students reported using the Cornell note-taking method (e.g., Quintus, Borr, Duffield, Napoleon, & Welch, 2012), graphic organizers (e.g., Ponce & Mayer, 2014), or matrix notes (e.g., Kiewra, Benton, Kim, Risch, & Christensen, 1995).

Regarding experiences with instructor-provided notes, students indicated that professors were more likely to provide a complete copy of the lecture information (e.g., copy of the PowerPoint slides) compared to a partially complete copy of the lecture information (e.g., copy of the PowerPoint slides with key terms or definitions deleted). Specifically, complete notes were provided in zero courses (Human blood, 11.9%; Human ear, 5.6%), one to two courses (Human blood, 38.1%; Human ear, 36.1%), three to four courses (Human blood, 11.9%; Human ear, 22.2%), five to six courses (Human blood, 7.1%; Human ear, 8.3%), seven to eight courses (Human blood, 7.1%; Human ear, 2.8%), nine to 10 courses (Human blood, 7.1%; Human ear, 5.6%), or 11+ courses (Human blood, 16.7%; Human ear, 19.4%). In contrast, partially complete notes were provided in zero courses (Human blood, 52.4%; Human ear, 55.6%), one to two courses (Human blood, 28.6%; Human ear, 25.0%), three to four courses (Human blood, 9.5%; Human ear, 8.3%), five to six courses (Human blood, 9.5%; Human ear, 11.1%), or seven or more courses (Human blood, 0%; Human ear, 0%). Finally, students reported that it is much more common for them to be able to first access the information before the lecture (Human blood, $n = 33$; 144 courses indicated; Human ear, $n = 30$; 115 courses indicated) relative to after the lecture (Human blood, $n = 19$; 67 courses indicated; Human ear, $n = 17$; 70 courses indicated).

**Data Analysis and Hypotheses**

**Preliminary Analyses.** Although students were randomly assigned to conditions, working memory capacity and prior knowledge were examined as a function of condition using separate univariate ANOVAs. For the blood lecture, students who completed outline notes had greater cognitive ability ($M = 58.95$, $SE = 2.59$) and more prior knowledge (*M* = 2.81, *SE* = .12) than students who completed cloze notes (working memory capacity: *M* = 48.33, *SE* = 2.58, $F(1, 40) = 8.43$, $p = .01$, $\eta_p^2 = .17$; prior knowledge: *M* = 2.43, *SE* = .12, $F(1, 40) = 4.92$, $p = .03$, $\eta_p^2 = .11$). In contrast, for the ear lecture, no differences in working memory capacity or prior knowledge between the two conditions were detected (*F*s < 1). Because prior knowledge was measured as a self-report, categorical variable, this variable was not included as a covariate. Each of the analyses reported below controlled for working memory capacity (Human blood: *M* = 53.64, *SD* = 12.88; Human ear: *M* = 58.36, *SD* = 10.70), allowing the current results to indicate the mnemonic benefits of note-taking above and beyond students' general cognitive ability. Table 1 presents the main effects of working memory capacity for each model reported below.

Table 1

*Main effects of working memory capacity for each model*

| | Human blood lecture | | Human ear lecture | |
|---|---|---|---|---|
| | *F* | $\eta_p^2$ | *F* | $\eta_p^2$ |
| Free recall | 1.76 | .04 | 2.55 | .07 |
| Verbatim (short answer) | 0.19 | .01 | 1.57 | .05 |
| Inference (short answer) | 1.09 | .03 | 0.81 | .02 |
| Online cognitive load | 0.61 | .02 | 5.80* | .15 |
| Note completeness | 1.46 | .04 | 1.38 | .04 |
| Difficult | 4.25 | .10* | 2.07 | .06 |
| Enjoyable | 0.13 | .00 | 1.00 | .03 |
| Comprehend | 0.09 | .00 | 0.87 | .03 |
| Helpful | 0.08 | .00 | 0.41 | .01 |
| Judgment of learning | 1.54 | .04 | 1.73 | .05 |

Note: *$p < .05$.

**Primary Analyses.** Separate one-way (note format: cloze, outline) between-subjects ANCOVAs were used to analyze memory performance, cognitive load, note completeness, and metacognitive ratings for the human blood and human ear lectures. Given the descriptive nature of the lectures, which is assumed to encourage item-specific processing, it was hypothesized that taking outline notes, which is assumed to encourage relational processing, would facilitate MAP and thus benefit memory performance on free recall and short answer inference questions relative to cloze notes. Furthermore, it was hypothesized that there would be no difference in accuracy between the two note-taking formats on short answer verbatim questions.

**Human Blood Lecture**

**Memory tests.** Memory performance as a result of completing the two note-taking conditions is reported below.

***Free recall.*** As shown in Figure 2, students who completed outline notes produced a higher proportion of total idea units during free recall compared to students who completed cloze notes, $F(1, 39) = 7.99$, $p = .01$, $\eta_p^2 = .17$.

***Short answer questions.*** No effect of note-taking format was detected for proportion of verbatim questions answered correctly ($F < 1$), but a marginal effect was found for inference questions answered correctly, $F(1, 39) = 4.07$, $p = .05$, $\eta_p^2 = .10$ (see Figure 2). Despite failing to reach statistical significance, students who completed outline notes answered more inference questions correctly than students who completed cloze notes. Because this result was trending in the hypothesized direction and produced a medium effect size, it may be educationally relevant and deserves attention in future research.

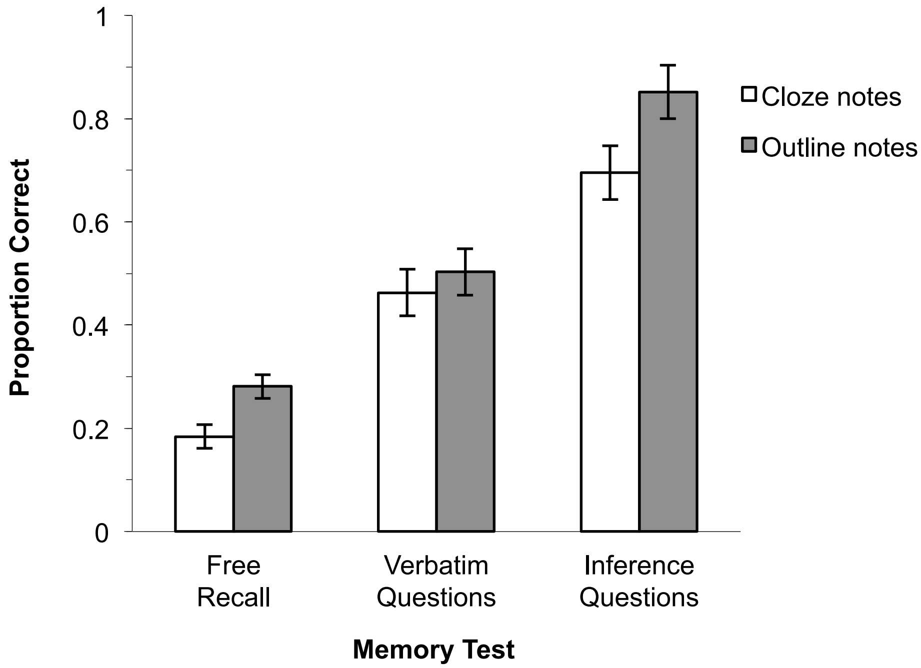


Figure 2. Mean proportion correct on free recall and short answer tests when students completed cloze notes or outline notes on the human blood lecture. Error bars represent ±1 standard error of the mean.

**Online cognitive load.** A total of 11 response times were replaced with a maximum response time, representing 2.2% of the total response times. Completing outline notes (*M* = 261.92, *SE* = 27.38) was marginally more cognitively demanding than completing cloze notes (*M* = 186.77, *SE* = 27.38), $F(1, 39) = 3.44$, $p = .07$, $\eta_p^2 = .08$.

**Note completeness.** Students who completed cloze notes (*M* = .96, *SE* = .02) recorded a higher proportion of total idea units during the lecture compared to students who completed outline notes (*M* = .49, *SE* = .02), $F(1, 39) = 327.81$, $p < .001$, $\eta_p^2 = .89$. Students who completed cloze notes recorded nearly twice as many idea units as students who completed outline notes. When considered in concert with the free recall results (i.e., outline notes led to better free recall performance), this finding appears to contradict conventional wisdom which suggests that when students have more complete notes they should remember more information and perform better on the exam. Importantly, the conventional wisdom cannot be completely ruled out by the current experiment because there was no opportunity to review the notes (i.e., the external storage benefit of note-taking; DiVesta & Gray, 1972). However, from an encoding perspective, the contradiction is noteworthy.

**Metacognitive ratings.** The metacognitive ratings are reported below and in Figure 3.

***Difficult.*** Students perceived the task of completing outline notes to be more difficult than completing cloze notes, $F(1, 39) = 30.20$, $p < .001$, $\eta_p^2 = .44$. This finding corroborates the note completeness results and is consistent with the direction of the online cognitive load results, suggesting that completing outline notes may be a desirable difficulty (Bjork & Bjork, 2011).

***Enjoyable.*** Students rated the note-taking task as more enjoyable when they completed cloze notes compared to outline notes, $F(1, 39) = 16.06$, $p < .001$, $\eta_p^2 = .29$, which is also consistent with the desirable difficulty view of outline notes.

***Comprehend.*** Students thought that completing cloze notes helped them better comprehend the lecture compared to outline notes, $F(1, 39) = 6.76$, $p = .01$, $\eta_p^2 = .15$. Interestingly, students' objective memory performance was inconsistent with this perception as outline notes increased learning relative to cloze notes.

***Helpful.*** Students perceived the task of completing cloze notes to be more helpful in learning the lecture content than completing outline notes, $F(1, 39) = 7.26$, $p = .01$, $\eta_p^2 = .16$. Importantly, any differences in memory performance cannot be attributed to the outline notes being perceived as more helpful than the cloze notes.

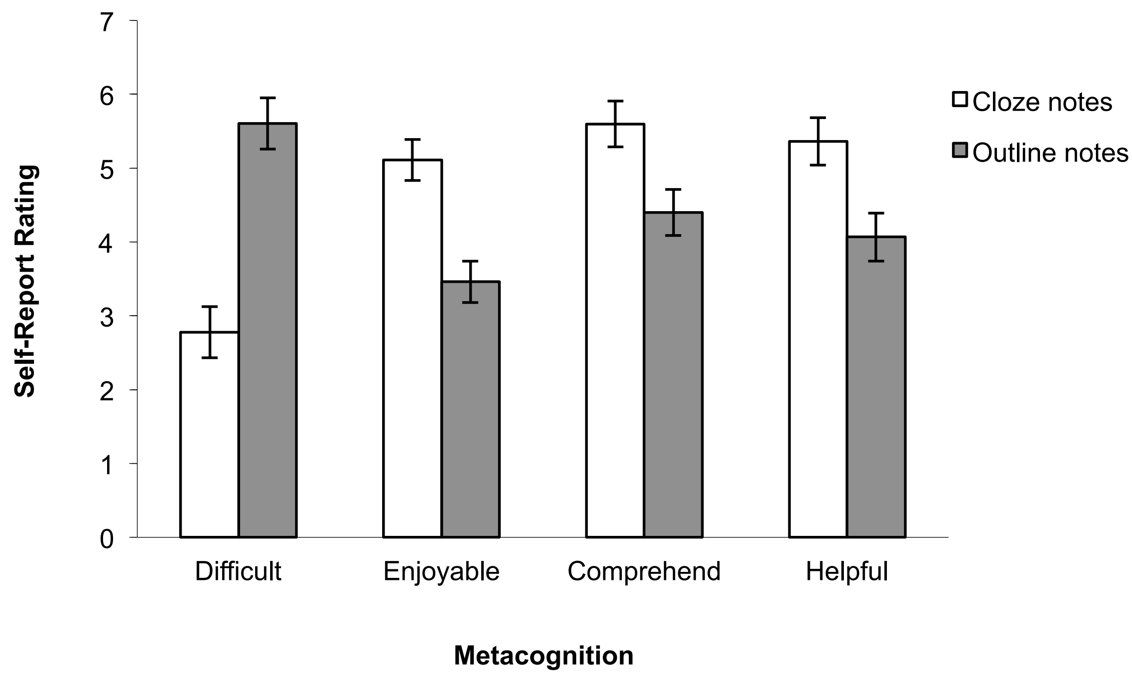


Figure 3. Mean self-report ratings of metacognitive factors regarding the experience of completing cloze notes or outline notes on the human blood lecture. Error bars represent ±1 standard error of the mean.

***Judgment of learning.*** The predictions from students who completed cloze notes ($M$ = .54, $SE$ =.04) did not differ from students who completed outline notes ($M$ = .52, $SE$ = .04), $F < 1$. Interestingly, these predictions specifically targeted future free recall performance. Consistent with prior literature (e.g., Karpicke, Butler, & Roediger, 2009; Koriat & Bjork, 2005), the current sample of students struggled to accurately judge their learning. In fact, they overestimated their learning (i.e., illusion of competence) as evidenced by their prediction that they would remember approximately twice as much information as they actually produced during free recall after utilizing both cloze (Predicted: $M$ = .54, $SE$ = .04; Observed: $M$ = .18, $SE$ = .02; $r$ = .47, $p$ = .04), $F(1,19)$ = 114.91, $p < .001$, $\eta_p^2$ = .86, and outline (Predicted: $M$ = .52, $SE$ = .04; Observed: $M$ = .28, $SE$ = .02; $r$ = -.02, $p$ = .94), $F(1,19)$ = 30.29, $p < .001$, $\eta_p^2$ = .62, notes.

**Human Ear Lecture**

**Memory tests.** Memory performance as a result of completing the two note-taking conditions is reported below and in Figure 4.

***Free recall.*** Consistent with the hypothesis as well as the findings with the human blood lecture, students who completed outline notes produced a higher proportion of total idea units during free recall compared to students who completed cloze notes, $F(1, 33) = 7.11$, $p = .01$, $\eta_p^2 = .18$.

***Short answer questions.*** No effect of note-taking format was detected for proportion of verbatim, $F(1, 33) = 2.60$, $p = .12$, $\eta_p^2 = .07$, questions answered correctly. In contrast, students who completed outline notes answered more inference questions correctly than students who completed cloze notes, $F(1, 33) = 5.15$, $p = .03$, $\eta_p^2 = .14$. These findings are consistent with the hypotheses as well as the findings with the human blood lecture.

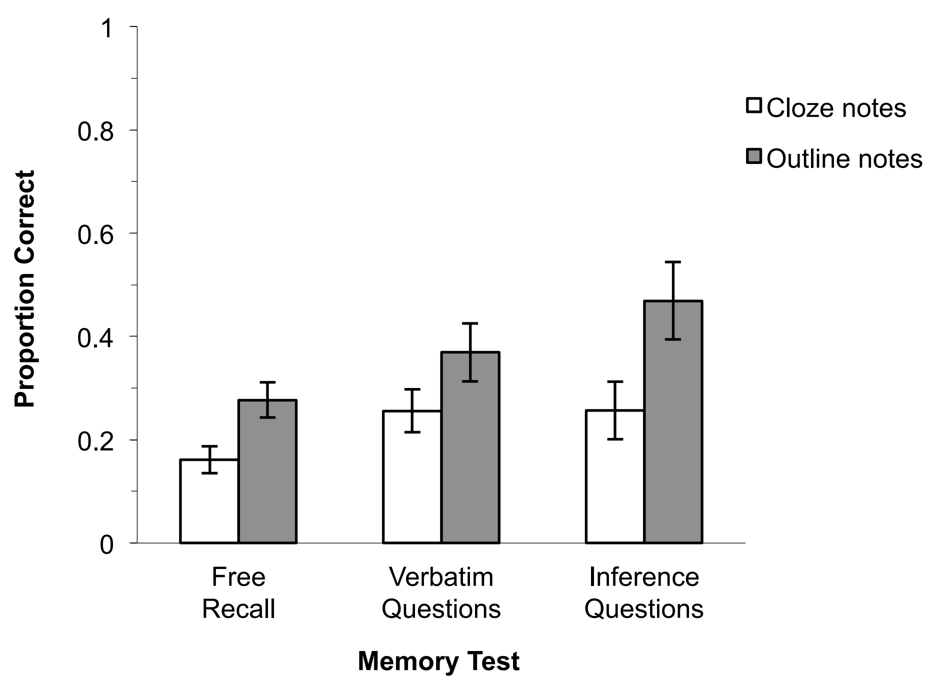


Figure 4. Mean proportion correct on free recall and short answer tests when students completed cloze notes or outline notes on the human ear lecture. Error bars represent ±1 standard error of the mean.

**Online cognitive load.** A total of 16 response times were replaced with a maximum response time, representing 3.7% of the total response times. Completing outline notes ($M$ = 238.02, $SE$ = 31.04) induced greater cognitive load compared to cloze notes ($M$ = 116.86, $SE$ = 23.27), $F(1, 33) = 9.66$, $p = .004$, $\eta_p^2 = .23$.

**Note completeness.** Students who completed cloze notes ($M$ = .98, $SE$ = .01) recorded a higher proportion of total idea units during the lecture compared to students who completed outline notes ($M$ = .41, $SE$ = .02), $F(1, 33) = 736.05$, $p < .001$, $\eta_p^2 = .96$. Consistent with the results of the human blood lecture, students who completed cloze notes recorded approximately twice as many idea units as students who completed outline notes. When considered in concert with the memory test results (i.e., outline notes led to better free recall and inference performance), these findings once again appear to contradict conventional wisdom which suggests that when students have more complete notes they should remember more information and perform better on the exam. Caution when interpreting this result must still be applied, because there was no opportunity to review the notes (i.e., the external storage benefit of note-taking; DiVesta & Gray, 1972). However, from an encoding perspective, the consistency of this result with Experiment 1 is striking.

**Metacognitive ratings.** The metacognitive ratings are reported below and in Figure 5.

***Difficult.*** Students perceived the task of completing the outline notes to be more difficult than completing the cloze notes, $F(1, 33) = 12.71$, $p = .001$, $\eta_p^2 = .28$. Once again, this finding corroborates the note completeness and online cognitive load results, suggesting that completing outline notes may be a desirable difficulty (Bjork & Bjork, 2011).

***Enjoyable.*** As with the human blood lecture, when students completed cloze notes compared to outline notes, they rated the note-taking task as more enjoyable, $F(1, 33) = 20.29$, $p < .001$, $\eta_p^2 = .38$.

***Comprehend.*** No effect of note-taking format was detected for comprehension ratings, $F(1, 33) = 1.03$, $p = .32$, $\eta_p^2 = .03$. Thus, any differences in memory performance cannot be attributed to one note-taking format being more confusing than the other.

***Helpful.*** Students perceived that completing cloze notes helped them learn the lecture content better than when completing outline notes, $F(1, 33) = 6.48$, $p = .02$, $\eta_p^2 = .16$. Given that the outline notes were viewed as less helpful but resulted in better memory performance, this finding replicates the results of the human blood lecture and supports the notion that students' metacognition can be poorly calibrated and even in direct opposition to actual performance.

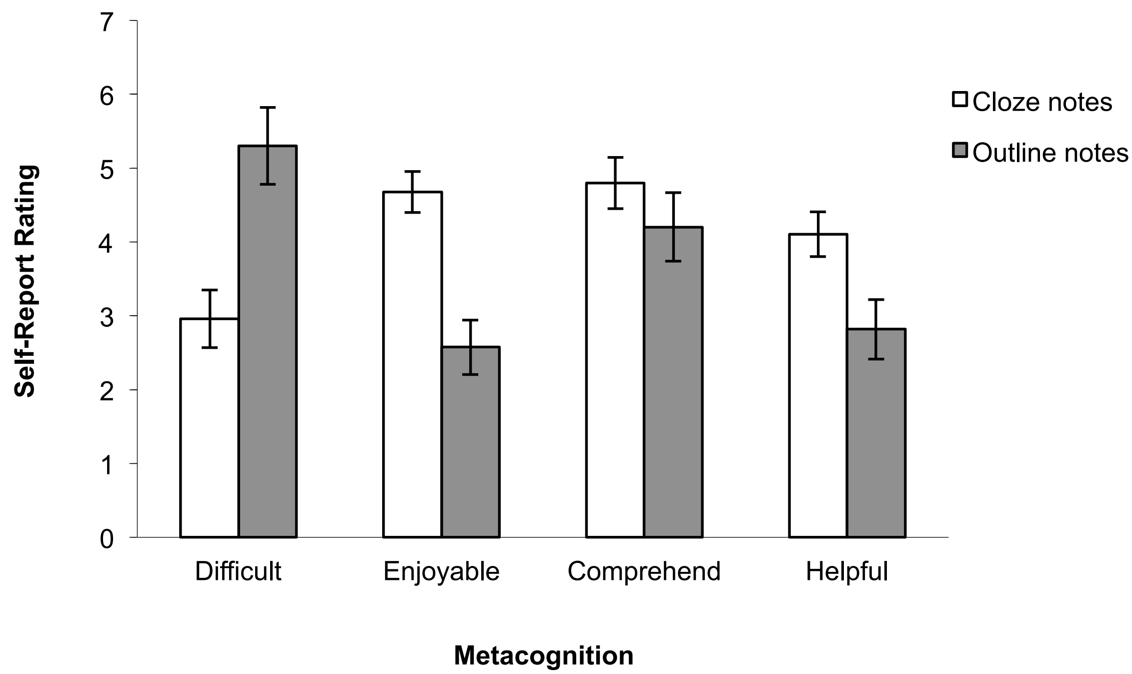


Figure 5. Mean self-report ratings of metacognitive factors regarding the experience of completing cloze notes or outline notes on the human ear lecture. Error bars represent ±1 standard error of the mean.

***Judgment of learning.*** The predictions from students who completed cloze notes ($M$ = .48, $SE$ =.04) did not differ from students who completed outline notes ($M$ = .36, $SE$ = .06), $F(1, 33) = 2.49$, $p = .12$, $\eta_p^2 = .07$. As found with the Human Blood lecture, students did not accurately predict their ability to remember information in the future. Specifically, students overestimated their learning after completing cloze notes (Predicted: $M$ = .48, $SE$ = .04; Observed: $M$ = .16, $SE$ = .03; $r$ = .14, $p$ = .54), $F(1,21)$ = 41.26, $p < .001$, $\eta_p^2 = .66$, but not after completing outline notes (Predicted: $M$ = .36, $SE$ = .06; Observed: $M$ = .28, $SE$ = .03; $r$ = .69, $p$ = .01), $F(1,11) = 3.94$, $p = .07$, $\eta_p^2 = .26$. The marginally significant difference for outline notes may be due to the lower average prediction and generally low free recall performance rather than an improvement in calibration.

CHAPTER IV

EXPERIMENT 2

Experiment 2 was designed to extend the investigation of instructor-provided, partially complete notes by testing whether the degree of support provided by the notes would moderate the mnemonic benefits of the two note-taking formats used in Experiment 1. Importantly, by providing different levels of support, cognitive load should be impacted and thus allow the note-taking formats to be compared under conditions of lower and higher cognitive load.

METHOD

Prior to data collection, all of the research materials and procedures were approved by the Institutional Review Board at the University of Louisville.

**Experimental Design**

A 2 (note-format: cloze, outline) × 2 (degree of support: less, more) between-subjects factorial design was employed.

**Participants**

Participants were undergraduate students from the psychology participant pool ($N$ = 120 [Cloze Less $n$ = 32, Cloze More $n$ = 27, Outline Less $n$ = 30, Outline More $n$ = 31], $M$ age = 20.23 years, $SD$ = 3.38, 64.2% female). The majority of students identified themselves as White (80%), with the remaining individuals identifying themselves as

Black (10%), Asian (5%), Hispanic or Latino (1%), or other (4%). Additional students were tested, but excluded from the analyses, for four reasons. First, students were excluded for not following experiment instructions: (a) completing less than 30% of the notes handout, indicating that students were not sufficiently exposed to the processing manipulation of the note-taking format ($n = 2$), (b) committing 15 or more errors on the automated reading span task ($n = 4$), or (c) missing data (i.e., did not complete the experiment; computer error; missing more than two responses across both reaction time tasks) ($n = 8$). Second, students were excluded for having a high degree of prior knowledge as indicated by (a) a self-report rating of maximum familiarity with the components and functions of human blood ($n = 3$) or (b) producing at least 50% (i.e., 4 out of 8) of the components or functions of human blood from memory on the cued recall prior knowledge question ($n = 45$). Third, students were excluded for reporting that English was not their first language ($n = 5$). Finally, students were excluded for experimenter error (i.e., administered incorrect example notes handout) ($n = 1$).

**Procedure**

The procedure mirrored Experiment 1 except for three changes. First, a cued-recall prior knowledge test was administered before introducing students to the experiment. This change acknowledges that students' metacognition regarding what they know about a topic may be inaccurate and that directly measuring students' knowledge via a memory test may provide a less biased estimate of their prior knowledge.

Second, to reduce measurement error regarding online cognitive load induced by the note-taking task, students were shown both a blank and completed example of the type of handout they would use to take their notes. Specifically, the example handouts covered a different topic (i.e., the Human Ear lecture used in Experiment 1) from the lecture and, once the handouts were explained, the experimenter directed the student to focus on the format of the notes rather than the content. The experimenter left the room for 60 seconds before returning to answer any questions. Then, the experimenter collected the example handouts, provided the student with the handout to be used during the lecture, and started the audio recording. This additional procedure was intended to help students familiarize themselves with the notes handout prior to using them during the lecture and thus remove any cognitive load associated with understanding the format of the note handout from the online measure of cognitive load. Overall, this methodological change should provide a more valid measure of cognitive load associated with learning the lecture content and using the handout to take notes.

Third, only the human blood lecture was used, so each student listened to one lecture. The experiment lasted approximately 50 minutes.

**Materials**

**Prior knowledge test.** Students completed a single cued-recall question asking them to list and match the components and functions of human blood (see Appendix K for details). There was no time limit to complete this question.

**Lecture.** See Experiment 1 and Appendix A for details about the human blood lecture.

**Reaction time task.** As in Experiment 1, the timing of the tones used during the blood lecture was consistent with those used during the baseline reaction time task. See Experiment 1 for details.

**Note-taking.** Appendices E-H illustrate each type of note-taking handout (cloze, outline) for each level of support (less, more). Both the cloze and outline notes with less support were used in the previous experiment (see Experiment 1 for more details). However, the cloze and outline notes with more support were unique to Experiment 2. Approximately half of the words that were missing from the cloze notes with less support (i.e., 33 words) were also missing from the cloze notes with more support (i.e., 17 words). The *outline notes* with more support identified the same organizational structure of the lecture as the outline notes with less support, but it also filled in some of the sub-topic information. Importantly, 17 words were deleted that corresponded to the same 17 words missing from the cloze notes with more support.

**Working memory capacity.** As in Experiment 1, the complex reading span task was used to measure working memory capacity.

**Questionnaires.** The same post-lecture questionnaire (shown in Appendix I) and post-experiment questionnaire (shown in Appendix J) were used as in Experiment 1.

**Memory tests.** See Experiment 1 for details. The reliability of the verbatim questions (Cronbach's $\alpha = .48$) and inference questions (Cronbach's $\alpha = .43$) was slightly lower compared to Experiment 1.

Two raters scored 20% of all memory tests and notes. Overall, Cohen's kappa coefficients indicated adequate consistency between raters (all *p*s < .001): prior knowledge (1.00), free recall (.97), verbatim short answer questions (.95), inference short answer questions (.96), Cloze Less notes (.91), Cloze More notes (1.00), Outline Less notes (.96), and Outline More notes (1.00). The remaining memory tests and notes were scored by only one of the raters.

## CHAPTER V

## EXPERIMENT 2 RESULTS & DISCUSSION

### Note-Taking Habits and Experiences

Students' note-taking habits and experiences in their post-secondary education mirrored those of students in Experiment 1. When asked about their note-taking habits in science courses, nearly all of the students (97.5%) reported taking some form of notes during lectures. The majority of students reported creating outlines (26.7%) or writing a list of bullet points (39.2%). One student (0.8%) stated that he or she took notes but did not indicate the typical format of those notes and another student (0.8%) noted that they highlight important information in their textbooks that they remember from class but did not indicate the typical format of their lecture notes. The remaining students indicated that they try to write down everything the instructor says (21.7%) or use the instructor's PowerPoint slides to guide their note-taking (i.e., take pictures of the PowerPoint slides during class or use printed slide handouts; 8.3%), both of which suggest that students value having notes that are as complete as possible. Additionally, no students reported using the Cornell note-taking method (e.g., Quintus et al., 2012), graphic organizers (e.g., Ponce & Mayer, 2014), or matrix notes (e.g., Kiewra et al., 1995).

Regarding experiences with instructor-provided notes, students indicated that professors were more likely to provide a complete copy of the lecture information (e.g., copy of the PowerPoint slides) compared to a partially complete copy of the lecture information (e.g., copy of the PowerPoint slides with key terms or definitions deleted). Specifically, complete notes were provided in zero courses (10.8%), one to two courses (23.3%), three to four courses (31.7%), five to six courses (10.0%), seven to eight courses (7.5%), nine to 10 courses (3.3%), or 11+ courses (13.3%). In contrast, partially complete notes were provided in zero courses (47.5%), one to two courses (34.2%), three to four courses (12.5%), five to six courses (3.3%), seven to eight courses (1.7%), nine to 10 courses (0.0%), or 11+ courses (0.8%). Finally, students reported that it is much more common for them to be able to first access the information before the lecture ($n$ = 110; 440 courses indicated) relative to after the lecture ($n$ = 61; 193 courses indicated).

**Data Analysis and Hypotheses**

**Preliminary Analyses.** Although students were randomly assigned to conditions, working memory capacity and prior knowledge were examined as a function of condition using separate 2 (note format: cloze, outline) × 2 (degree of support: less, more) between-subjects factorial ANOVAs. Separate 2 × 2 ANOVAs revealed that neither working memory capacity nor prior knowledge differed based on note format [$F < 1$; $F(1, 116) = 1.78$, $p = .19$, $\eta_p^2 = .02$, respectively] or degree of support [$F(1, 116) = 3.15$, $p = .08$, $\eta_p^2 = .03$; $F(1, 116) = 1.41$, $p = .24$, $\eta_p^2 = .01$, respectively]. Furthermore, no interaction between note format and degree of support was detected for working memory capacity or prior knowledge ($F$s < 1), indicating that the four note-taking conditions were statistically equivalent regarding working memory capacity and prior knowledge.

Each of the analyses reported below controlled for working memory capacity ($M$ = 57.11, $SD$ = 9.49) and prior knowledge ($M$ = .12, $SD$ = .15), allowing the current results to clearly indicate the presence or absence of an encoding benefit of note-taking above and beyond students' general cognitive ability (i.e., working memory capacity) and prior knowledge. Table 2 presents the main effects of working memory capacity and prior knowledge for each model reported below.

Table 2

*Main effects of working memory capacity and prior knowledge for each model*

| | Working memory capacity | | Prior knowledge | |
|---|---|---|---|---|
| | $F$ | $\eta_p^2$ | $F$ | $\eta_p^2$ |
| Free recall | 2.36 | .02 | 12.36** | .10 |
| Verbatim (short answer) | 2.30 | .02 | 7.64** | .06 |
| Inference (short answer) | 0.04 | .00 | 7.64** | .06 |
| Online cognitive load | 0.14 | .00 | 2.04 | .02 |
| Note completeness | 1.45 | .01 | 3.75 | .03 |
| Difficult | 4.27* | .04 | 0.10 | .00 |
| Enjoyable | 0.35 | .00 | 0.26 | .00 |
| Comprehend | 0.04 | .00 | 7.72** | .06 |
| Helpful | 2.59 | .02 | 0.73 | .01 |
| Judgment of learning | 5.64* | .05 | 11.81** | .09 |

Note: *$p < .05$; **$p < .01$.

**Primary Analyses.** Separate 2 (note format: cloze, outline) × 2 (degree of support: less, more) between-subjects factorial ANCOVAs were used to analyze memory performance, cognitive load, note completeness, and metacognitive ratings for the lecture. Building on the results of Experiment 1, the covariate-adjusted means for Outline Less notes were compared with each of the other note-taking conditions using a series of planned follow-up univariate ANCOVAs.

To reiterate the hypotheses, no differences in accuracy on the short answer verbatim questions were expected between the four note-taking formats. The two outline notes were expected to facilitate MAP, with the one that leads to the best free recall and inference accuracy depending on whether students are able to overcome the added difficulty associated with Outline Less notes and benefit from additional semantic processing (i.e., germane load). It was hypothesized that Outline Less notes would be more advantageous than Outline More notes.

## Memory Tests

**Free Recall.** Degree of support did not significantly impact free recall performance, $F(1, 114) = 2.52$, $p = .12$, $\eta_p^2 = .02$, but a main effect of note format indicated that outline notes led to superior memory compared to cloze notes, $F(1, 114) = 4.38$, $p = .04$, $\eta_p^2 = .04$. However, this effect was qualified by a significant interaction between note format and degree of support, $F(1, 114) = 18.30$, $p < .001$, $\eta_p^2 = .14$. As shown in Figure 6, students who completed Outline Less notes produced a higher proportion of total idea units during free recall compared to students who completed Cloze Less, $F(1, 58) = 18.86$, $p < .001$, $\eta_p^2 = .25$, Cloze More, $F(1, 53) = 7.42$, $p = .01$, $\eta_p^2 = .12$, and Outline More notes, $F(1, 57) = 18.67$, $p < .001$, $\eta_p^2 = .25$. The superior memory performance of students who completed Outline Less notes compared to Cloze Less notes replicates the findings of Experiment 1. In addition, Outline Less notes also led to significantly better free recall performance compared to both cloze and outline notes with more support, suggesting that "less is more" in terms of support provided by guided lecture notes.

**Short Answer Questions.** As predicted, and consistent with the findings of Experiment 1, there were no main effects of note format, $F(1, 114) = 1.09$, $p = .30$, $\eta_p^2 = .01$, or degree of support nor an interaction on verbatim performance, *F*s < 1. In contrast, inference performance was not influenced by a main effect of degree of support ($F < 1$), but there was a main effect of note format, $F(1, 114) = 4.02$, $p = .047$, $\eta_p^2 = .03$, with outline notes leading to more accurate inferences compared to cloze notes. However, this effect was qualified by a significant interaction between note format and degree of support, $F(1, 114) = 10.99$, $p = .001$, $\eta_p^2 = .09$. Follow-up comparisons (see Figure 6) indicated that students who completed Outline Less notes answered more inference questions correctly than students who completed Cloze Less, $F(1, 58) = 17.46$, $p < .001$, $\eta_p^2 = .23$, Cloze More, $F(1, 53) = 5.49$, $p = .02$, $\eta_p^2 = .09$, and Outline More notes, $F(1, 57) = 7.19$, $p = .01$, $\eta_p^2 = .11$. Mirroring the results of free recall performance, completing Outline Less notes led to more accurate inferences compared to all of the other guided notes. Collectively, the memory test findings are consistent with the notion that completing Outline Less notes acted as a desirable difficulty and students benefited from the additional semantic processing (i.e., germane load).

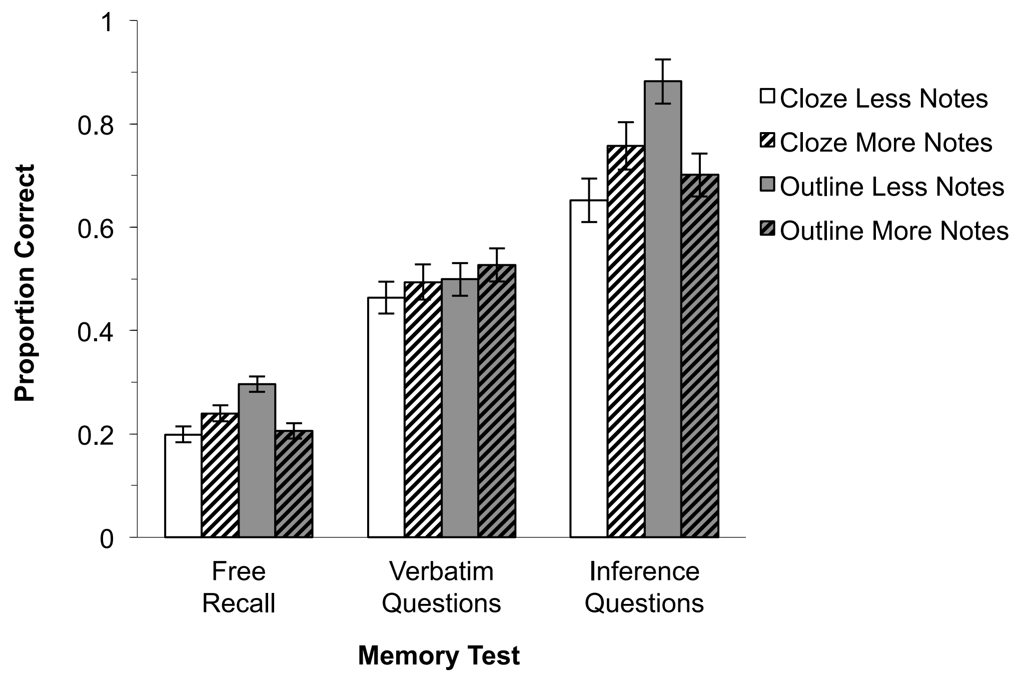


Figure 6. Mean proportion correct on free recall and short answer tests when students completed cloze notes or outline notes with more or less support on the human blood lecture. Error bars represent ±1 standard error of the mean.

**Online Cognitive Load**

A total of three response times were replaced with a maximum response time, representing 0.2% of the total response times. Completing outline notes ($M = 243.58$, $SE = 16.66$) induced greater cognitive load compared to cloze notes ($M = 127.85$, $SE = 17.00$), $F(1, 114) = 23.41$, $p < .001$, $\eta_p^2 = .17$. In addition, notes with more support ($M = 158.09$, $SE = 17.22$) decreased cognitive load relative to notes with less support ($M = 213.34$, $SE = 16.61$), $F(1, 114) = 5.23$, $p = .02$, $\eta_p^2 = .04$. No interaction between note format and degree of support on median IRT was detected, $F < 1$. Follow-up comparisons indicated that completing Outline Less notes ($M = 265.56$, $SE = 23.85$) was more cognitively demanding than completing Cloze Less ($M = 161.13$, $SE = 23.13$), $F(1, 58) = 9.59$, $p = .003$, $\eta_p^2 = .14$, and Cloze More ($M = 94.57$, $SE = 25.12$), $F(1, 53) =$

28.14, $p < .001$, $\eta_p^2 = .35$, but not Outline More notes ($M = 221.61$, $SE = 23.36$), $F(1, 57) = 1.50$, $p = .23$, $\eta_p^2 = .03$. The finding that Outline Less notes induced greater cognitive load relative to Cloze Less notes is consistent with the direction of results for the blood lecture and replicates the results for the ear lecture in Experiment 1. Furthermore, Outline Less notes had the slowest reaction times compared to all of the other guided notes, indicating that it required the greatest amount of cognitive processing.

**Note Completeness**

Cloze notes ($M = .97$, $SE = .01$) were more complete than outline notes ($M = .67$, $SE = .01$), $F(1, 114) = 338.62$, $p < .001$, $\eta_p^2 = .75$, and notes with more support ($M = .90$, $SE = .01$) were more complete than notes with less support ($M = .74$, $SE = .01$), $F(1, 114) = 94.52$, $p < .001$, $\eta_p^2 = .45$. However, these main effects were qualified by an interaction between note format and degree of support, $F(1, 114) = 55.66$, $p < .001$, $\eta_p^2 = .33$. Follow-up comparisons indicated that Outline Less ($M = .53$, $SE = .02$) notes were less complete than Cloze Less ($M = .95$, $SE = .02$), $F(1, 58) = 356.54$, $p < .001$, $\eta_p^2 = .86$, Cloze More ($M = .99$, $SE = .02$), $F(1, 53) = 387.25$, $p < .001$, $\eta_p^2 = .88$, and Outline More ($M = .81$, $SE = .02$), $F(1, 57) = 80.43$, $p < .001$, $\eta_p^2 = .59$, notes.

Consistent with Experiment 1, Outline Less notes were the least complete but led to the best free recall and inference performance. The current data cannot speak to how the less complete notes would impact the storage benefit of note-taking, but the encoding benefit of Outline Less notes is clear. It is also noteworthy that despite the Outline More and Cloze More notes missing the same 17 words, the outline format led to notes that were 18% less complete (i.e., approximately three fewer idea units were recorded).

**Metacognitive Ratings**

**Difficult.** Outline notes were rated as more difficult than cloze notes, $F(1, 114) = 75.42$, $p < .001$, $\eta_p^2 = .40$. In addition, notes with less support were rated as more difficult than notes with more support, $F(1, 114) = 22.99$, $p < .001$, $\eta_p^2 = .17$. No interaction between note format and degree of support was detected ($F < 1$). As shown in Figure 7, follow-up comparisons indicated that completing Outline Less notes was perceived as more difficult than completing Cloze Less, $F(1, 58) = 48.16$, $p < .001$, $\eta_p^2 = .45$, Cloze More, $F(1, 53) = 82.15$, $p < .001$, $\eta_p^2 = .61$, and Outline More notes, $F(1, 57) = 13.94$, $p < .001$, $\eta_p^2 = .20$. This finding mirrors the results of Experiment 1 and corroborates the note completeness and online cognitive load results above. When considered in concert with the memory test outcomes, completing outline notes with less support may be a desirable difficulty (Bjork & Bjork, 2011).

**Enjoyable.** A main effect of support was revealed, $F(1, 114) = 11.01$, $p = .001$, $\eta_p^2 = .09$, whereby students enjoyed using notes with more support compared to notes with less support. There was no main effect of note format, $F(1, 114) = 1.40$, $p = .24$, $\eta_p^2 = .01$, nor an interaction between note format and degree of support, $F(1, 114) = 2.67$, $p = .11$, $\eta_p^2 = .02$. As shown in Figure 7, follow-up comparisons indicated that Outline Less notes were perceived as the least enjoyable of the guided notes. Specifically, completing Outline Less notes was rated as less enjoyable relative to completing Cloze Less, $F(1, 58) = 4.30$, $p = .04$, $\eta_p^2 = .07$, Cloze More, $F(1, 53) = 9.67$, $p = .003$, $\eta_p^2 = .15$, and Outline More, $F(1, 57) = 11.48$, $p = .001$, $\eta_p^2 = .17$, notes. Desirable difficulties are often viewed as unenjoyable and challenging despite being beneficial to memory performance, which may help explain why students typically elect to not employ these strategies in favor of more enjoyable but less effective alternatives. Consistent with the characteristic pattern of desirable difficulties, students perceived Outline Less notes as the least enjoyable of the guided notes, but they were also the most beneficial to memory.

**Comprehend.** Students who completed notes with more support thought they comprehended the lecture better than students who completed notes with less support, $F(1, 114) = 5.06$, $p = .03$, $\eta_p^2 = .04$. There was no main effect of note format, $F(1, 114) = 1.58$, $p = .21$, $\eta_p^2 = .01$, nor an interaction between note format and degree of support ($F < 1$). As shown in Figure 7, follow-up comparisons indicated that completing Outline Less notes led to lower comprehension ratings than completing Cloze More notes, $F(1, 53) = 5.43$, $p = .02$, $\eta_p^2 = .09$. No differences in comprehension ratings between Outline Less and Cloze Less ($F < 1$) or Outline More, $F(1, 57) = 2.64$, $p = .11$, $\eta_p^2 = .04$, notes were detected. Given that Outline Less notes resulted in the highest free recall performance and also the lowest comprehension ratings, these findings illustrate that metacognitive ratings may not accurately reflect memory performance. Furthermore, this finding is consistent with a cue utilization approach to metacognitive judgments (Koriat, 1997), which asserts that a variety of factors influence students' estimations of how well they have learned something (e.g., students think they learn more when the processing during a learning activity is easier). Because notes with more support make it easier to process the lecture (see difficulty ratings above), students estimated their comprehension to be higher than when less support was provided by the notes.

**Helpful.** A main effect of support was detected, $F(1, 114) = 10.33$, $p = .002$, $\eta_p^2 = .08$, whereby students perceived using notes with more support as more helpful than notes with less support. There was no main effect of note format ($F < 1$) nor an interaction between note format and degree of support, $F(1, 114) = 1.09$, $p = .30$, $\eta_p^2 =$

.01. As shown in Figure 7, follow-up comparisons indicated that Outline Less notes were perceived as no more or less helpful than completing Cloze Less ($F < 1$), Cloze More, $F(1, 53) = 3.37$, $p = .07$, $\eta_p^2 = .06$, and Outline More, $F(1, 57) = 2.81$, $p = .10$, $\eta_p^2 = .05$, notes. Both the cloze and outline notes with more support received higher helpfulness ratings than the notes with less support. This pattern is intuitive given that the notes with more support provided the students with more of the lecture information and thus could understandably be viewed as more helpful.

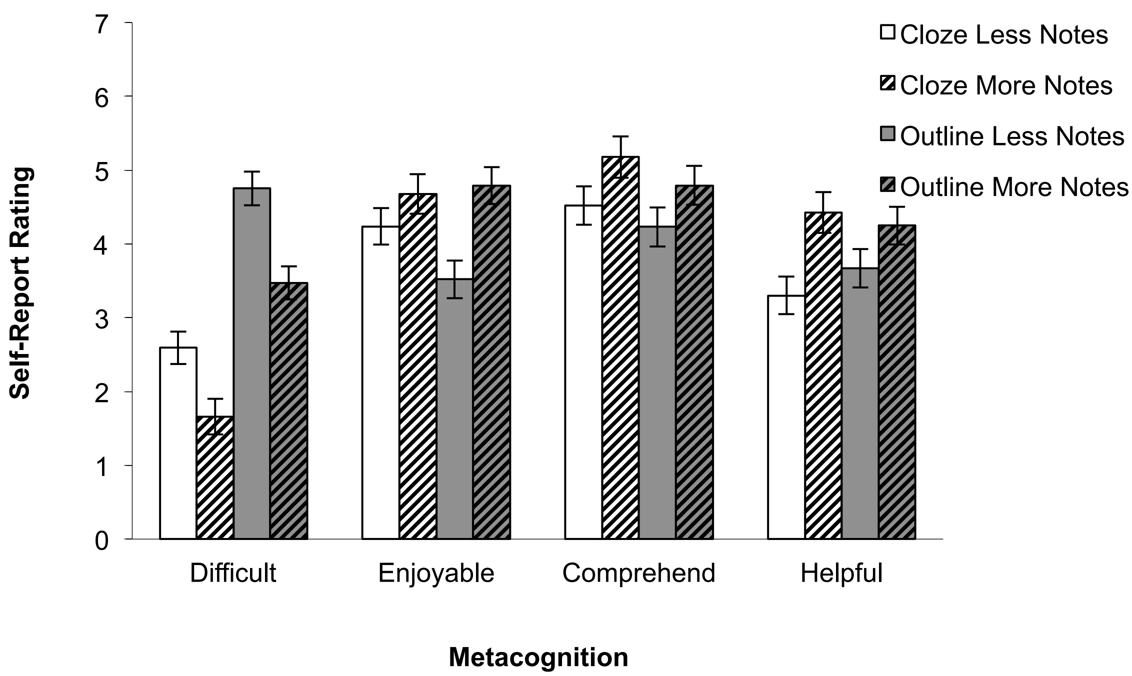


Figure 7. Mean self-report ratings of metacognitive factors regarding the experience of completing cloze notes or outline notes with more or less support on the human blood lecture. Error bars represent ±1 standard error of the mean.

**Judgment of Learning.** There was no main effect of support, $F(1, 114) = 1.30$, $p = .26$, $\eta_p^2 = .01$ , but students predicted that they would remember more after completing outline notes compared to cloze notes, $F(1, 114) = 6.59$, $p = .01$, $\eta_p^2 = .06$. However, this effect was qualified by a significant interaction between note format and degree of support, $F(1, 114) = 8.03$, $p = .01$, $\eta_p^2 = .07$. Follow-up comparisons indicated that

Outline Less ($M$ = .52, $SE$ = .04) notes led to higher predicted free recall performance than Cloze Less ($M$ = .32, $SE$ = .04) notes, $F(1, 58) = 13.89$, $p < .001$, $\eta_p^2 = .19$. Students' predictions did not differ when they completed Outline Less compared to Cloze More ($M$ = .47, $SE$ = .04), $F < 1$, and Outline More ($M$ = .46, $SE$ = .04), $F(1, 57) = 1.37$, $p = .25$, $\eta_p^2 = .02$, notes.

Consistent with prior literature (e.g., Karpicke et al., 2009; Koriat & Bjork, 2005) and Experiment 1, the current sample of students struggled to accurately judge their learning. In fact, they overestimated their learning (i.e., illusion of competence) as evidenced by their prediction that they would remember much more information than they actually produced during free recall after utilizing Cloze Less (Predicted: $M$ = .32, $SE$ = .04; Observed: $M$ = .20, $SE$ = .02; $r$ = .57, $p$ = .001), $F(1, 29) = 15.22$, $p = .001$, $\eta_p^2 = .34$, Cloze More (Predicted: $M$ = .47, $SE$ = .04; Observed: $M$ = .24, $SE$ = .02; $r$ = .19, $p$ = .37), $F(1, 24) = 36.69$, $p < .001$, $\eta_p^2 = .61$, Outline Less (Predicted: $M$ = .52, $SE$ = .04; Observed: $M$ = .30, $SE$ = .02; $r$ = .49, $p$ = .01), $F(1, 27) = 43.48$, $p < .001$, $\eta_p^2 = .62$, and Outline More (Predicted: $M$ = .46, $SE$ = .04; Observed: $M$ = .21, $SE$ = .02; $r$ = .61, $p$ < .001), $F(1, 28) = 74.49$, $p < .001$, $\eta_p^2 = .73$, notes.

## CHAPTER VI

## GENERAL DISCUSSION

The current experiments were designed to make progress toward answering an important practical question: assuming instructors provide their students with guided notes before the lecture, what is the optimal combination of note format and degree of support in order to maximize learning outcomes? Experiment 1 compared learning outcomes between outline and cloze notes with less support, and found superior free recall and inference short answer accuracy for outline notes. This experiment extended the work of Einstein et al. (1990) in two important ways. First, because skeletal outlines had been shown to induce relational processing while reading text passages, this experiment provides initial evidence that they can also be used to induce relational processing while learning from audio lectures. Second, in order to fully test MAP predictions, researchers need learning materials and encoding tasks that each induce qualitatively different types of processing. The current experiment facilitates this methodological requirement by specifying an encoding task (i.e., completing cloze notes) that induces item-specific processing and thus can be contrasted with skeletal outlines. Together, these opposing note formats enable MAP predictions to be tested using ecologically-valid tasks in educationally relevant situations (i.e., lecture learning).

Experiment 2 compared outline and cloze notes with two degrees of support, to examine whether reducing the consumption of cognitive resources further increases or decreases learning in a note-taking condition that achieves MAP. Of the four guided notes examined, Outline Less (i.e., skeletal outline) notes consistently led to superior free recall and inference performance compared to the other versions. This finding is counterintuitive for two reasons. First, Outline Less notes clearly posed the greatest challenge for students – as evidenced by creating the most interference in reaction time (i.e., online cognitive load), earning the highest ratings of difficulty, and resulting in the least complete notes. Second, students' metacognitive ratings of Outline Less notes were unfavorable. Specifically, students did not enjoy completing these notes and thought they were among the least helpful and led to lower levels of comprehension. Collectively, the evidence suggests that Outline Less notes triggered encoding processes that supported learning from science lectures and thus acted as a desirable difficulty.

A key finding of this research is the importance of achieving MAP to enhance learning. Prior MAP research on text learning suggests that complementary processing between the learning material and encoding task is a two-way street – regardless of whether the learning material affords item-specific or relational processing, learning is enhanced when the encoding task induces the opposite type of processing (e.g., Einstein et al., 1990). Applying this logic to learning from lectures, MAP might also be achieved by completing cloze notes (item-specific processing) during a narrative lecture (relational processing; e.g., detailing the interconnected events of the Civil Rights Movement or an account of Stanley Milgram's 20+ experimental variations while studying obedience to authority). Given that the current experiments solely examined descriptive lectures, future research could determine if the importance of MAP and less support extend to narrative lectures. If so, then Cloze Less notes would be optimal. The prediction that cloze notes can be the optimal type of guided notes is important, because it illustrates that outline notes are not necessarily a panacea for lecture learning – rather, the mnemonic benefits of note-taking likely depend on the interaction between the processing afforded by the lecture and the processing induced by the note format.

Interestingly, there was no evidence that the overall cognitive load induced by the combination of the lecture and skeletal outline consistently exceeded students' cognitive resources. The current data clearly indicate that skeletal outlines received the highest ratings of difficulty, were the most cognitively demanding, resulted in the least complete notes, and led to the most accurate memory performance compared to other guided notes. Thus, it can be acceptable to increase cognitive load by introducing a difficulty during the learning process. However, this benefit is constrained to encoding tasks that achieve MAP. Overall, skeletal outlines are best described as being a desirable difficulty given the current sample of students and learning materials.

Although the obvious distinction between Outline Less and Outline More notes is that they differ in the amount of processing required, it is impossible to determine if these two conditions also differed in the type of semantic processing induced. Specifically, Outline Less notes have been shown to induce relational processing (Einstein et al., 1990). However, providing the additional support to create Outline More notes may have shifted the type of processing that was encouraged from relational to item-specific. Specifically, even though the notes indicated the organizational structure, students were not required to process this relational information because they did not organize any of the lecture content on their own. Instead, they simply filled in missing words. Thus, Outline More notes could be viewed as more similar to both of the cloze notes than the Outline Less notes. If so, only the Outline Less notes should induce relational processing and thus be the only condition that achieves MAP and results in superior memory performance.

One way to circumvent this potential confound in future research is by using a narrative lecture and manipulating the cognitive load induced by different levels of support for cloze notes. This design isolates the impact of cognitive load because, unlike outline notes, cloze notes should not shift to a different type of semantic processing as the degree of support is manipulated. Despite the advantage of this approach for future research, practically speaking, the current experiments showed that Outline More notes led to inferior learning from science lectures regardless of the cause of this outcome (i.e., the type of processing shifted from relational to item-specific or the additional support decreased the amount of generation required of the student) and thus should be dismissed in favor of using Outline Less notes.

The implication of these findings is a tentative prescriptive recommendation for instructors and students: when learning from descriptive lectures, students should take notes using skeletal outlines. However, the conditions created for the current experiments were not intended to fully replicate the conditions found in the classroom and thus some important limitations must be noted. For example, the lecture was brief (i.e., two minutes), informationally dense (e.g., 33 unique idea units), and delivered at a relatively quick pace (e.g., 117 words per minute), which may not be representative of many lectures. Furthermore, students were tested within an hour of listening to the lecture and without the opportunity to review their notes, so the mnemonic benefits of skeletal outlines over longer retention intervals or after having a chance to review the notes are unknown. Finally, two important individual differences (i.e., working memory capacity and prior knowledge) were controlled for in the current experiments, but other learner characteristics may moderate the advantages of skeletal outlines (e.g., younger students, motivation to learn the material, learning disabilities).

Despite these practical limitations, the current experiments provide additional evidence that enhances our understanding of the processes underlying the encoding benefit of lecture note-taking. Specifically, these findings provide strong empirical evidence that both note format and degree of support are important variables that can directly impact the efficacy of guided notes. Finally, these results extend the encoding variability literature and, more specifically, the MAP literature from generation tasks that manipulate a text passage (e.g., sentence scrambling) to an ecologically-valid task of note-taking while listening to a lecture.

Based on the current data, instructors would be wise to invest their time in developing learning activities (e.g., guided note taking) that focus on achieving MAP via generative processing rather than trying to minimize the cognitive load induced by their instructional interventions. This point is particularly germane in light of the current sample of students' reports on their experiences with instructor-provided notes in post-secondary courses: instructors are much more likely to provide complete than partial notes. Furthermore, in the current sample, only 27-39% of students elect to create outlines during science lectures, suggesting that the majority of students do not choose the optimal note format. By adopting a "less is more" approach to instructor-provided notes, students will be both supported and encouraged to assume a more active role in the learning process. Given the ubiquitous use of lectures and the importance of note-taking for capitalizing on this learning opportunity, the development of skeletal outlines for descriptive lectures is a promising educational intervention.

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APPENDIX A

HUMAN BLOOD LECTURE SCRIPT WITH IDEA UNITS MARKED

**Make-up of Human Blood**

The four components that make up blood $/_1$ each serve a different function in the human body. $/_2$

Plasma, the first component, $/_3$ functions as a transport system for blood cells. $/_4$

Plasma is about 90% water $/_5$ and contains various chemical compounds in liquid form. $/_6$

These compounds are mostly proteins, $/_7$ but plasma also contains amino acids, minerals, and vitamins. $/_8$

The other three components of blood are actually cell-like in form. $/_9$

Red blood cells, the second component, $/_{10}$ contain an iron-rich protein called hemoglobin, $/_{11}$ which combines with oxygen in the lungs. $/_{12}$

The red blood cells are then responsible for releasing the oxygen to other cells in the body. $/_{13}$

Red blood cells are unusual $/_{14}$ because they have no nuclei. $/_{15}$

White blood cells are the third component $/_{16}$ and they are responsible for fighting disease. $/_{17}$

When there is an infection somewhere within the body $/_{18}$ white blood cells move toward, $/_{19}$ surround, $/_{20}$ take into themselves, $/_{21}$ and digest the bacteria and other foreign materials that are causing the infection. $/_{22}$

White blood cells are less numerous than red blood cells. $/_{23}$

There is about one white blood cell for every 6,000 red blood cells. $/_{24}$

Platelets, the fourth component, $/_{25}$ serve an important role in the process of minimizing blood loss from a wound. $/_{26}$

Platelets begin a series of chemical reactions that produce the protein, fibrin. $/_{27}$

The fibrin forms a meshwork of microscopic fibers. $/_{28}$

These fibers trap blood cells $/_{29}$ and create a clot. $/_{30}$

The clot closes off the cut or wound $/_{31}$ so that bleeding stops $/_{32}$ and the wound begins to heal. $/_{33}$

APPENDIX B

HUMAN EAR LECTURE SCRIPT WITH IDEA UNITS MARKED

**The Human Ear**

Sound waves are actually mechanical vibrations of air molecules $/_{1}$ which move at a regular pattern. $/_{2}$

Sound waves go through a five step process in the human ear. $/_{3}$

Hearing begins when sound waves enter the external portion of the ear. $/_{4}$

The outer ear's function is to focus or concentrate these sound waves. $/_{5}$

Orienting the ear towards a sound can also assist this initial pick-up of sound waves. $/_{6}$

From the outer ear the sound waves travel down the auditory canal $/_{7}$ which is a tube embedded in the bones of the skull. $/_{8}$

At the end of the auditory canal, $/_{9}$ the sound waves strike the tympanic membrane, or eardrum, $/_{10}$ causing it to vibrate. $/_{11}$

These vibrations are then transmitted by a series of very small bones $/_{12}$ located in the middle ear. $/_{13}$

Named for their shape, $/_{14}$ they are called the malleus (meaning hammer), incus (meaning anvil), and stapes (meaning stirrup). $/_{15}$

Next, the sound waves enter the inner ear, $/_{16}$ which is called the cochlea because it is curled up like the shell of a snail. $/_{17}$

It is at this point that the vibrations are translated into nerve signals $/_{18}$ that are then sent to the brain. $/_{19}$

The cochlea is divided down its length by a flexible membrane $/_{20}$ called the basilar membrane. $/_{21}$

Thousands of tiny hair cells which vary in length $/_{22}$ line this membrane. $/_{23}$

Longer hair cells will respond to low frequency sounds $/_{24}$ and shorter ones to high frequency sounds, $/_{25}$ enabling us to detect a range of sounds. $/_{26}$

When a hair cell is stimulated, $/_{27}$ it sends a neural signal to the cerebrum $/_{28}$ for interpretation. $/_{29}$

APPENDIX C

HUMAN EAR OUTLINE WITH LESS SUPPORT

**The Human Ear**

A. **Sound waves**

1. **Definition**

a. ____________________________________________

2. **Characteristic movement**

a. ____________________________________________

B. ____________________________________________

1. **Step 1**

a. **Location and behavior/effect of sound waves**

1. ________________________________________

b. **Function**

1. ________________________________________

c. **Improvement**

1. ________________________________________

2. **Step 2**

a. **Location and behavior/effect of sound waves**

1. ________________________________________

b. **Physical description**

1. ______________________________________________

3. **Step 3**

a. **Location and behavior/effect of sound waves**

1. ______________________________________________

______________________________________________

4. **Step 4**

a. **Location and behavior/effect of sound waves**

1. ______________________________________________

______________________________________________

a. How are these bones named: ______________________

b. Name & shape of each bone: ______________________

______________________________________________

______________________________________________

5. **Step 5**

a. **Location and behavior/effect of sound waves**

1. ______________________________________________

______________________________________________

______________________________________________

______________________________________________

a. Details about the cochlea

1. ____________________________________________

____________________________________________

a. Longer hair cells ______________________________

b. Shorter hair cells ______________________________

c. These hair cells enable us _______________________

d. When a hair cell is _____________________________

_____________________________________________

_____________________________________________

APPENDIX D

HUMAN EAR CLOZE NOTES WITH LESS SUPPORT

**The Human Ear**

Sound waves are actually mechanical __________ of air molecules which move at a __________ pattern.

Sound waves go through a __________ step process in the human ear.

Hearing begins when sound __________ enter the external portion of the ear.

The outer ear's function is to __________ or concentrate these sound waves.

__________ the ear towards a sound can also assist this initial pick-up of sound waves.

From the outer ear the sound waves travel down the auditory __________ which is a __________ embedded in the bones of the skull.

At the __________ of the auditory canal, the sound waves __________ the tympanic membrane, or eardrum, causing it to __________.

These vibrations are then __________ by a series of very small bones located in the __________ ear.

Named for their __________, they are called the malleus (meaning hammer), incus (meaning anvil), and __________ (meaning stirrup).

Next, the sound waves enter the __________ ear, which is called the __________ because it is curled up like the shell of a snail.

It is at this point that the vibrations are translated into __________ signals that are then sent to the __________.

The cochlea is divided down its length by a __________ membrane called the basilar __________.

Thousands of __________ hair cells which vary in length __________ this membrane.

Longer hair cells will respond to __________ frequency sounds and shorter ones to __________ frequency sounds, enabling us to detect a __________ of sounds.

When a hair cell is __________, it sends a neural __________ to the cerebrum for __________.

APPENDIX E

HUMAN BLOOD OUTLINE WITH LESS SUPPORT

**Make-up of Human Blood**

A. ______________________________________________________________

______________________________________________________________

1. ______________________________________________________________

a. **Function/Responsibility/Role**

1. ______________________________________________________________

b. **Physical form**

1. ______________________________________________________________

c. **Additional details**

1. Contains ______________________________________________________

______________________________________________________________

______________________________________________________________

2. ______________________________________________________________

a. **Function/Responsibility/Role**

1. ______________________________________________________________

b. **Physical form**

1. ______________________________________________________________

c. **Additional details**

1. Contains ____________________________________________

____________________________________________

2. Unusual because ____________________________________________

3. ____________________________________________

a. **Function/Responsibility/Role**

1. ____________________________________________

b. **Physical form**

1. Cell-like

c. **Additional details**

1. Relation to infection within the body: ______________________________

____________________________________________

____________________________________________

2. Prevalence: ____________________________________________

____________________________________________

4. ____________________________________________

a. **Function/Responsibility/Role**

1. ____________________________________________

b. **Physical form**

1. Cell-like

c. **Additional details**

1. Process of stopping blood flow: ______________________________

____________________________________________

____________________________________________

APPENDIX F

HUMAN BLOOD CLOZE NOTES WITH LESS SUPPORT

**Make-up of Human Blood**

The __________ components that make up blood each serve a different __________ in the human body.

__________, the first component, functions as a __________ system for blood cells.

Plasma is about __________ water and contains various chemical compounds in __________ form.

These compounds are mostly __________, but plasma also contains amino acids, __________ and vitamins.

The other three components of blood are actually __________ -like in form.

__________ blood cells, the second component, contain an iron-rich protein called __________, which combines with oxygen in the __________.

The red blood cells are then responsible for releasing the __________ to other cells in the body.

Red blood cells are __________ because they have no __________.

__________ blood cells are the third component and they are responsible for fighting __________.

When there is an __________ somewhere within the body white blood cells move __________, __________, take __________ themselves, and digest the __________ and other foreign materials that are causing the infection.

White blood cells are __________ numerous than red blood cells.

There is about one white blood cell for every __________ red blood cells.

__________, the fourth component, serve an important role in the process of __________ blood loss from a wound.

Platelets begin a series of chemical reactions that produce the protein, __________.

The fibrin forms a __________ of microscopic fibers.

These fibers __________ blood cells and create a __________.

The clot __________ off the cut or wound so that bleeding __________ and the wound begins to __________.

APPENDIX G

HUMAN BLOOD OUTLINE WITH MORE SUPPORT

**Make-up of Human Blood**

A. __________ components that each serve a different function in the human body

1. __________

   a. **Function/Responsibility/Role**

      1. Transport system for blood cells

   b. **Physical form**

      1. Liquid – about _____% water

   c. **Additional details**

      1. Contains various chemical compounds, including (mostly) proteins, amino acids, __________, and vitamins

2. __________ blood cells

   a. **Function/Responsibility/Role**

      1. Release __________ to other cells in the body

   b. **Physical form**

      1. __________-like

   c. **Additional details**

      1. Contains an iron-rich protein called __________, which combines with oxygen in the lungs

2. Unusual because they have no __________

3. __________ blood cells

a. **Function/Responsibility/Role**

1. Fight __________

b. **Physical form**

1. Cell-like

c. **Additional details**

1. Relation to infection within the body: These cells move toward, surround, take into themselves, and digest the __________ and other foreign materials that are causing the infection

2. Prevalence: Less numerous – there is about one white blood cell for every _________ red blood cells

4. __________

a. **Function/Responsibility/Role**

1. __________ blood loss from a wound

b. **Physical form**

1. Cell-like

c. **Additional details**

1. Process of stopping blood flow: (a) Platelets help produce __________, (b) which forms a meshwork of microscopic fibers, (c) which traps blood cells, (d) which creates a __________, (e) which closes off the wound, (f) which stops the bleeding, (g) which allows the wound to heal

APPENDIX H

HUMAN BLOOD CLOZE NOTES WITH MORE SUPPORT

**Make-up of Human Blood**

The __________ components that make up blood each serve a different function in the human body.

__________, the first component, functions as a transport system for blood cells.

Plasma is about __________ water and contains various chemical compounds in liquid form.

These compounds are mostly proteins, but plasma also contains amino acids, __________ and vitamins.

The other three components of blood are actually __________ -like in form.

__________ blood cells, the second component, contain an iron-rich protein called __________, which combines with oxygen in the lungs.

The red blood cells are then responsible for releasing the __________ to other cells in the body.

Red blood cells are unusual because they have no __________.

__________ blood cells are the third component and they are responsible for fighting __________.

When there is an infection somewhere within the body white blood cells move toward, surround, take into themselves, and digest the __________ and other foreign materials that are causing the infection.

White blood cells are less numerous than red blood cells.

There is about one white blood cell for every __________ red blood cells.

__________, the fourth component, serve an important role in the process of __________ blood loss from a wound.

Platelets begin a series of chemical reactions that produce the protein, __________.

The fibrin forms a meshwork of microscopic fibers.

These fibers trap blood cells and create a __________.

The clot closes off the cut or wound so that bleeding stops and the wound begins to heal.

APPENDIX I

POST-LECTURE QUESTIONNAIRE

How well did you comprehend the lecture?

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Did not comprehend it very well | | | | | | Comprehended it very well |

How easy or difficult was it to complete the note-taking task?

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Very easy | | | | | | Very difficult |

How helpful was the note-taking strategy in terms of *helping you learn* the information?

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Not at all helpful | | | | | | Very helpful |

Why do you think it was or was not helpful?

______________________________________________

______________________________________________

Relative to not taking any notes, how enjoyable was it to use the note-taking strategy?

| | | | | | | |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| Not at all enjoyable | | | | | | Very enjoyable |

Why do you think it was or was not enjoyable?

______________________________________________

______________________________________________

*[*Human Blood only*]*
How familiar were you with the physical structures and steps involved in hearing sounds BEFORE listening to the lecture? (circle one)

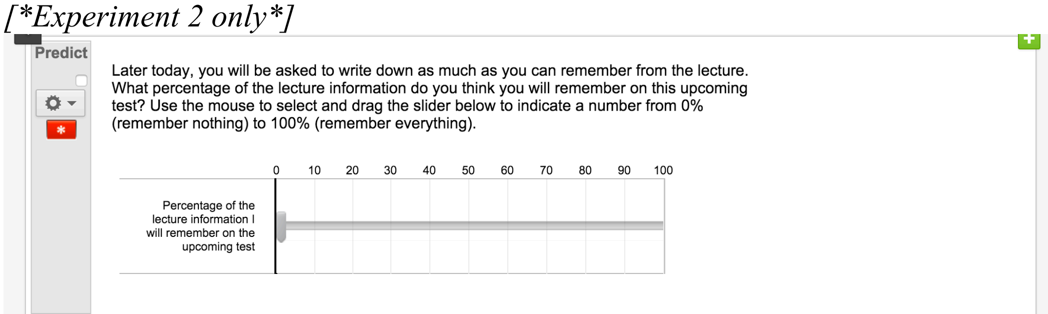
A. I had never heard of any of the physical structures or steps
B. I had heard of at least some of the physical structures but did not know the steps
C. I had heard of at least some of the physical structures and knew some of the steps
D. I could list each physical structure and correctly order the steps

*[*Human Ear only*]*
How familiar were you with the physical structures and steps involved in hearing sounds BEFORE listening to the lecture? (circle one)

A. I had never heard of any of the physical structures or steps
B. I had heard of at least some of the physical structures but did not know the steps
C. I had heard of at least some of the physical structures and knew some of the steps
D. I could list each physical structure and correctly order the steps

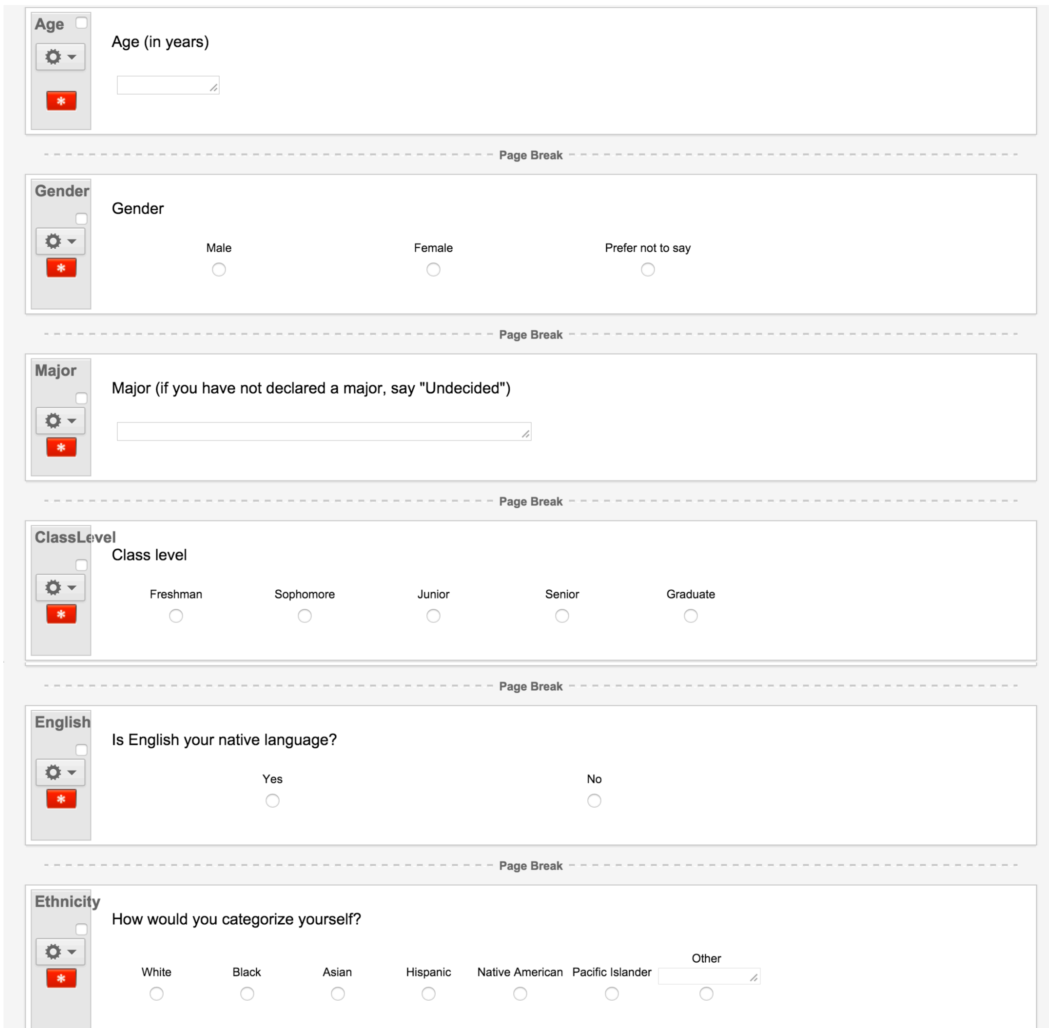
*[*Experiment 1 only*]*
Later today, you will be asked to write down as much as you can remember from the lecture. What percentage of the lecture information do you think you will remember on this upcoming test? [write a number from 0% (remember nothing) to 100% (remember everything); please do NOT write a range (40-50%)] __________ %

*[*Experiment 2 only*]*



# APPENDIX J

## POST-EXPERIMENT QUESTIONNAIRE


Age

Age (in years)

Page Break

Gender

Gender

Male Female Prefer not to say

Page Break

Major

Major (if you have not declared a major, say "Undecided")

Page Break

ClassLevel

Class level

Freshman Sophomore Junior Senior Graduate

Page Break

English

Is English your native language?

Yes No

Page Break

Ethnicity

How would you categorize yourself?

White Black Asian Hispanic Native American Pacific Islander Other

Page Break

Approach

Which approach to note-taking do you use *most often* during lectures in science courses?

- I do not take notes during lectures
- I try to write down everything the instructor says
- I take pictures of the PowerPoint slides (or other visuals) to get all of the information
- I use the "Cornell" (also called the "2-column") note-taking system
- I create a "matrix" (also called a "graphic organizer") to guide my note-taking
- I try to create an outline of main and supporting information as I listen to the lecture
- I write a list of bullet points containing information that I want to remember later
- I draw pictures to represent the information presented during the lecture
- Other (type a brief description in the space below):

Page Break

NoteHabit1

For how many courses have your instructors (at the college level) provided you with:

An incomplete outline or partially complete notes (meaning some important information was missing)?

- Zero courses
- 1-2 courses
- 3-4 courses
- 5-6 courses
- 7-8 courses
- 9-10 courses
- More than 10 courses

Page Break

NoteHabit2

For how many courses have your instructors (at the college level) provided you with:

A complete copy of all important information presented during lecture (e.g., copy of the PowerPoint slides)?

- Zero courses
- 1-2 courses
- 3-4 courses
- 5-6 courses
- 7-8 courses
- 9-10 courses
- More than 10 courses

Page Break

NoteHabit3

If your instructors provided you with notes (i.e., an outline or a copy of the PowerPoint slides), when could you first access the information? (you may select more than one answer if you have had access both before and after the lecture)

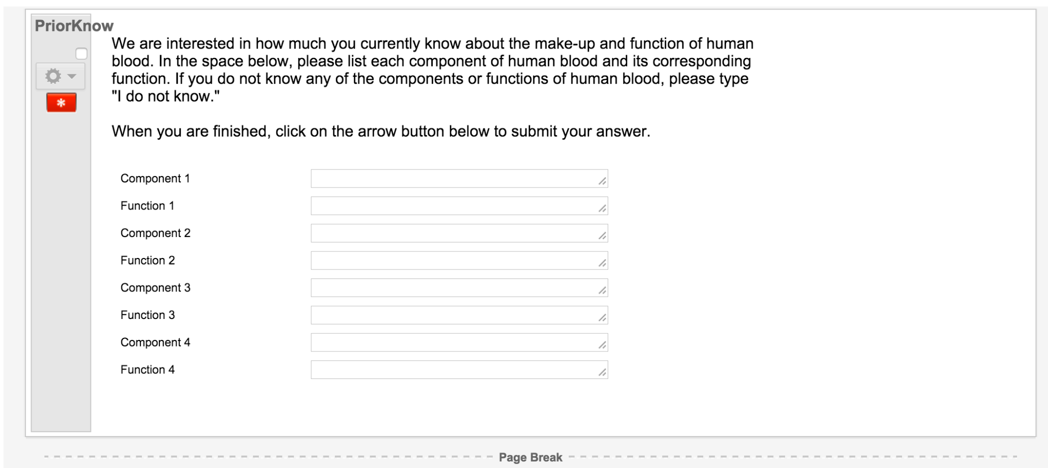
- My instructors have never provided me with a copy of the PowerPoint slides
- Before the lecture: (type the number of courses where this was true)
- After the lecture: (type the number of courses where this was true)

APPENDIX K

HUMAN BLOOD PRIOR KNOWLEDGE QUESTION AND ANSWERS

**Make-up of Human Blood**

Cued recall prior knowledge question



PriorKnow

We are interested in how much you currently know about the make-up and function of human blood. In the space below, please list each component of human blood and its corresponding function. If you do not know any of the components or functions of human blood, please type "I do not know."

When you are finished, click on the arrow button below to submit your answer.

Component 1
Function 1
Component 2
Function 2
Component 3
Function 3
Component 4
Function 4

Page Break

Answer key

| | Component | Function |
|---|---|---|
| **1** | Plasma | Transport system (for blood cells) |
| **2** | Red blood cells; Erythrocyte | Release oxygen (to other cells in the body) |
| **3** | White blood cells; Leukocyte | Fight disease; Immune response; Immunity; Antigen |
| **4** | Platelets | Minimize blood loss |

Scoring instructions:
1 point for each component (4 total points possible)
1 point for each function (4 total points possible)

APPENDIX L

HUMAN BLOOD SHORT ANSWER QUESTIONS AND ANSWERS

**Make-up of Human Blood**

Verbatim

1. How many components make up the blood?
   **(1) Four**
2. What percentage of plasma is water?
   **(1) 90**
3. Aside from proteins, name two other compounds contained in plasma?
   **(1) amino acids/ minerals/ vitamins** (must have 2 of 3)
4. What is the iron-rich protein contained in red blood cells called?
   **(1) Hemoglobin**
5. What happens after hemoglobin combines with oxygen in the lungs?
   **(1) Oxygen is released to cells in the body**
6. Why are red blood cells unusual?
   **(1) They have no nuclei**
7. What is the main function of white blood cells?
   **(1) Fight disease**
8. For every white blood cell, how many red blood cells are there?
   **(1) 6,000**
9. Platelets are an important part of what process?
   **(1) Stopping/Minimizing blood flow/loss from wound; clotting**
10. Platelets begin chemical reactions to produce which protein?
    **(1) Fibrin**

Inference

1. What would happen if blood did not contain white blood cells and bacteria was introduced to the body?
   **(1) The body would not be able to fight off the bacteria/disease; get sick**
2. What would happen to the blood flow from a wound if the body had no fibrin?
   **(1) No clotting/bleeding would not stop** because fibrin forms a meshwork of microscopic fibers that trap blood cells and create a clot to stop bleeding.
3. Which blood component is most dependent on water?
   **(1) Plasma** (plasma is 90% water)
4. An iron deficiency would be most harmful to what blood component?
   **(1) Red blood cells**

APPENDIX M

HUMAN EAR SHORT ANSWER QUESTIONS AND ANSWERS

**The Human Ear**

Verbatim

1. What are sound waves?
   **(1)** Mechanical **vibrations of air molecules** which move at a regular pattern (writing only "vibration" is not specific enough)
2. What is the function of the outer ear?
   **(1) Focus/concentrate sound waves**
3. What can the body do to assist in the pick-up of sound waves?
   **(1) Orienting the ear towards a sound**
4. What happens when sound waves get to the end of the auditory canal?
   **(1)** They **strike the tympanic membrane/eardrum**
5. What happens to the vibrations of the eardrum?
   **(1)** They are **transmitted through the middle** ear by a series of very small bones
6. What are the names of two of the three small bones in the ear?
   **(1) Malleus** /hammer, **Incus** /anvil, **Stapes** /stirrup (must have 2 of 3)
7. What is the inner ear called?
   **(1) Cochlea**
8. What happens at the cochlea?
   **(1) Sound vibrations are translated/turned into nerve signals**
9. What is the basilar membrane?
   **(1) Flexible membrane lined with hairs**
10. What happens when a hair on the basilar membrane is stimulated?
    **(1) Neural signal is sent** to the cerebrum for interpretation.

Inference

1. What would be the consequences of having all the hairs on the basilar membrane be the same length?
   **(1) A range of sound would not be detectable** because longer hair cells respond to low frequency sounds and shorter ones to high frequency sounds.
2. Fluid can accumulate in the auditory canal. What would fluid in the canal prevent from vibrating as normal?
   **(1) Tympanic membrane/eardrum**
3. Why is the basilar membrane lined with flexible hairs?
   **(1) Allows the hairs to respond/vibrate to send a neural signal**

4. Do neural signals play a key role in the transmission of sound from the tympanic membrane to the middle ear?
   **(1) No** (sound is still sound waves at this point)

CURRICULUM VITAE

DAVID B. BELLINGER

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## EDUCATION

*Ph.D., Experimental Psychology*
*M.S., Experimental Psychology*
University of Louisville (Louisville, KY), 2012 – 2016
Specialization: Cognitive and Developmental Sciences
Advisor: Marci S. DeCaro, Ph.D.

*M.S., Sport Studies*
Miami University (Oxford, OH), 2006 – 2008
Specialization: Sport Behavior and Performance
Advisor: Robin S. Vealey, Ph.D.

*B.S., Psychosocial Kinesiology*
Texas Christian University (Fort Worth, TX), 2002 – 2006
Minors: Psychology and Sociology
Advisor: Matthew S. Johnson, Ph.D.

## PUBLICATIONS

**Bellinger, D. B.**, DeCaro, M. S., & Ralston, P. A. S. (2015). Mindfulness, anxiety, and high-stakes mathematics performance in the laboratory and classroom. *Consciousness and Cognition, 37*, 123-132. http://dx.doi.org/10.1016/j.concog.2015.09.001

**Bellinger, D. B.**, Honken, N. A., & Ralston, P. A. S. (2015). Exploring the impact of test anxiety on performance and retention of first year engineering students. Paper published in the conference proceedings for the annual meeting of the American Society for Engineering Education (North Central Section), Cincinnati, OH.

**Bellinger, D. B.**, Budde, B. M., Machida, M., Richardson, G. B., & Berg, W. P. (2009). The effect of cellular telephone conversation and music listening on response time in braking. *Transportation Research Part F: Traffic Psychology and Behaviour, 12*, 441-451. http://dx.doi.org/10.1016/j.trf.2009.08.007

## CONFERENCE PRESENTATIONS

**Bellinger, D. B.**, & DeCaro, M. S. (2015). *What makes generation a desirable difficulty? Comparison of two appropriate processing frameworks*. Poster presented at the annual meeting of the Psychonomic Society, Chicago, IL.

**Bellinger, D. B.**, DeCaro, M. S., & Ralston, P. A. S. (2015). *Mindfulness, anxiety, and mathematics performance in the laboratory and classroom.* Lecture presented at the annual meeting of the Midwestern Psychological Association, Chicago, IL.

**Bellinger, D. B.**, Honken, N. A., & Ralston, P. A. S. (2015). *Exploring the impact of test anxiety on performance and retention of first year engineering students.* Paper presented at the annual meeting of the American Society for Engineering Education (North Central Section), Cincinnati, OH.

**Bellinger, D. B.**, DeCaro, M. S., & Ralston, P. A. S. (2015). *Mindfulness benefits exam performance by reducing test anxiety.* Poster presented at the annual meeting of the Society for Personality and Social Psychology, Long Beach, CA.

**Bellinger, D. B.**, & DeCaro, M. S. (2014). *Gestalt-enhanced illustrations and learning from scientific text: The role of cognitive load.* Poster presented at the annual Midwestern Cognitive Science Conference, Dayton, OH.

Altairi, M. A., **Bellinger, D. B.**, DeCaro, M. S., & Ralston, P. A. S. (2014). *The impact of mindfulness and test anxiety on academic performance*. Poster presented at the Kentucky Honors Roundtable Conference, Bowling Green, KY.

**Bellinger, D. B.**, & DeCaro, M. S. (2013). *Learning from scientific illustrations: Do Gestalt principles matter?* Poster presented at the annual meeting of the Psychonomic Society, Toronto, ON.

Smith, M. A., **Bellinger, D. B.**, DeCaro, D. A., & DeCaro, M. S. (2013). *Does focusing on mastery goals reduce the effects of performance pressure?* Poster presented at the University of Louisville Undergraduate Research Symposium, Louisville, KY.

Pfenninger, G., Cheadle, C., Carlson, E., & **Bellinger, D. B.** (2010). *From striving to surviving to thriving: The development of a private consulting practice.* Symposium conducted at the annual meeting of the Association for Applied Sport Psychology, Providence, RI.

**Bellinger, D. B.**, Carlson, E., Lesyk, J., Pfenninger, G., & Walker, B. (2009). *Establishing a full-time consulting business: It's possible, but how?* Symposium conducted at the annual meeting of the Association for Applied Sport Psychology, Salt Lake City, UT.

**Bellinger, D. B.** (2008). *Performance consulting group: The triumphs and trials of a student-based consulting service.* Lecture presented at the Midwest Sport & Exercise Psychology Symposium, Champaign, IL.

Vealey, R. S., & **Bellinger, D. B.** (2007). *Sport psychology: Field of dreams?* Coleman Griffith lecture presented at the annual meeting of the Association for Applied Sport Psychology, Louisville, KY.

## TEACHING EXPERIENCES

| University (Department) | Position title (Years) | Undergraduate course title | Frequency |
|---|---|---|---|
| University of Louisville (Psychological & Brain Sciences) | Graduate teaching assistant (2015-2016) | Quantitative methods in psychology | 2 |
| | (2015) | Human memory: A user's guide | 1 |
| | (2015) | Experimental psychology | 1 |
| | (2014) | Child development | 1 |
| | (2014) | Sensation and perception | 1 |
| Texas A&M University – Central Texas (Psychology & Counseling) | Adjunct professor (2010-2011) | Sport psychology | 3 |
| Miami University (Kinesiology & Health) | Instructor (2006-2008) | Weight training | 2 |
| | | Marathon training | 1 |
| | | Triathlon training | 2 |
| | | Racquetball | 4 |

## GUEST LECTURES

Why students forget most of what they learn and what to do about it (Fall 2015)
Cognition in education: Improving retrieval from long-term memory (Fall 2015)

## BUSINESS & CONSULTING EXPERIENCES

2009 – 2012
*Comprehensive Soldier Fitness – Performance & Resilience Enhancement Program* (Fort Hood, TX)
Conducted needs assessments with unit leadership, provided performance psychology education to entire unit in a classroom setting, facilitated application of mental skills during field training exercises, accelerated skill mastery during individual meetings with Soldiers, and collaborated with researcher team to examine performance psychology in the military

2010 – 2012
*Performing Minds* (Georgetown, TX)
Created and registered the business, delivered psychological skills training to athletes, coaches, and parents, managed finances (e.g., budgets, expenses, taxes), created marketing materials (e.g., website, business cards), and completed the client sales/retention process

*2008 – 2009*
*Excellence in Sport Performance* (Pleasanton & Walnut Creek, CA)
Facilitated team captains' leadership course, conducted team building exercises, provided psychological skills training to athletes, established a second office to geographically expand our region of service delivery, produced marketing materials (e.g., website content and design, electronic and print ads, brochures, quarterly newsletters), promoted services by attending athletic events, and managed the client sales/retention process

*2008*
*Evert Tennis Academy – International Management Group (IMG)* (Boca Raton, FL)
Developed and implemented a periodized mental conditioning program that applied psychological techniques to tennis, delivered 114 hours of group presentations and 58 hours of individual athlete consultations

## HONORS & DISTINCTIONS

Graduate Teaching Assistantship, Department of Psychological & Brain Sciences, University of Louisville, 2014 – 2016

Graduate Research Fellowship, Department of Psychological & Brain Sciences (Learning & Performance Lab), University of Louisville, 2012 – 2014

Graduate Teaching & Research Assistantship, Department of Kinesiology & Health, Miami University, 2006 – 2008

*cum laude*, Texas Christian University, 2006