“SIMPLE AS DO RE ME, ABC”: LANGUAGE, MUSIC, AND WORKING MEMORY

By Ryan P. Atherton

The present study examines the underlying cognitive framework involved in the active processing of information. Active processing takes place in working memory, popularly associated with Baddeley and Hitch’s (1974) multicomponent working memory model. According to this model, incoming information from the environment is temporarily stored to perform verbal and nonverbal tasks. Information is stored in one of two formats: visuospatial or phonological. Important to the present experiment is phonological information. Phonological information refers to the sounds of language (e.g., speech), that occur in a phonological store and are maintained there by rehearsal via an articulatory loop. Yet, the storage of phonological information in the multicomponent working memory model does not account for all auditory information (e.g., music). Research investigating this discrepancy has produced inconclusive findings. Whether or not phonological and non-linguistic auditory information share a structure for storage in working memory is still unknown.

The current study benefits from the utilization of an auditory interference task to help rectify this inconsistency.

Results indicate that linguistic and musical information do not completely share a storage mechanism in the multicomponent working memory model, however, they are not completely separate either. Also, musicians and non-musicians may exhibit different cognitive underpinnings in the storage of linguistic and musical information.

Keywords: language, music, phonological loop, storage, working memory

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by

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For Mom: From childhood to adulthood you have nurtured, guided, and embraced any endeavor I have taken on with the same vigor and pride that any son could succeed with. May this accomplishment make you proud.

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Whether it is taking part in a conversation, listening to a song, or reading a book, people need to engage in complex comprehension and reasoning to make sense of the vast array of incoming information coming into awareness. For example, when watching television a person needs to concurrently organize the sights and sounds entering the brain in order to achieve a coherent, meaningful experience. The general ability to accomplish this task is afforded by a cognitive architecture that supports both the temporary storage and active processing of information. This collection of cognitive abilities is generally referred to as “working memory.”

The leading model that describes the nature of working memory is the multicomponent working memory model (Baddeley, 2000; Baddeley & Hitch, 1974). Essentially, working memory can be thought of as the “mental workbench” where information is stored, manipulated, and processed (Baddeley, 1992). Information that enters working memory can come from one of two sources: sensory information and information from long-term memory. Regardless of the source, information in working memory is represented and processed in one of two different formats: visuospatial or phonological. Visuospatial representations can consist of purely visual information (e.g., shape or color) or spatial information (i.e., the location of objects in three-dimensional space) and are generally based on visual inputs. By contrast, phonological information refers to representations based on the sounds of language. Both forms of information must be rehearsed, or silently repeated, to be processed in working memory.

An important question facing researchers is how exactly phonological information is rehearsed in working memory, and how that process might differ from the rehearsal of purely auditory information. Evidence suggests that instead of rehearsing acoustic information about words, actual phonological rehearsal is completed by rehearsing the motor movements needed to produce those sounds (Wilson and Emmorey, 1997; Wilson and Emmorey, 1998; Zatorre, Chen, and Penhune, 2007). In other words, phonological information from the environment enters working memory and activates the neural resources of the jaw, lips, tongue, etc. to mimic the information. A common instance that illustrates the relation between motor movements and thought is when a person's lips are moving while silently reading. Yet, an important question still remains: How can purely auditory information, which is simply making sense of detected vibrations collected by the ear (i.e., the physiological processing of sound), be processed in working memory?

According to the early versions of the working memory model other forms of sensory information (e.g., gustatory, tactile) are only capable of being rehearsed when they are processed in one of the above-mentioned formats (typically phonological). From a meta-cognitive standpoint this occurs because one must describe to themselves the sensations he or she is experiencing (e.g., tasting a spicy food and silently telling yourself, "This is too spicy"). Fitting with this notion, purely auditory information (such as music) could not be directly stored or processed in working memory because it has no phonological equivalent. However, a study by Williamson, Baddeley, and Hitch (2010) suggests that non-linguistic auditory information is processed in a manner similar to phonological information. Consequently, important questions remain regarding where this information is stored. The current investigation is designed to further explore the underlying storage mechanism(s) of phonological and non-linguistic auditory information in the multicomponent working memory model.

An Overview of Working Memory

The multicomponent working memory model is a theoretical system that provides a bridge between sensory input, long-term memory, and behavior (Figure 1). This model accounts for the active processing and temporary storage of incoming information. It is composed of several different core components: the central executive, phonological loop, visuospatial sketchpad, and episodic buffer. The central executive system directs the control of attention. Cognitive functions are planned and coordinated in this system by directing information to the appropriate sub-system for processing. There are two sub-systems in the multicomponent working memory model: the phonological loop and visuospatial sketchpad. Specifically, the phonological loop processes and stores phonological representations and the visuospatial sketchpad processes and stores visual and spatial representations. The final component of the multicomponent working memory model is the episodic buffer. This component acts as a link between different types of information. It integrates information from visual, spatial, or phonological domains and places it in a chronological sequence (e.g., organizing the details of a story or movie) (Baddeley, 2003a). Overall, the multicomponent working memory model can be viewed as the system that allows humans to experience complex thought.

Willingham (2001) provides a useful example of the functioning of the various components of the working memory model using the processing of a standard algebra problem. Imagine the problem (3+4)*2/3+(12/3). To solve this problem the central executive recruits the phonological loop to process the language-based characteristics of the numbers and symbols. In other words, the phonological loop is needed to silently read the problem (i.e., rehearsal). The phonological loop then activates information from long-term storage regarding the rules and factual content necessary to solve mathematical problems. The information is consequently processed according to the rules retrieved from long-term memory. Hence, processing the order of operations requires some of the information to be temporarily stored and rehearsed in the phonological loop to combine separate portions (i.e., the different sub-answers obtained through the order of operations) for the execution of presenting a final answer. While working through the problem the episodic buffer must be continually recruited to make a decision as to what has already been accomplished (i.e., the chronology of actions). This common example demonstrates the applicable nature of the multicomponent working memory model and why it is one of the most influential and accepted models of active cognitive processing (Baars & Franklin, 2003).

Phonological Information in Working Memory

Of particular interest to the present study is the phonological loop, which stores and processes information that has speech-based characteristics (i.e., language) (Figure 2). A common example of how information is processed in the phonological loop is during a conversation, in which spoken language must be encoded into meaningful information for comprehension to occur. The loop has two parts: a phonological store and an articulatory rehearsal process (Baddeley, 2003a & 2003b). The phonological store holds phonological information, while the articulatory rehearsal process continually rehearses information until it is no longer needed. In general, rehearsal is akin to sub-vocal speech, as it takes place by internally repeating information. Overall, information is stored in the phonological store of the phonological loop and that information must be continually rehearsed to retain it.

Two experimental findings help to illustrate the capabilities of the phonological loop. The phonological similarity effect refers to the fact that people have increased difficulty recalling letters and words that sound similar. For example, it is more difficult to recall “t, c, v, d, b, g” than “b, w, y, k, r, x” due to acoustic correspondence within the former group, but not the latter (Baddeley, 2003a; Conrad & Hull, 1964). This finding supports the notion that the format of information is indeed based on the sound code. In addition, the limited capacity of the phonological loop has been evidenced by the word-length effect. Specifically, the word-length effect is the negative correlation between the number of syllables in a word and accuracy of correct recall (Baddeley, Thompson & Buchanan, 1975). For instance, a list of five words with five syllables each will result in a lower percentage of correctly recalled words than a list of five words with one syllable each. Overall then, research has demonstrated the nature of information in the phonological loop (i.e., based on sound) as well as the fact that it is limited in capacity. However, research has only recently begun to investigate whether or not other types of information (e.g., non-linguistic auditory information) make use of the phonological loop and hence the articulatory rehearsal process.

Inherently, rehearsal is a covert mental operation and, as a result, is difficult to measure. Nonetheless, it is theorized that auditory speech information has direct access to the phonological store (Figure 2). This means that auditory speech information can directly access the phonological store, but it must be continually rehearsed to remain there. Evidence for this notion comes from research utilizing articulatory suppression. Articulatory suppression refers to studies designed to "block" the rehearsal mechanism of the phonological loop (Henry, 2011). For example, one study had participants recall phonologically similar words presented in a spoken format while repeating an irrelevant word (e.g., "the, the, the…") (Baddeley, Thomson, and Buchanan, 1975). The phonological similarity effect was exhibited when words were presented in a spoken format; hence, information presented in a spoken format can access the phonological loop without being rehearsed first. By contrast, when participants were also asked to recall phonologically similar words presented in a visual format, the phonological similarity effect was not observed. The knowledge that auditory speech information, but not visual information, can directly access the phonological loop raises an important question: how are other forms of information, such as non-linguistic auditory information, processed and stored in working memory?

Auditory Information in Working Memory

Research on non-linguistic auditory information in the multicomponent working memory model has traditionally used tones as stimuli. While the term is not well defined in the working memory literature, a tone typically refers to a single electronically-produced pitch presented outside of a musical context (e.g., melody or chord). One of the first studies to examine the processing of non-linguistic auditory information in working memory was completed by Deutsch (1970). Specifically, Deutsch sought to explore whether tonal and phonological information had separate storage areas. She presented participants with an initial tone followed by an interfering tone or word followed by a comparison tone. Participants were asked to indicate whether the comparison tone was the same as or different from the initial tone. Overall, participants performed worse if the initial and comparison tones were separated by intervening *tones* rather than *words*. Deutsch thus concluded that tonal and phonological information have separate storage areas – as the latter type of intervening stimulus (i.e., words) failed to interfere with the to-be-remembered information.

Semal, Demany, Ueda, and Halle (1996) sought to further investigate this logic and explore the findings of Deutsch (1970). In an effort to establish a framework to describe the storage of speech and non-speech information in working memory the researchers presented the "speech-specificity hypothesis" (Figure 3). This hypothesis has two primary accounts that differ in terms of the specific sub-systems that they postulate. According to the "strong" account, there are two separate pitch memory stores, one for speech sounds and one for non-speech sounds. The "weak" account also posits that there are two pitch stores, one for speech sounds and the other (the "universal" store) for *both* speech and non-speech sounds. In other words, the "universal" store processes and maintains the acoustic characteristics of speech and non-speech sounds (e.g., intonation). If the store recognizes a speech sound it is transferred to the sole speech store for general phonological processing (e.g., semantic recognition). Once this is accomplished, the sole speech store can independently process and store speech sounds while non-speech sounds continue to be maintained in the universal store. Overall, the "strong" account coincides with the results of Deutsch (1970), as both suggest that phonological information (i.e., speech) and non-linguistic auditory information (i.e., non-speech sounds) are stored in completely separate areas in working memory. On the contrary, the "weak" account proposes that phonological information and non-linguistic auditory information share a storage area in working memory.

Hence, the "speech-specificity hypothesis" provides a framework through which to test whether speech and non-speech sounds are stored in similar or distinct areas of working memory.

Thus, the researchers conducted two experiments to test the "speech-specificity hypothesis." Similar to Deutsch (1970), participants heard an initial stimulus (a tone in Experiment 1 and a word in Experiment 2), listened to intervening sounds (tones or words), and then heard a comparison sound of the same type presented initially. In contrast to the method used by Deutsch (1970), however, the intervening tones and words were presented according to planned sound frequencies (this information was not reported in Deutsch). A planned sound frequency refers to the use of tones that were experimentally controlled by measuring the distance, in hertz, between tones. This is important because Deutsch's findings may have been due to the similarity in frequency of the initially presented sound and intervening stimuli, which may have resulted in unintended interference. This interference could have been the primary reason for the results obtained by Deutsch (as opposed to their necessarily being two separate storage systems for phonological and tonal information). As in the Deutsch paradigm, participants were instructed to indicate whether the comparison sound was the same as or different from the initial stimulus. Results failed to support the "strong" version of the "speech-specificity hypothesis," which would predict that intervening words would not affect the recall of the initial tone because words and pitches are located in completely separate pitch stores. Instead, results indicated that an intervening speech sound interfered with tonal recall (Experiment 1) and intervening tone sounds interfered with word recall (Experiment 2). Taken together, these results suggest that, contrary to the "strong" account and the findings of Deutsch, there may be shared storage of phonological and tonal information in working memory. Evidence regarding the "weak" account of the "speech-specificity hypothesis" has emerged in more recent studies, as well.

Specifically, Williamson, Baddeley, and Hitch (2010) expanded on these results in a study comparing differences in retention of sound information using non-musicians and musicians. According to the authors, it is important to study both musicians and non-musicians in the same study, as it is possible that the two process musical information in different ways. In this study, the pitch of the stimuli (whether word or tone) was directly examined in order to determine if it is the mere presence of phonological interfering information (or tonal information, depending on the condition) that disrupts recall, or the similarity of the frequency of the presented sounds that disrupts recall. This was accomplished by studying the "pitch-proximity" effect. The "pitch-proximity" effect refers to the finding that tones close together (i.e., pitch-proximal) are recalled with less accuracy than tones that are further apart (i.e., pitch-distal) – a finding akin to the phonological similarity effect. Thus, this study further examined auditory information in an effort to understand the differences between musicians and non-musicians' working memory faculties, as well as further investigate the similarities and differences of phonological information relative to non-linguistic auditory information.

Studied together, musical expertise and the pitch-proximity effect could offer further insight into the storage of non-linguistic auditory information. Particularly, this study used tones that were based upon frequencies characteristic of musical notes. Hence, unlike standard tonal information, musical information directly references notes, chords, etc. If there is shared storage between musical and phonological information, pitch proximity should affect recall of both types of information in an interference/recall paradigm. This would also provide evidence in favor of aspects of the “weak” account of the speech-specificity hypothesis (one speech store for speech sounds and one universal store) – as it would imply that sounds of both types of information would be similarly maintained in a “universal” store.

Indeed, results with non-musicians support the shared storage of phonological and musical information in working memory. Over a series of three experiments non-musicians demonstrated a pitch proximity effect that was comparable to the phonological similarity effect. In other words, musical information was subject to the same cognitive difficulties as phonological information. Sounds that were proximal (i.e., similar or “close together”) were more difficult to accurately recall than sounds that were distal (i.e., different or “further apart”) – much like the phonological similarity effect, suggesting that musical and phonological information are stored in similar areas in the brain.

Interestingly, while both the phonological similarity and pitch proximity effects were observed in non-musicians, the pitch proximity effect was not demonstrated in musicians. This suggests that the cognitive architecture may differ between musicians and non-musicians, a finding consistent with evidence that indicates that there are anatomical brain differences between these two groups of people (e.g., Schlaug, Jancke, Huang, Staiger, & Steinmetz, 1995). Unfortunately, however, it is not possible to determine if these differences in performance on working memory tasks are consistent enough to draw definite conclusions (Keenan, Thangaraj, Halpern, & Schlaug, 2001). Specifically, the limited research on this topic has not consistently used the same tasks or guidelines for distinguishing a musician from a non-musician. That said, the critical conclusion from this study remains the same: the existence of the “pitch-proximity effect" in non-musicians supports the notion that musical and phonological information share storage in the phonological loop of the multicomponent working memory model.

The Present Study

In general, there is a limited amount of empirical research investigating the storage mechanisms of linguistic (i.e., phonological) and musical (i.e., non-linguistic auditory) information in working memory. Overall, the research that has been done has provided conflicting results. Some research has supported the shared storage of phonological and purely auditory information in the multicomponent working memory model (Salame & Baddeley, 1989; Semal et al., 1996; Williamson et al., 2010), while other research suggests completely separate storage mechanisms (Berz, 1995; Deutsch, 1970). These conflicting results appear to occur for two different reasons. First, there are a number of problems with the stimuli that have been used in previous research, with some experiments using tonal information and others musical information. This is particularly problematic as there is no available evidence to suggest that tonal information is functionally equivalent to musical information. Along the same lines, the stimuli have not been properly controlled for in terms of similarity (e.g., the phonological similarity and "pitch-proximity" effects). Second, the study that has used the most conceptually accurate stimuli (Williamson et al., 2010) suffers from a methodological limitation. Specifically, the dependent measure used across all three experiments was a serial recall task. Although this measure is frequently used as a measure of working memory capacity, its usefulness in determining the *location* of information in working memory has not yet been established. Thus, the present study seeks to clarify these conflicting results by improving on the experimental conditions used in Deutsch (1970), Semal et al. (1996), and Williamson et al. (2010). Specifically, the present study uses musical information as both the test and intervening stimuli (Deutsch, 1970 and Semal et al. 1996, only used tonal information) and a discrimination task as the final dependent measure (Williamson et al. 2010 used a serial recall task).

If linguistic and musical information are held in separate storage systems, then the two should not interfere with one another on a memory discrimination task. To investigate this idea, the present study implements a 2 (target stimulus: language vs. music) x 3 (interference type: language, music, silence) factorial design (Figure 4). The dependent measure of interest is the extent to which participants correctly identify the comparison stimulus as same or different than the originally presented stimulus. In addition, collected information on musical expertise will help to further define the nature of working memory storage differences between musicians and non-musicians.

Hypotheses

Utilizing working memory theory and previous research, it was hypothesized that:

1) Non-musicians will demonstrate lower accuracy scores in music conditions than in language conditions.
2) Musicians will demonstrate higher accuracy scores in music conditions compared to non-musicians.
3) Both non-musicians and musicians will demonstrate their highest accuracy scores in silence-interference conditions.

4) Both non-musicians and musicians will demonstrate their lowest accuracy scores in conditions where the intervening stimulus is the same format of information as the presented and comparison stimulus (i.e., language presented and language intervening, music presented and music intervening).
5) Both non-musicians and musicians will demonstrate accuracy scores lower than silence conditions but higher than same-format conditions in trials where the intervening stimulus is a different format of information as the presented and comparison stimulus (i.e., language presented and music intervening, music presented and language intervening).

Overall, this pattern of results would provide evidence that language and music share storage in the phonological loop of the multicomponent working memory model.

Method

Participants

A total of 99 introductory psychology students (35 males and 64 females) were administered the task. Participants signed up for the experiment via the University of Wisconsin Oshkosh participant recruitment software (SONA). Students completed the experiment for course credit. Table 1 displays an overview of the demographic information of participants.

Materials

Music stimuli were created by the experimenter and recorded on an iMac computer using chords generated from a Casio keyboard. The volume and length of the stimuli were then edited using the Audacity software program. Language stimuli consisted of monosyllabic words also recorded and edited using the Audacity software program on an iMac computer. Spoken words were matched in pitch corresponding to the music conditions to control for any acoustic confounds. Specifically, to avoid observing any pitch-proximity effects in the language stimuli, the words were recorded then matched to the musical frequencies used in the music conditions.

It is important to discuss the comparability of language and music stimuli before identifying the precise materials used. In principal, there is no direct comparison between language and music. For example, there is no musical equivalent to a noun or verb. Along the same lines, there is no linguistic equivalent to a musical sound. Hence, a comparison between language and music must be made at the conceptual level (Patel, 2008; 2012). Language and music are both hierarchically organized information and, as a result, one might expect similarity in terms of memorability. For example, proximal musical sounds and similar words should be processed and stored similarly in working memory. Furthermore, distal and dissimilar sounds and words, respectively, should require less working memory resources for storage because there would be no cognitive overlap in terms of their processing. In other words, distal or dissimilar intervening stimuli should ease the difficulty of a discrimination task between proximal or similar targets. Thus, the conceptual comparison of language and music justified the use of similar/dissimilar words and proximal/distal sounds for the present study.

Language Stimuli

Language stimuli were selected primarily from a list of phonologically similar and dissimilar words used by Coltheart (1993). The pool of words reported by Coltheart (1993) were shown to significantly display the phonological similarity effect, so it was assumed they would demonstrate the same pattern in the present study (see Appendix A for the full list of words used by Coltheart (1993)). Words were randomly presented and consisted of nine monosyllabic, 3-letter target words. Intervening language stimuli consisted of four randomly presented monosyllabic, 3-letter phonologically dissimilar words. Comparison language stimuli were also randomly presented, and consisted of either the same word as the test word or one of two monosyllabic, 3-letter phonologically similar words, in reference to the target word (Figure 5).

Music Stimuli

As discussed previously, musical information, versus tonal information, must reference specific musical notes, chords, etc. (versus generic noise frequencies); this was accomplished by utilizing the organization presented in the Circle of Fifths (Figure 6). The Circle of Fifths is a circular visual representation that exhibits the harmonic relationships between the major and minor chords of the chromatic scale. Music stimuli consisted of 9 randomly presented major chords located on the circle of fifths. Intervening chords were displayed in a randomized order for each trial. These chords were chosen based on their distance from the target chord on the circle of fifths. Specifically, the intervening chords were the following number of turns from the target chord on the circle of fifths: 4 turns clockwise, 5 turns clockwise, 4 turns counter-clockwise, and 5 turns counter-clockwise (all distal). Comparison chords were the same chord or a chord that is different from the target by either 2 turns clockwise or 2 turns counter-clockwise (both proximal) from the target chord on the Circle of Fifths (Figure 7).

Questionnaires

Demographic information was collected using a write-in questionnaire (see Appendix B) and used to conduct exploratory analyses of the impact of various characteristics (e.g., age) on performance. In addition, an adapted music background questionnaire originally developed by Dunleavy (2000) was administered to examine the effects of musical expertise (see Appendix C). Both questionnaires were presented at the end of the experiment in order to prevent self-fulfilling effects (i.e., noting that you are not a musician could result in poorer performance for musical stimuli) or hinting at the goals of the experiment.

Procedure

General Task

Participants entered a campus computer lab and sat down in front of a computer with the monitor turned off. Upon arrival, the experimenter instructed the participants to sit at a computer station with a folder on it. The folder contained, in order: 2 consent forms, instructions, answer sheets, demographics questionnaire, music background questionnaire, and debriefing script. Participants were instructed to not open the folder or turn on the computer. When it was time to begin the session the experimenter instructed participants to open the folder in front of them and only read the top sheet, which was the informed consent form (see Appendix D). Next, the experimenter told participants to turn the signed consent form over and set it next to themselves. Participants were told that the next sheet (a copy of the consent form) was for them to keep. The experimenter then read aloud the instructions to participants as they silently read along (see Appendix E). Crucially, the experimenter instructed them to ignore any intervening sounds or silence – the primary goal was to simply judge whether or not an initially presented word or musical chord was the same as or different from a referenced word or musical chord. Participants then completed 12 practice trials (2 trials each, of the to-be-discussed 6 total conditions). The main experiment followed the practice trials. Upon completion participants filled out both the demographic information and musical background questionnaires. The experimenter then read aloud a final debriefing script (see Appendix F) as participants silently read along that explained the full aims of the experiment and answered any final questions.

Main Experiment

Practice Trials

A total of 12 practice trials were completed in an effort to familiarize participants with the experimental procedure. Furthermore, only data from participants that scored better than chance (i.e., a score of 7 correct or more) were included in the final analyses. This resulted in the exclusion of 10 participants' data. Thus, the practice trials served as a covert filter to eliminate participants that may have struggled with the task for one reason or another (e.g., hard-of-hearing participants). Participants received 2 trials of each of the experimental conditions (e.g., language-silence, language-language, language-music, music-silence, music-language, and music-music). As the practice trials were essentially identical to the experimental trials, a complete description of the task is provided in the next section.

Experimental Trials

Participants were tested in groups of 24-29 in campus computer labs. Two very similar campus computer labs were used. Both had approximately 30 computers on tables with office chairs in front of them. Speakers were placed at one end of the lab facing all of the participants. Each lab had a separate set of the same type of speakers that were connected to an iPod preloaded with the necessary auditory stimuli. The volume was the same for every session (i.e., 70% of maximum volume) with no participants indicating during debriefing that he or she could not clearly hear the stimuli.

The initial tonal beep, signifying the start of each trial, was played for 750 milliseconds, followed by 250 milliseconds of silence. Next, the initial stimulus was played for 750 milliseconds, also followed by 250 milliseconds of silence. At this point, the intervening stimulus phase of the trial began. This phase lasted 6 seconds total. It began and ended with 1 second of silence. Between the moments of silence was the onset of the intervening stimuli. Four separate chords or words (depending upon the condition) each displayed for 750 milliseconds, followed by 250 milliseconds of silence before the onset of the next stimulus, were presented in the experimental conditions. If it was the control condition the intervening phase would simply be 6 seconds of silence. Following the last second of silence the comparison phase began. A comparison word or chord was then played for 750 milliseconds, followed by 250 milliseconds of silence, as in the initial stimulus presentation phase. Finally, 5 seconds of silence were provided for participants to record their responses. Participants were required to indicate whether they thought the comparison stimulus was the same as or different from the initial stimulus by circling the appropriate word on their answer sheet (Appendix G). The task ended when the 5 seconds elapsed, and then the next trial began.

Each participant completed 162 trials (not including practice trials), divided evenly as 27 tasks per condition (6). Every participant encountered each music and language target stimulus, with either a music, language, or silence intervention, and the same or 1 of 2 different comparison stimuli. Hence, every condition included 27 tasks divided amongst 9 possible stimuli and 3 possible comparisons. To avoid fatigue effects participants were granted 5 minutes for a break after experimental trial number 80. The complete time to complete a session was approximately 60 minutes. The research was conducted in accordance with Ethical Principles and Code of Conduct of the American Psychological Association (APA) (1992) and Institutional Review Board protocol (Appendix H).

Results

All data were collected, scored, and entered by the experimenter. Data was analyzed using SPSS software. Again, ten participants were excluded due to not meeting the practice score criteria.

Demographic Information

In total, 78 participants were included in analyses for non-musicians and 11 participants were included in analyses for musicians. A participant was coded as a musician following the recommendations of Cohen, Evans, Horowitz, and Wolfe (2011) and Schlaug (2003). The two qualifications for categorization as a musician were:

1) 10+ years of formal (e.g., private) music lessons.
2) 15+ hours of practice on an instrument per week over the past month

Table 1 displays the relevant demographic information. Non-musician participants were 72% female, 81% Caucasian, 14% Asian, 5% African-American, and 1% Hispanic. Musician participants were 82% female, 73% Caucasian, 18% Asian, 9% African-American, and 0% Hispanic. Non-musician participants were an average of 20.46 years of age with a minimum age of 18 and maximum of 48. Musician participants were an average of 19.27 years of age with a minimum age of 18 and maximum of 22.

Non-musicians

A Pearson chi-square was conducted to determine whether there was a difference in the discrimination accuracy (percentage correct) of intervening stimuli (i.e., silence, language, music) between presented and comparison stimuli (i.e., language and music) in non-musicians. Chi-squares are the statistical procedure of choice when both variables are categorical. In addition, due to the fact that frequency data were present for both variables this statistical procedure was viewed as the most advantageous test to use. Finally, the available sample size per cell was more than five due to the large number of observations. Thus, the assumptions for utilizing a chi-square were met.

In an attempt to investigate whether different forms of auditory stimuli interfere with the accuracy of discriminating information presented in a similar or different format participants were presented with six conditions. The six conditions, first presented/comparison stimulus then intervening stimulus were: language-silence, language-language, language-music, music-silence, music-language, and music-music (see Table 2). Hence, each participant was exposed to all types of information. Results suggest that accurate recall of the originally presented auditory stimulus does indeed depend on the nature of the intervening stimulus, $\chi^2(2) = 13.55$, $p < .01$, Cramer's V = .04.

Given the omnibus nature of the Pearson chi-square test, individual follow-up comparisons were conducted. As per the recommendations of Gardner (2001), one-to-one chi-square tests were conducted with a Bonferroni corrected alpha level so as to limit the potential for type I error. It must be noted that when accounting for the Bonferroni corrected alpha level ($p < .001$) only the language-silence vs. language-language, music-silence vs. music-music, and language-music vs. music-music conditions exhibit significant differences. However, the Bonferroni adjusted alpha level is a conservative estimate and, taking that into account, only the language-silence vs. language-music and language-language vs. language-music conditions were not significant.

Does Intervening Information Disrupt Memory Performance?

In general, it had to first be concluded that the intervening information actually disrupted memory performance. Specifically, performance in the language-silence condition (92.2%) was more accurate than in the language-language condition (81.8%), $\chi^2(1) = 12.97$, $p < .001$. Likewise, performance in the music-silence condition (85.7%) was more accurate than in the music-music condition (72.7%), $\chi^2(1) = 22.51$, $p < .001$. Taken together, these results indicate that intervening information that matches that of presented information does in fact disrupt recall. A similar pattern of results was found when comparing performance in interference mismatched conditions (e.g., music-language) to the silence control conditions. Specifically, performance in the music-silence condition (85.7%) was more accurate than in the music-language condition (78.3%), $\chi^2(1) = 7.05$, $p < .01$. Along those same lines, performance in the language-silence condition (92.2%) was more accurate than in the music-silence condition (85.7%), $\chi^2(1) = 4.94$, $p < .05$. Overall, these results suggest that information in conditions with no intervening information (i.e., silence) was recalled with greater ease than conditions with either the same or different intervening information.

Does “Matched” Interfering Information Disrupt Memory to a Greater Extent than “Mismatched” Interfering Information?

The critical data for the present study concerns interference effects for "mismatched" information; in other words, does phonological information disrupt memory for musical information and vice versa? Performance in the language-language (81.8%) condition was less accurate than in the language-music condition (89.7%), $\chi^2(1) = 7.72$, $p < .01$. Similarly, performance in the music-music condition (72.7%) was less accurate than in the music-language condition (78.3%), $\chi^2(1) = 4.38$, $p < .05$. Taken together, these results suggest that "type matched" intervening information disrupts recall more so than "type mismatched" intervening information. Also, it appears that the intervening music stimuli did not adequately interfere with the language stimuli, but the intervening language stimuli did adequately interfere with the music stimuli. Thus, of critical importance, phonological and musical information were not immune to "mismatched" intervening information in a mutually exclusive manner, leading to the conclusion that there is a degree of overlap for linguistic and musical information in working memory.

Musicians

A Pearson chi-square was conducted to investigate the previously mentioned associations on the subset of participants that were determined to be "musicians" (see Table 3). The result was not statistically significant, $\chi^2(2) = 0.78$, *ns*, Cramer's V = .02, though this is likely an artifact of the small sample size (n=11). Due to the fact that an omnibus test did not detect a difference, follow-up comparisons were not conducted. An inspection of the discrimination accuracy percentages, though, does reveal some useful information open to speculation. Specifically, performance in the language-silence condition was 92.9%, language-language condition 84.5%, and language-music condition 89.9%. Similarly, performance in the music-silence condition was 91.2%, music-language condition 86.5%, and music-music condition 82.5%. Hence, intervening information disrupted accurate judgment of presented information most effectively in matched format conditions (e.g., language-language and music-music). Conditions with mismatched formats (e.g., language-music and music-language) did not seem to disrupt accurate recall as much as same format conditions. Consider first the data for when the initial stimulus was a linguistic stimulus. Relative to the silence baseline, musicians were less disrupted by the musical interference (3.0% decrease) than the linguistic interference (8.4% decrease). Likewise, when the initial stimulus was a musical stimulus, musicians were less disrupted, relative to the silence baseline, by the linguistic interference (4.7% decrease) than the musical interference (8.7% decrease). These particular differences were seemingly more exaggerated in non-musicians. Thus, it would seem as though musicians may possibly house different working memory capabilities than non-musicians.

Discussion

Before reviewing the hypotheses of the current investigation and whether or not they were supported, it is important to first describe the theoretical results that would be predicted to fit the notion that there are completely shared and completely separate storage areas for linguistic and musical information in working memory. Additionally, it is important to note that these theoretical results are only one way of viewing them. Furthermore, these theoretical results assume that linguistic and musical information share functional equivalence. If there is complete overlap for the storage of linguistic and musical information then each form of information should interfere (i.e., produce lower performance scores) with the other in an equal manner (see Table 4). In other words, linguistic information should interfere with musical information and musical information should interfere with linguistic information to the same extent as linguistic-linguistic and musical-musical information pairings. Of course, overall, accuracy scores in conditions with musical information as the presented sound should be slightly less accurate than conditions utilizing language due to participants overall familiarity and expertise with language. This prediction holds true regardless of whether or not phonological or musical information serve as intervening stimuli.

Contrarily, if there are completely separate storage components in working memory for linguistic and musical information then each form of information should not interfere (i.e., not produce lower performance scores) with the other (see Table 5). In other words, neither linguistic-musical or musical-linguistic information pairings should result in interference. Rather, those conditions should demonstrate similar performance scores compared to no interference (i.e., conditions with silence as intervening information) conditions. However, interference should be observed in both the language-language and music-music conditions.

Interpretations in Relationship to Hypotheses

Different Versus Shared Storage

The primary aim of the current study was to provide empirical evidence in regard to whether or not linguistic and musical information share storage in working memory. Indeed, the present investigation accomplished this as seen by confirmation in non-musicians of hypotheses 3 ("Both non-musicians and musicians will demonstrate their highest accuracy scores in silence-interference conditions"), 4 ("Both non-musicians and musicians will demonstrate their lowest accuracy scores in conditions where the intervening stimulus is the same format of information as the presented and comparison stimulus"), and 5 ("Both non-musicians and musicians will demonstrate accuracy scores lower than silence conditions but higher than same-format conditions in trials where the intervening stimulus is a different format of information as the presented and comparison stimulus"). Specifically, non-musicians demonstrated their highest accuracy scores in silence-interference conditions, lowest accuracy scores in "matched" conditions (e.g., language-language), and scores in "mismatched" conditions (e.g., language-music) lower than silence conditions but higher than "matched" conditions. Thus, the current results support the conclusion that linguistic and musical information do indeed share storage in working memory. Furthermore, while controlling for the phonological similarity and "pitch-proximity" effects there is a degree of overlap for linguistic and musical information in working memory. Overall, then, linguistic and musical information do not completely share storage nor have completely separate storage mechanisms in the phonological loop of the multicomponent working memory model.

The present study contradicts the interpretation of Deutsch (1970). Deutsch utilized an auditory interference task with tones to conclude that linguistic and musical information have completely separate storage mechanisms. A possible reason for the contradiction has to do with the nature of the materials used in each study. In the current investigation linguistic information was used as a presented/comparison stimulus. By contrast, Deutsch (1970) only used linguistic information as an intervening stimulus (musical information was always presented for comparison). It is also worth noting that auditory, non-linguistic stimuli also differ between the two experiments, with musical chords being used in the present study and tones being used in Deutsch (1970). In other words, the results obtained from the tonal stimuli were generalized to phonological information. This is important because, as previously mentioned, it is unknown whether or not tonal information can be functionally generalized to musical information. Thus, it would seem as though the present study provides more robust evidence for a degree of overlap in storage of linguistic and non-linguistic auditory information in working memory.

However, the present results are in accord with more recent research investigating processing resources and working memory. Specifically, the current results are similar to those reported by Semal et al. (1996). That study was an improvement over the Deutsch (1970) study in that presented/comparison stimuli included linguistic stimuli. However, there were several problems with the linguistic stimuli used in Semal et al. (1996) that have been addressed in the current investigation. First, the authors used a limited number of words – which may have led to participants learning the information and not actually discriminating the presented stimuli. In addition, there was no clear theoretical rationale for which words were chosen as the experimental stimuli. By contrast, in the current study words were selected from a list that had previously demonstrated the phonological similarity effect. This is an important distinction because interference in the Semal et al. method could be attributed to semantic similarity; the present study strips the results down to basic auditory processing of the information. Also, this allowed for controlled manipulation of linguistic information, which helps for future generalization of the research. Thus, the current study offers a more refined approach to the investigation of auditory information in working memory. Yet, Semal et al. (1996) obtained results in support of a weak version of their speech-specificity hypothesis, in which language and music operate in parallel within a universal store. The present results (i.e., language interfering with music) support those findings, in that there must be a combined store for linguistic and non-linguistic auditory information in working memory.

Likewise, the present study obtained results similar to Williamson, Baddeley, and Hitch (2010). Williamson et al. investigated the storage and capacity of tonal memory between musicians and non-musicians. Their results supported a degree of overlap for phonological and non-linguistic auditory information in working memory. However, these results were obtained using a serial recall task. By contrast, the present results were found using a discrimination task. This paradigm has the results of solely investigating the location of storage for information, whereas the method used by Williamson et al. more specifically speaks to the capacity of information in working memory (i.e., how many items can be accurately recalled in the order presented). Thus, the current results demonstrate similar findings using a different paradigm and, as a result, provide more robust evidence for a shared storage in working memory for linguistic and musical information.

Musical Background

A secondary aim of the present study was to clarify any differences in the working memory capabilities of musicians versus non-musicians. In particular, hypotheses 1 ("Non-musicians will demonstrate lower accuracy scores in music conditions than in language conditions") and 2 ("Musicians will demonstrate higher accuracy scores in music conditions compared to non-musicians") were directed toward this query. Indeed, it was found that non-musicians demonstrated lower accuracy scores in music conditions than in language conditions and musicians demonstrated higher accuracy scores in music conditions compared to non-musicians. These results imply that musical training would improve the accuracy scores for non-musicians in the music conditions. Overall, these results correspond with previous research that suggests musical training could improve working memory capabilities (Lee, Lu, & Ko, 2007).

Related Neurological Evidence

In addition to the aforementioned behavioral evidence, the present study also pertains to neurological investigations of linguistic and musical information in working memory. Research in this area has produced differing results based on the method of investigation. Neuropsychological evidence, which is primarily based on case studies of patients with brain damage, has supported different storage mechanisms for both language and music. Specifically, evidence pertaining to this issue has been found in a patient suffering from amusia (impaired musical ability) without aphasia (impaired linguistic processing). After suffering from a series of strokes, patient, G.L., suffered bilateral temporal lobe damage (Patel, 2012; Peretz, 1993; Peretz et al., 1994). As a result, G.L. experienced a profound decrement in his ability to discriminate sounds presented in different keys. However, despite the presence of amusia, patient G.L. did not test positively to be aphasic. Thus, it was concluded that linguistic and musical information were domain-specific (i.e., stored in different regions).

However, recent neuroimaging research challenges these findings. Research has demonstrated that tasks that involve processing linguistic information activate the same regions of the brain that are involved with the processing of musical information. This correspondence between activation has been found with a variety of neuorimaging measures such as electrophysiological measures, fMRI (functional magnetic resonance imaging), and PET (positron emission tomography) scans (Brown, Martinez, & Parson, 2006; Koelsch et al., 2002; Patel, 2012; Tillmann, Janata, & Bharucha, 2003). The results from the present study are in accordance with this research in that they both favor shared storage mechanisms for language and music. However, the results from neuropsychological research should not be dismissed out of hand. Replicating the present study with participants exhibiting amusia and aphasia could certainly help to contribute to the existing literature in that it would tell us if phonological and musical information in working memory correspond to these deficits.

Limitations and Future Directions

Although the present study supports the existence of shared working memory resources for linguistic and musical information, several limitations should be mentioned. First, it was expected that the tasks of primary interest (e.g., discriminating between proximal auditory information) would be sufficiently difficult. However, participants demonstrated relatively above chance performance scores. By contrast, participants from Williamson, Baddeley, and Hitch (2010) demonstrated serial recall of similar tones around 60% correct and participants from Semal, Demany, Ueda, and Halle (1996) displayed accuracy rates of 65% for non-speech sounds and 70% for speech sounds in similar conditions (i.e., difference in pitch was small). Hence, the skill of participants was certainly underestimated due to the findings of previous research. Also, given the nature of the results (i.e., music did not seem to interfere with language as much as language interfered with music) task difficulty may have been compromised by participants' fluency with language versus music. Future research should increase task difficulty by implementing all phonologically similar words and proximal musical chords. In other words, the intervening stimuli were phonologically dissimilar words and distal musical chords; the implementation of all phonologically similar words and proximal musical chords would undoubtedly increase the difficulty of the task. This would magnify the differences between participants' accuracy (i.e., increase disparity between conditions) because the intervening stimuli would be more similar, thereby increasing discrimination difficulty, which would speak more broadly to the effects found in the present study.

Second, informal questioning at the end of the experiment indicated that a significant number of participants tired of the experiment task – despite a brief break halfway through the trials. Although performance did not seem to suffer (indeed, comparisons of the first half of trials versus the second half of trials indicates that performance did not suffer), such indifference may have differentially affected performance on more difficult trials (e.g., music-music). In other words, control conditions (e.g., silence as the intervening stimulus) would be easier to correctly answer with less attentional resources, whereas the more difficult trials require more. The differences between difficult and easy conditions may have been mediated by participants' attention. Future studies should attempt to diminish this concern by reducing the allotted answer time (e.g., from 5 to 2 seconds).

Finally, the current investigation contained a relatively small number of "musicians." Future research with a larger sample size will be needed to verify the tentative data from the current investigation which suggests that musical training may improve working memory performance. This relationship seems quite plausible upon review of previous research. It has been exhibited that working memory is related to general intelligence (*g*) (Conway, Kane, & Engle, 2003). Additionally, it has been demonstrated that music lessons may increase full-scale intelligence quotient (IQ) scores (Schellenberg, 2004). Hence, the mechanism of this relationship would be seen as: music training improves working memory performance which, in turn, increases one's IQ. Thus, future research should investigate task performance scores from the present study in relation to intelligence tests to examine this relationship.

Implications

If the limited data on musicians from the current study is indicative of a larger trend, the benefits are abundant. The data (e.g., musicians' higher scores in each condition) indicate that musicians may store information in a more efficient manner than non-musicians. To that end, studying music and music training may reap important benefits in terms of an individual's overall working memory ability. This is critical, as research has shown that working memory span is a reliable predictor of attentional control, problem-solving ability, and academic success.

Given the recent cuts on musical training in public education (e.g., Abril & Gault, 2009; Kratus, 2007; Major, 2012), it is imperative that research address the issue of the relationship between working memory span and linguistic and musical ability.

Conclusion

Do linguistic and musical information share storage mechanisms in the phonological loop of the multicomponent working memory model? Previous research has produced inconclusive findings in answer to this question. Utilizing an auditory interference task, the present study has produced results in favor of an unknown degree of overlap between phonological and non-linguistic auditory information. Future research should seek to further investigate the differences between musicians and non-musicians' processing of information in working memory.

Table 1

Demographic Information for Non-musicians and Musicians

	Mean Age (years)	Race (frequency)				Sex (frequency)	
		Caucasian	African-American	Asian	Hispanic	Male	Female
Non-Musicians	20.46	63	4	10	1	30	48
Musicians	19.27	8	1	2	0	2	9

Table 2

Accuracy Percentages for Non-musicians

	Silence	Language	Music
Language	92.2	81.8	89.7
Music	85.7	78.3	72.7

Table 3

Accuracy Percentages for Musicians

	Silence	Language	Music
Language	92.9	84.5	89.9
Music	91.2	86.5	82.5

Table 4

Theoretical Results if Language and Music Completely Share Storage in Working Memory

	Silence	Language	Music
Language	92	80	80
Music	87	70	70

Table 5

Theoretical Results if Language and Music Have Completely Separate Storage Mechanisms in Working Memory

	Silence	Language	Music
Language	92	80	92
Music	87	87	80

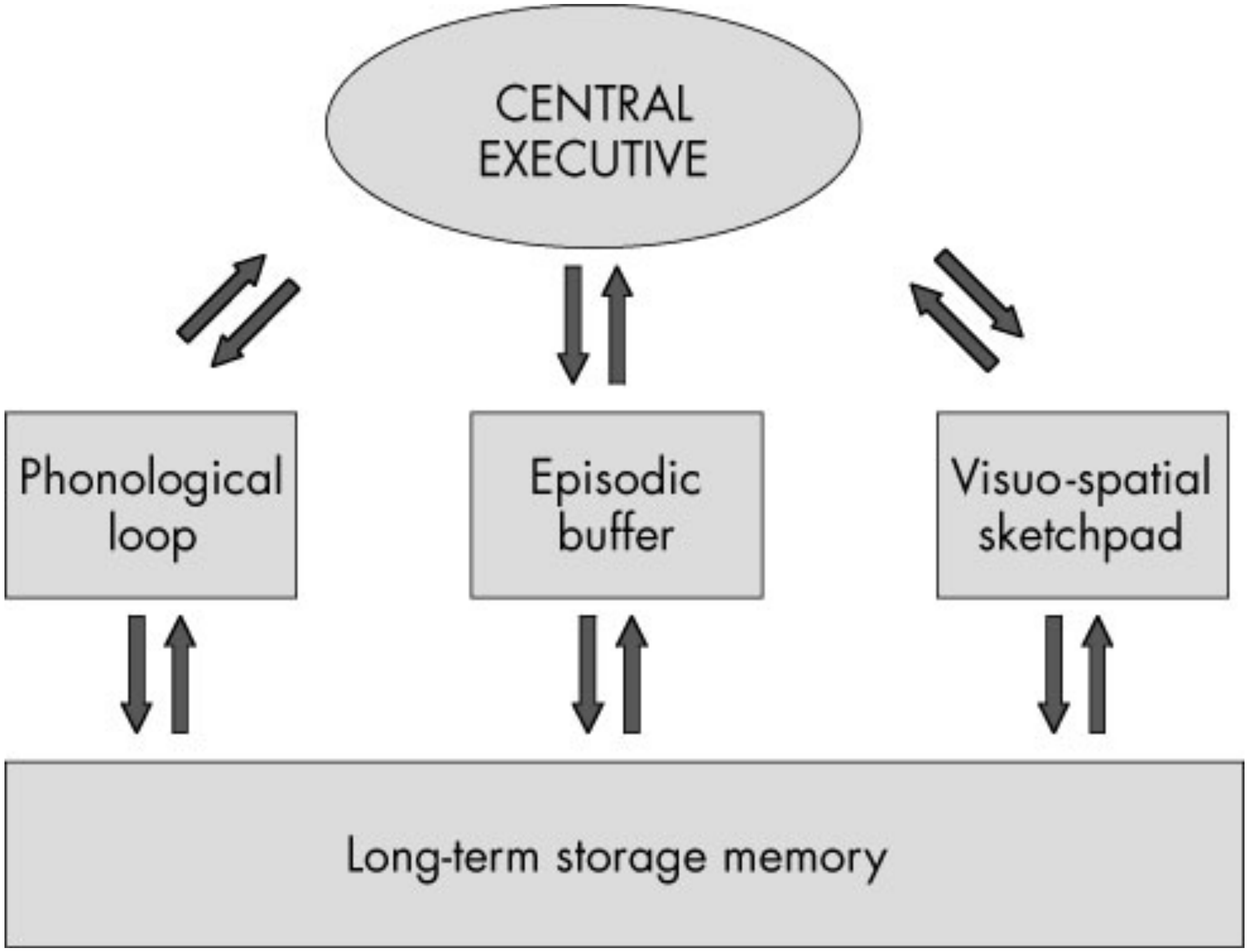


Figure 1. A Common Visual Representation of the Multicomponent Working Memory Model. Incoming information from the environment first encounters the central executive. The central executive directs information to the proper subsystem. At this point, a subsystem processes the information, recalls long-term memory to assist in processing, or integrates with another subsystem to make a decision regarding the incoming information.

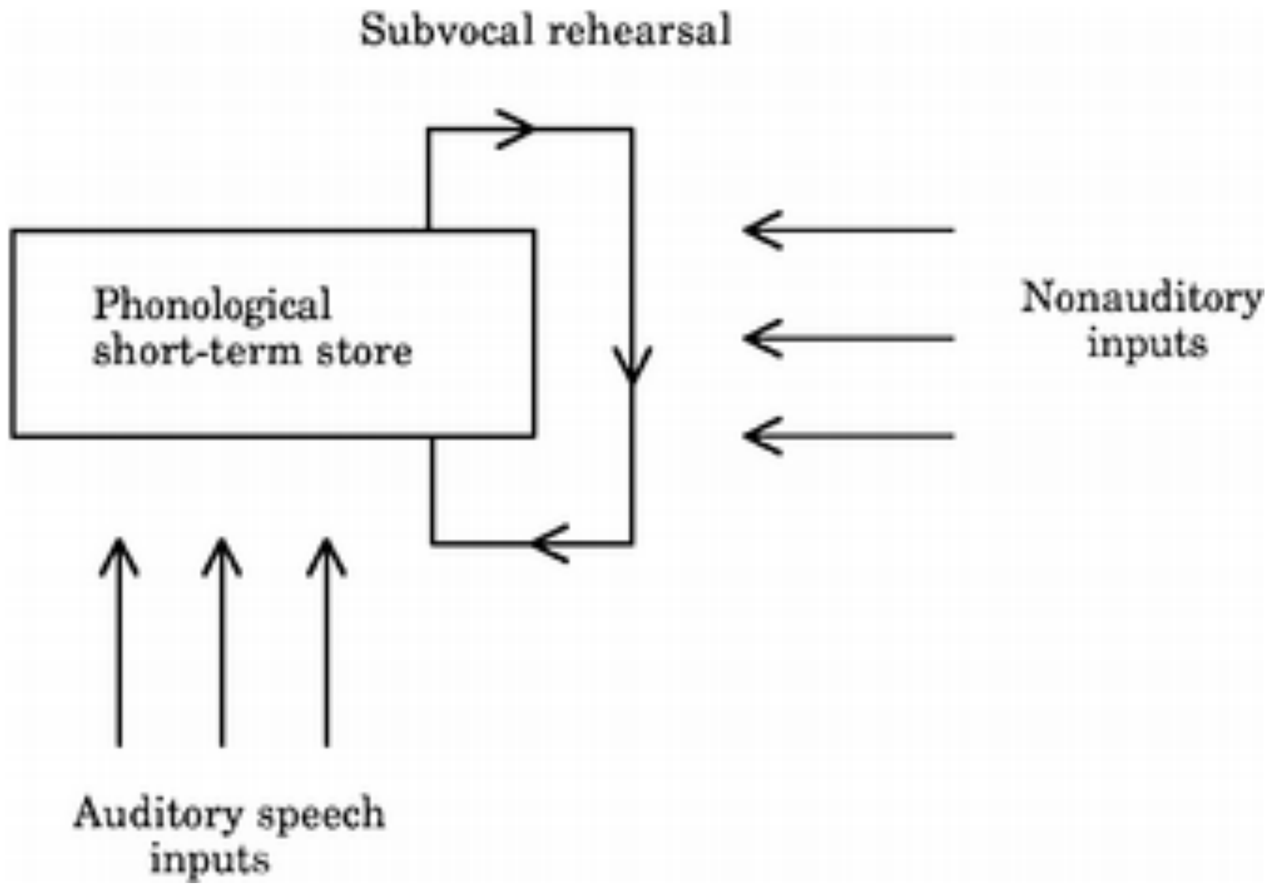
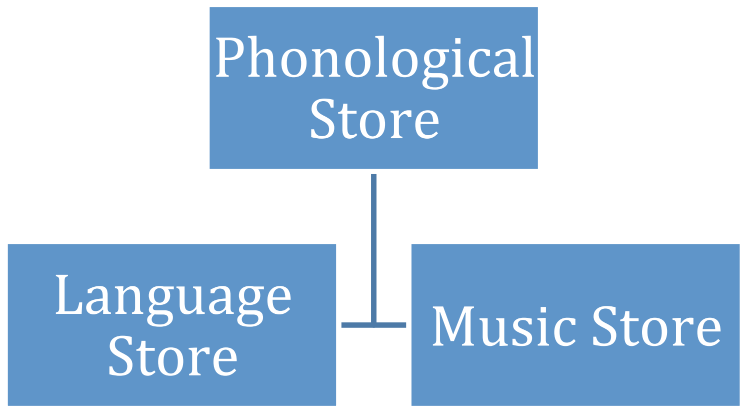


Figure 2. A Visual Representation of the Phonological Loop. The phonological loop has two primary components: a short-term memory store and rehearsal mechanism. Auditory speech information is directly encoded into the short-term store, but must be rehearsed to remain there. Non-auditory information must be rehearsed prior to entering the short-term store, and then continuously rehearsed to remain there. Adapted from “Neuropsychology and Working Memory: A Review,” by S. E. Gathercole, Neuropsychology, 8(4), p. 484-505. Copyright 1994 by the American Psychological Association.

The “strong” account of the “speech-specificity hypothesis”



The “weak” account of the “speech-specificity hypothesis”

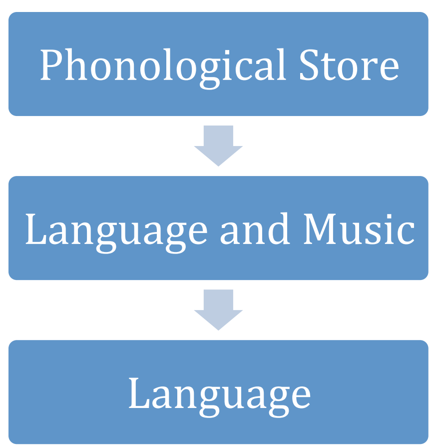


Figure 3. The Speech-Specificity Hypothesis. Information enters the phonological loop and is transferred to the phonological store. According to the “strong” account, the sounds of language and the sounds of music are stored in completely distinct temporary stores. According to the “weak” account, the sounds of language and music are stored together; while in the “universal” store information regarding the sounds (e.g., intonation) are retrieved from a separate store specifically for language-based information. Note: This infers what was posited in the original phonological loop in that sounds are understood phonologically.

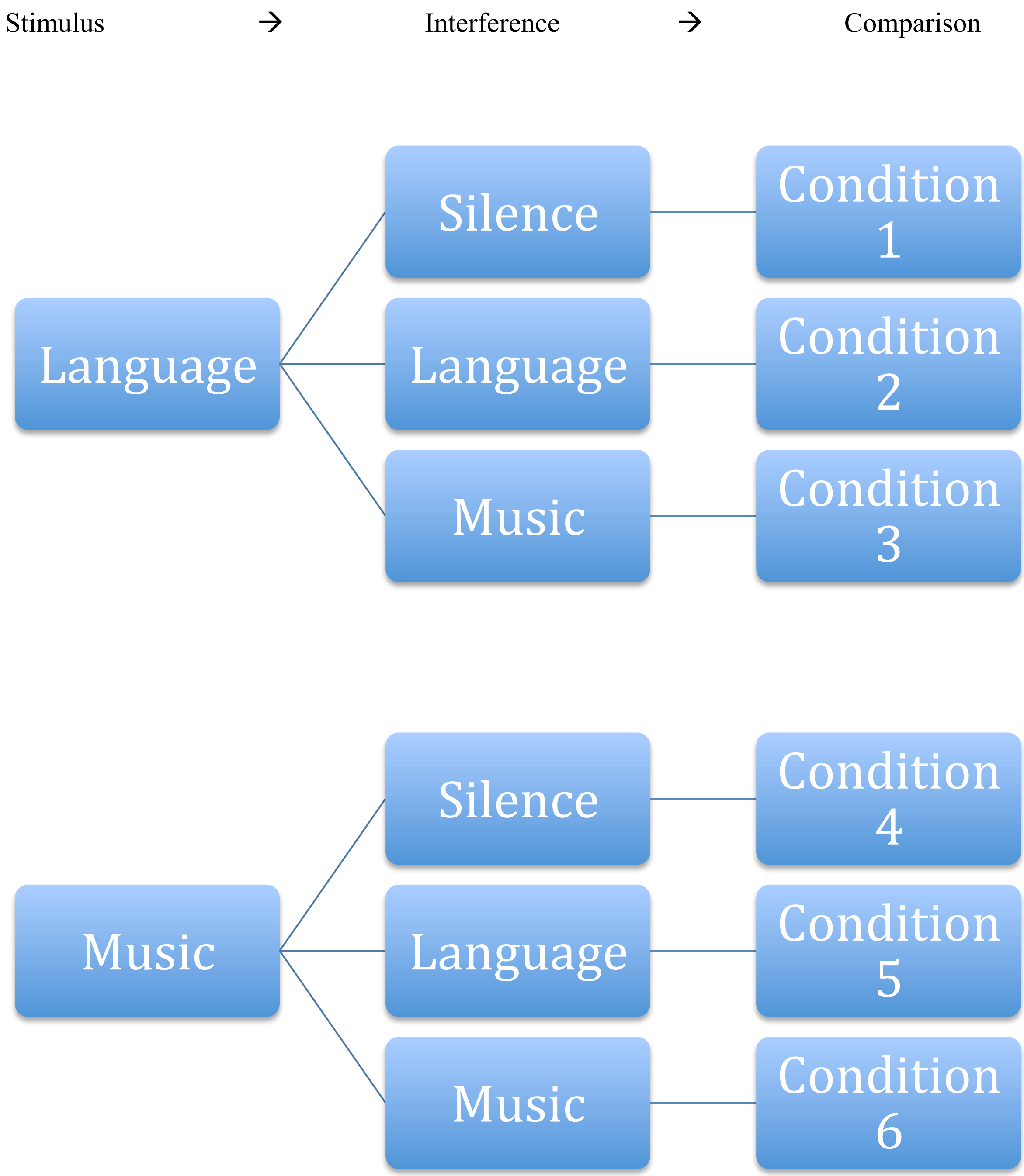


Figure 4. A Design Matrix of the Present Study. Six total conditions result from 2 forms of initially presented information (language and music) both followed by 1 of 3 intervening forms of information (silence, language, music).

Target Word	Intervening Words				Comparison Words		
	Dissimilar – e	Dissimilar – i	Dissimilar – o	Dissimilar – u	Same	Similar – First	Similar – Last
cap	few	tic	joy	hub	cap	cab	gap
mad	gel	rib	mop	dux	mad	man	had
sat	hem	dim	fog	sup	sat	sax	bat
cad	vet	mix	don	cur	cad	can	fad
mat	web	zip	cox	rum	mat	*mal	hat
sap	beg	win	hot	*hug	sap	*sac	lap
cat	sew	pit	cow	bus	cat	*cal	rat
map	fed	jig	god	mud	map	*maw	tap
sad	pen	his	low	nut	sad	*san	pad

Figure 5. Stimuli for the Language Conditions in the Present Study. Every word is three letters long. Each target word consists of the same middle letter (“a”). Also, each beginning letter (“c”, “m”, and “s”) and ending letter (“p”, “d”, and “t”) is used 3 times without repeating a word. Comparison words can be the same or similar by either the first or last letter of the target word. * refers to a word added by author. While not from the list of Coltheart (1993) they are still phonologically similar and should not present any added ease or difficulty in a discrimination task.

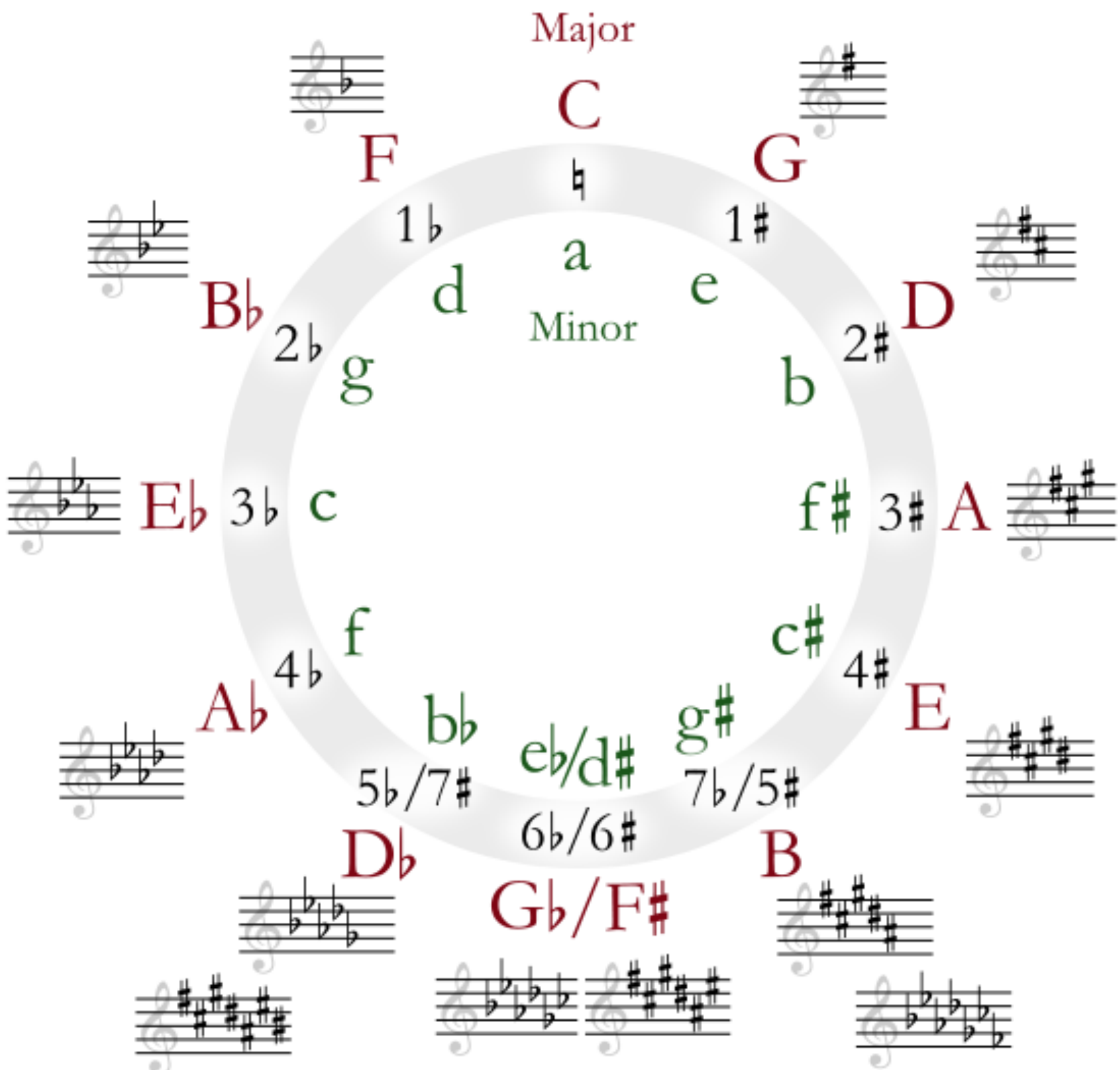


Figure 6. The Circle of Fifths. This is one version of the circle of fifths. It is a visual representation of the relationship between the 12 tones of the chromatic scale. Each pitch is separated by 7 semitones.

	Intervening Chords				Comparison Chords		
Presented Chord	4+	5+	4-	5-	Same	Different+	Different-
C	E	B	A♭	D♭	C	D	B♭
G	B	F♯	E♭	A♭	G	A	F
D	F♯	D♭	B♭	E♭	D	E	C
A	D♭	A♭	F	B♭	A	B	G
E	A♭	E♭	C	F	E	F♯	D
F	A	E	D♭	G♭	F	G	E♭
B♭	D	A	G♭	B	B♭	C	A♭
E♭	G	D	B	E	E♭	F	D♭
A♭	C	G	E	A	A♭	B♭	G♭

Figure 7. Stimuli for the Music Conditions of the Present Study. The "Different+" column refers to a clockwise rotation on circle of fifths and the "Different-" column refers to a counter-clockwise rotation on circle of fifths. Additionally, "Different" refers to 2 turns on the circle of fifths in the indicated direction.

APPENDIX A

List of Original Words Used by Coltheart (1993)

Phonologically Similar Words

rat, lap, tab, fad, nan, sap, yam, cab, fan, cad, nap, jab, can, dad, ham, lab, bat, lad, sat, ban, pad, gap, mad, nab, cat, hat, van, sax, mat, pan, bag, rap, gag, ram, map, wax, lag, tax, dam, tag, lax, jam, had, tap, pat, man, sad, gab, dab, cap

Phonologically Dissimilar Words

few, joy, tic, vat, bar, gal, mop, rob, dux, rib, gel, cur, ham, dim, sup, hem, day, vet, beg, don, win, mix, rum, web, jig, hot, bid, zip, cow, rag, bus, pit, jaw, mud, jug, fed, wan, god, pen, nap, nut, fad, cox, low, hub, tab, sew, his, fog, fir

Coltheart, V. (1993)

APPENDIX B

Demographic Questionnaire

Demographic Information

1) Sex: ________________

2) Age: ________________

3) Race: _______________

4) Is English your primary spoken language (yes or no)? ________________

APPENDIX C

Music Background Questionnaire

Music Background Questionnaire

1.) Total years of formal (e.g., private lessons) musical training (circle one):

none 1-4 5-9 10-19 20+

2.) Do you play a musical instrument currently? Y N

3.) If so, what instrument(s) do you play: ______________

4.) How many consecutive years have you played that instrument: ______

5.) Over the last year, approximately how many hours per week have you played?

0-4 5-9 10-14 15-19 20+

6.) Do you play in a band, orchestra, etc.? Y N

7.) If so, please specify: __________________

8.) Have you ever been paid to perform music? Y N

9.) If so, please specify: __________________

10.) Are you currently pursuing or have a degree/certificate in a music-related field? Y N

11.) If so, please specify: __________________

12.) Would you be able to pass a basic music theory test? Y N maybe

13.) Have you ever composed a musical piece on paper? Y N

14.) How would you rate your ability as a musician? (circle one number only)

Novice				Intermediate					Expert
1	2	3	4	5	6	7	8	9	10

APPENDIX D

Consent Form

UWO Department of Psychology Consent Form

The Department of Psychology supports the practice of protecting human participants in research. The following information is provided so that you can decide whether you wish to participate in the present study. Your participation is solicited but is strictly voluntary.

You are invited to participate in a study investigating how humans process auditory (sound) information

If you decide to participate, you will be asked to complete an auditory based memory task. Specifically, you will be presented with a series of auditory stimuli and be asked to remember them for a short period of time. After a brief delay, you will be tested on your memory for the originally presented information. At the end of the experiment, you will also be asked to fill out two brief questionnaires that ask about your background and experiences. It is anticipated that the experiment will take approximately 60 minutes to complete. Although there are no immediate benefits to you from this study, the data that you provide will lead to a greater understanding of the way in which humans process and remember auditory information.

If you agree to participate, you will be free to withdraw at any time and will receive credit for your participation. If you decide not to participate in this study, please let the researcher know and she or he will excuse you from the study. You do not need to tell the researcher your reasons for choosing not to participate. If you decide to withdraw from the study, any information collected from you up to that point will be destroyed.

Any responses you provide will be confidential and will not be associated in any way with your name. No information that could identify you will be released in any form.

If you have any unresolved questions, please contact the faculty supervisor for this project or myself:

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Ryan Atherton
Department of Psychology Graduate Student – University of Wisconsin Oshkosh
(414) 418-0721 or atherr79@uwosh.edu

If you have any complaints about your treatment as a participant in this study, please contact the following individual:

Chair, Institutional Review Board
For Protection of Human Participants
c/o Grants Office
UW Oshkosh
920-424-1415

Although the chairperson may ask for your name, all complaints are kept in confidence.

Consent Statement: You are making a decision whether or not to participate. Your signature indicates you have read the information provided above and have decided to participate. You may withdraw at any time without prejudice after signing this form should you choose to discontinue participation in this study.

____________________________________ ______________
Name Date

This research has been approved by the University of Wisconsin Oshkosh IRB for the Protection of

Human Participants for a one year period, valid until (February, 2014).

APPENDIX E

Instructions

INSTRUCTIONS

Hello! My name is Ryan Atherton, and I am a student in the Psychology Department here at UWO. Thank you for agreeing to participate in this experiment. Please take a moment now to turn off your cell phones. Thanks. Now let me begin by telling you what I would like you to do.

First, as you read in the consent form – you will be completing an auditory experiment. The experiment will consist of a number of different trials. Each trial will start when you hear a beep. The beep will immediately be followed by a sound. This sound may either be a spoken word or a tone. Please try your best to remember this sound. After a short delay, one of three things may occur. You will either hear: a series of tones, a series of spoken words, or silence. Finally, after another second, you will hear a final sound for that trial. Your job is to determine whether the very first sound you heard after the initial beep is the same as or different from the last sound that you heard. In other words, you should ignore the intervening sounds to the best of your ability in an effort to accurately judge the first and last target sounds as same or different. You will have 5 seconds to record your response. If the sounds are identical, circle "same." If they are different, circle "different." Please respond as quickly and accurately as possible. Afterward, the next trial will begin. The answer sheet begins with the number 1 in the upper left hand corner and increases downward until the next column begins. Each page of the answer sheet will follow this general format. Trials begin with the number 1 and increase by 1 with each trial. When we reach the end of a sheet I will give you an additional 5 seconds to turn the page.

You will complete 12 practice trials before the actual experiment begins in order to familiarize yourself with the task. After the practice trials, a total of 162 experimental trials will be given. You will not be provided with feedback as to how you are doing on each trial.

When everyone is done with the listening portion of the experiment, I will hand out two brief questionnaires. Please sit quietly until everyone has completed the questionnaires. Once everyone has completed them, I will give you a little more information about the experiment. Overall, it will take approximately 60 minutes to complete the entire study.

Does anyone have any questions?

Please turn over your practice trials answer sheet, which is the sheet with only 12 answer spaces on it, and we will begin the practice trials.

Begin practice trials.

Okay. Does anyone have any questions?

Now we will begin the actual experiment. Please note, you will receive a 5-minute break near the midpoint of the experimental sessions. So, after question #80 we will take a 5-minute break.

Begin experiment.

Hand out questionnaires.

Debrief, and answer questions.

Thank you again for your participation. I really appreciate it.

APPENDIX F

Debriefing Script

“Simple as Do Re Me, ABC”: Language, Music, and Working Memory
UWO Department of Psychology Debriefing Script

Thank you for your participation in the study. I would like to take a few minutes to provide you with some additional information about the purpose of this study. The goal of this study is to examine how people actively process and remember different forms of auditory information. Specifically, we are interested in the processing, interpretation, and storage of language and music in the brain. Additionally, we are interested in how this ability may differ between people that have musical expertise and those that do not.

The task that you just performed was designed to whether or not some forms of auditory information (for example, spoken words) make it harder to process and remember other types of auditory information (for example, musical notes). We designed the experiment to see if the intervening sound that you heard interfered with what you heard initially – thus making it harder to remember.

Overall, this study is intended to provide information about where these different types of information are stored in the brain. We did not inform you of our specific predictions at the start of the study because we did not want that knowledge to influence your performance in any way.

All of the information that was collected today will be kept in complete confidentiality and there will be no way of identifying your responses with your identity. We are not interested in any one participant’s responses by themselves. Rather, we are interested in the general responses of all participants when they are combined together.

Your participation today was greatly appreciated and will help in furthering our understanding of how people actively process, interpret, and remember auditory information. We ask that you do not discuss this research with anyone else because it could ruin the study for other participants and call into question the validity of the research. Would that be ok with you?

If you have any questions or concerns regarding your participation in this study please contact the faculty supervisor for this project, Dr. Quin Chrobak. His contact information is listed on your copy of the consent form.

APPENDIX G

Answer Sheets

1)	same	different
2)	same	different
3)	same	different
4)	same	different
5)	same	different
6)	same	different
7)	same	different
8)	same	different
9)	same	different
10)	same	different
11)	same	different
12)	same	different

1)	same	different	**24)**	same	different
2)	same	different	**25)**	same	different
3)	same	different	**26)**	same	different
4)	same	different	**27)**	same	different
5)	same	different	**28)**	same	different
6)	same	different	**29)**	same	different
7)	same	different	**30)**	same	different
8)	same	different	**31)**	same	different
9)	same	different	**32)**	same	different
10)	same	different	**33)**	same	different
11)	same	different	**34)**	same	different
12)	same	different	**35)**	same	different
13)	same	different	**36)**	same	different
14)	same	different	**37)**	same	different
15)	same	different	**38)**	same	different
16)	same	different	**39)**	same	different
17)	same	different	**40)**	same	different
18)	same	different	**41)**	same	different
19)	same	different	**42)**	same	different
20)	same	different	**43)**	same	different
21)	same	different	**44)**	same	different
22)	same	different	**45)**	same	different
23)	same	different	**46)**	same	different

47) same different

48) same different

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84) same different

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87) same different

88) same different

89) same different

90) same different

91) same different

92) same different

93)	same	different	**116)**	same	different
94)	same	different	**117)**	same	different
95)	same	different	**118)**	same	different
96)	same	different	**119)**	same	different
97)	same	different	**120)**	same	different
98)	same	different	**121)**	same	different
99)	same	different	**122)**	same	different
100)	same	different	**123)**	same	different
101)	same	different	**124)**	same	different
102)	same	different	**125)**	same	different
103)	same	different	**126)**	same	different
104)	same	different	**127)**	same	different
105)	same	different	**128)**	same	different
106)	same	different	**129)**	same	different
107)	same	different	**130)**	same	different
108)	same	different	**131)**	same	different
109)	same	different	**132)**	same	different
110)	same	different	**133)**	same	different
111)	same	different	**134)**	same	different
112)	same	different	**135)**	same	different
113)	same	different	**136)**	same	different
114)	same	different	**137)**	same	different
115)	same	different	**138)**	same	different

139)	same	different
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145)	same	different
146)	same	different
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160)	same	different
161)	same	different
162)	same	different

APPENDIX H

Institutional Review Board (IRB) Approval Form

OSHKOSH

3/2/2013

Mr. Ryan Atherton
W349N8140 Norwegian Road
Oconomowoc, WI 53066

Dear Mr. Atherton:

On behalf of the UW Oshkosh Institutional Review Board for Protection of Human Participants (IRB), I am pleased to inform you that your application has been approved for the following research: "Simple as do re me, ABC": Language, music and working memory. The approval is valid for one year from the date of this letter.

Your research protocol has been classified as EXEMPT. This means you will not be required to obtain signed consent. However, unless your research involves **only** the collection or study of existing data, documents, or records, you must provide each participant with a summary of your research that contains all of the elements of an Informed Consent document, as described in the IRB application material. Permitting the participant, or parent/legal representative, to make a fully informed decision to participate in a research activity avoids potentially inequitable or coercive conditions of human participation and assures the voluntary nature of participant involvement.

Please note that it is the principal investigator's responsibility to promptly report to the IRB Committee any desired changes in the research project, whether these changes occur prior to undertaking, or during the research. In addition, if harm or discomfort to anyone becomes apparent during the research, the principal investigator must contact the IRB Committee Chairperson. Harm or discomfort includes, but is not limited to, adverse reactions to psychology experiments, biologics, radioisotopes, labeled drugs, or to medical or other devices used. Please contact me if you have any questions (PH# 920/424-2328 or e-mail: mirona@uwosh.edu).

Prior to the end date of the approval period, please return a summary report "IRB Status Form" to the Office of Grants and Faculty Development. The form may be found electronically at: http://www.uwosh.edu/grants/forms/grants-forms/IRB-Status-Form-2012-09-04.docx and may be returned via e-mail to irb@uwosh.edu or to our office in Room 214 in Dempsey Hall.

Sincerely,

AMiron

Dr. Anca Miron
IRB Chair

Protocol Number 972345
cc: Dr. Quin Chrobak

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