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The Effect of Background Music on the Visual Categorization of Printed Words in Normal Younger and Older Adults

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Research Advisor
Mary L. Erickson, Ph.D.

Committee
Mark S. Hedrick, Ph.D. Kristin A. King, Ph.D. John C. Malone, Ph.D.

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The Effect of Background Music on the Visual Categorization of Printed Words in Normal Younger and Older Adults

A Dissertation
Presented for
The Graduate Studies Council
The University of Tennessee
Health Science Center

In Partial Fulfillment
Of the Requirements for the Degree
Doctor of Philosophy
From The University of Tennessee

By
Sukhada Vaidya Mairal
August 2015

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DEDICATION

To my beloved parents, Ram and late Savita Vaidya; my guardian parents, Shubhada and late Prabhakar Khadilkar; my co-guardians, Sheetal and Shrikant Vaidya; my grandparents; my sister Dnyanada; my cousins, Shishir and Shalaka, for building me together.

And to my beloved husband, Anurag, for building us together.

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My heartfelt gratitude to my dad for his extraordinary caring, support and motivation. I am truly thankful to my family and friends for being a solid support system throughout. I am deeply grateful to my family on in-laws side who was equally, immensely supportive and encouraging to help me complete the dissertation. A special token of thanks to my office-mate and friend, Daniela Oliveira for her involvement in discussing research ideas and lending a huge personal support. Another special token of thanks to my room-mate and friend, Vandna Gahlot for an extraordinary personal support.

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ABSTRACT

Aim: Research has shown that background music, with and without vocal content, has a detrimental effect on cognitive task performance. Research has also shown a decline in processing speed as age increases. The present study seeks to answer the following questions: 1. Will background vocal music have any detrimental effects on performance of a visual semantic word categorization task? 2. Does age have any effect on performance of visual semantic word categorization in the presence of background music?

Participants: Participants consisted of 36 adult native speakers of English with normal speech and language divided in to two groups based on age, an older group (63-79 years) and a younger group (18-33 years). The younger group was recruited from the population of students of the University of Tennessee and the Knoxville community. The older group was recruited from the Knoxville Office on Aging and the Knoxville community.

Stimuli: Printed words were chosen from superordinate categories such as tools, utensils, animals, food, clothing, furniture, body parts, vehicles, toys, instruments, and insects. The auditory stimulus was Adele's song "Someone Like You," from the commercial CD recording. Instrumental recordings of the song were constructed using the music notation software program, Finale and sampled instruments.

Procedure: Participants performed a categorization task of printed words on the computer screen in the presence of background music. Participants' reaction times and the accuracy of their responses were recorded by a software program, SuperLab Pro. The experiment was presented four times consecutively for four randomized auditory conditions consisting of 26 word sets per condition. A questionnaire was administered at the end of the final experiment.

Statistical Analysis: A mixed design 2x4 ANOVA was performed (between subjects factor – age group and within-subjects factor – condition) to test the main effects and/or interactions between groups and within groups. Paired sample T-tests were computed to test for comparisons within groups for any significant differences among conditions. Correlations and covariate analyses were performed for questionnaire data.

Results: The results did not indicate any significant effect of auditory condition on categorization task performance. Vocal music did not increase reaction times or decrease the accuracy of word categorization. On the other hand, a significant effect of age was found for reaction time and accuracy. Older adults performed significantly more slowly and less accurately than younger adults.

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CHAPTER 1. INTRODUCTION

State of the Art

The effect of background noise and music on cognitive performance has been extensively studied over the last five decades. While most studies show that listening to instrumental and vocal music impairs performance of a cognitive task (Alley & Greene, 2008; Avila, Furnham, & McClelland, 2012; Cassidy & MacDonald, 2007; Furnham & Bradley, 1997; Salame & Baddeley, 1982; Smith, 1985; Stroupe, 2005), a few studies suggest that background music does not interfere with performance. For example, teenagers and college students have expressed lower levels of concentration and higher levels of distraction during academic assignments while listening to certain kinds of music (Jones, 2010; Schellenberg & Weiss, 2013). Similarly, background music has been found to have a negative impact on productivity in some workplaces (Uhrbrock, 1961). On the other hand, Furnham, Trew, and Sneade (1999) showed that performance in the presence of background music did not significantly differ from that during a silent condition.

The content of background music – nonvocal vs. vocal – seems to play a key role in the performance of a cognitive task (Alley & Greene, 2008; Stroupe, 2005). In order to predict the performance level of a cognitive task in the presence of background music, an important consideration is the total degree of semantic processing taking place. Contributions to the degree of semantic processing can come from allocating either voluntary or involuntary attentional resources to the background music as well as from semantic processing required by a cognitive task. Past auditory-visual dual-processing task studies analyzing the effect of listening to a meaningful auditory stimulus or background music have noted detrimental effects on reading comprehension (Oswald, Tremblay, & Jones, 2000; Sörqvist, Halin, & Hygge, 2010), memory recall (Enmarker, 2004; Schlittmeier, Hellbrück, Thaden, & Vorländer, 2008), and proofreading (Jones, Miles, & Page, 1990; Venetjoki, Kaarlela-Tuomaala, Keskinen, & Hongisto, 2006) tasks. However, a similar investigation of a visual semantic word categorization task has not yet been undertaken.

In a visual semantic categorization task, the time it takes to access semantic information contributes significantly to the measurement of processing time (Horn & Manis, 1987). In fact, the processing time or the speed of processing is thought to be a primary factor in cognitive decline with aging (Baddeley, Logie, Bressi, Sala, & Spinnler, 1986; Birren & Fisher, 1995; Hartley, Stojack, Mushaney, Annon, & Lee, 1994; Hasher & Zacks, 1988; Pfütze, Sommer, & Schweinberger, 2002; Salthouse, 1996; Van der Linden et al., 1999) along with decline in the ability to ignore irrelevant information (Craik & Salthouse, 2011; Kliegl, Maayr, & Krampe, 1994; Mayr & Kliegl, 1993; Van der Linden et al., 1999).

Purpose of the Study

The present study was designed to investigate the performance of a task involving the visual categorization of printed words in the presence of background music. The study explored the effects of age and content of background music on performance.

CHAPTER 2. LITERATURE REVIEW

The Effect of Background Music on Cognitive Tasks

The literature on the effects of noise on task performance shows that the concept of noise covers a wide variety of auditory stimuli. While continuous white noise has been of great interest in previous studies investigating information-processing tasks, few researchers (Salame & Baddeley, 1982; Smith, 1985) have investigated the potentially disruptive effect of meaningful or more patterned sources of auditory stimulation. It is predicted that processing the meaning of a patterned auditory stimulus could have a greater impact on task performance than processing white noise; semantic processing in case of the former has higher chance of interfering with the cognitive task at hand, in particular a semantic task. Consequently, the meaning of the stimulus is considered a more important parameter to manipulate than intensity of the stimulus.

The evidence of the impact of a variety of auditory stimuli on cognitive task performance suggests a number of factors that may play a role, including syntax and the semantics of the stimulus, as well as subjects' familiarity with the stimulus. Among the few early studies of the effect of patterned auditory stimulation on cognitive tasks, Salame and Baddeley (1982) focused on the effect of unattended speech on a serial recall for visually presented sequences of 9 random digits. Unattended speech was in the form of noise bursts (250-3500 Hz), meaningful and nonsense monosyllabic words, meaningful disyllabic words, spoken digits, and irrelevant words made from the same phonemes as the digits and were simultaneously or alternately presented with each of the digits at 75dB (A) from a loudspeaker. Subjects were instructed to read the digits aloud and recall the digits by writing them down while ignoring the words. Authors found more impairment (in the form of percentage of error) in recall caused by phonologically similar material for the unattended spoken digits and irrelevant words made from the same phonemes as visually presented digits.

In another study, Smith (1985) compared the effect of different types of noise (continuous, intermittent, and meaningful conglomerate) on a syntactic reasoning test and a semantic processing test. Conglomerate noise contained typewriting, music, and unattended speech. Background noise was presented to subjects at 85 dB SPL. In a semantic processing test, subjects marked as many sentences as possible as either semantically correct or incorrect. Their performance was measured in terms of number of completed items in three minutes. In a syntactic reasoning test, the subjects decided sentences were true or false based on the information provided; performance was measured in terms of the combination of number of items completed and number of errors made in three minutes. Smith found that performance on both tests was not impaired by continuous noise but was affected by meaningful, conglomerate noise. Furthermore, performance on the semantic processing test was affected by intermittent noise but not on the syntactic reasoning test. Thus, these findings suggest that whether noise is meaningful and whether it is consistent are important factors for both semantic and syntactic processing. This further implies that the type of cognitive task plays a key role in the effect that a background auditory stimulus can produce on task performance.

The effect of background music on task performance has been a focus of studies investigating productivity at work and study environments. In a review of these studies, Uhrbrock (1961) indicated that a majority of working staff preferred instrumental music over vocal while working. Another point put forth by the same review was that age was an important factor in the preference for music at work. A vast number of studies have utilized observations of high school or college students in order to gain more insights on their study or work habits, preference of background music, and effects of such preferences on cognitive performance and learning. Students who frequently studied in the presence of background music performed better during a laboratory experiment that examined comprehension in the presence of music, whereas students who rarely studied in the presence of background music performed better in silence (Etaugh & Ptasnik, 1982).

In a brief report, Jones (2010) summarized her findings from an on-line voluntary survey of 36 students. The study investigated habits associated with music, the participants' perceptions about music, and the effect of music on learning processes; the survey consisted of seven questions about study habits associated with music and five demographic questions. Jones found that 75% of the students reported opting for listening to music while studying; the stated reasons included increased concentration, facilitation of study, and higher motivation. Moreover, 41.7% of the students indicated a preference for classical music, 41.7% for pop music, 25% for rock music, and the remainder for other genres. Classroom music was preferred by 69.4% of the students. The survey results pointed towards a crucial observation: the students made a conscious choice of listening to music, particularly a "softer" style of music, while studying.

An experiment conducted by Furnham and Bradley (1997) explored the effect of a popular song (chosen from a mid-morning radio program on Virgin 105.8 FM) on the ability of introverts and extroverts to perform a memory test and reading comprehension tests. Three upbeat pop songs – *Sowing the Seeds of Love,* by Tears for Fears; *A New Sensation,* by INXS; *Strange Girl*, by Cream – were selected for the study. Twenty undergraduates (10 introverts and 10 extroverts) participated in a reading comprehension test based on the GMAT range of tests, consisting of a 400-word passage and six multiple-choice questions completed in ten minutes, (Martison, 1992) and a memory test based on the British Ability Scales range of tests in which participants were asked to recall everyday objects from 20 pictures, seen for two minutes, while listening to pop music excerpts for ten minutes. The study observed a detrimental effect in immediate recall on the memory test; moreover, extroverts performed significantly better than introverts. Another study by Furnham, Trew, and Sneade (1999) examined the effects of vocal and instrumental music on the reading comprehension, logical problem solving, and a coding skills of introverts and extroverts. The authors used vocal music as a way to add to the complexity and information load of music; they chose vocal and instrumental versions of the same songs in order to attribute any differences found between test responses to the presence of vocal content. The songs were *Shine,* by Monaco; *Papa was* *a Rolling Stone* ,by Was Not Was; *Change the World,* by Eric Clapton; and *What Do You Want From Me?,* by Monaco. The participants, 142 secondary school students, performed a reading comprehension test based on the GMAT range of tests (Martison, 1992), a logic test based on the LSAT range of tests, (which is 90-word passage containing three rules and 6 multiple-choice questions completed in nine minutes) (White, 1997), and a coding test in which the participants wrote symbols corresponding to specified keys (Sogin, 1988). The study found that background music did not significantly affect the test scores on the three tasks as compared to tasks undertaken in silence.

Cassidy and MacDonald (2007) used music with lyrics to test the performance of five cognitive tasks: immediate recall, free recall, numerical and delayed recall, and the Stroop task. In the Stroop test, subjects were asked to read aloud a list of color names printed in a non-concurrent color of ink. In the immediate recall test, subjects were asked to recall a short news story; they were then asked to recollect the same story in a delayed recall test after a gap of few minutes. The free recall test required subjects to recall 20 everyday six-letter words after performing a distraction task in the form of numerical reasoning test. In order to simulate everyday listening situations, in which students and adolescents give highest preference to music which contains lyrics, the authors provided vocal tracks. Forty undergraduate students in four groups of ten took part in the study. Each group listened to one of the four background sound conditions: positive low arousal music labeled as relaxing (LA), negative high arousal music labeled as aggressive (HA), background noise at the level of 60 dB, and silence. Background musical stimuli were generated by rating popular music pieces for arousal potential (high or low) and affect (negative or positive) in a pilot study. The findings showed a decline in performance across all cognitive tasks in the presence of background sound, either music or noise, as opposed to performance of the same tasks in the silent condition. In addition, the HA condition resulted in a greater decline in all cognitive tasks compared to LA and silent conditions.

Alley and Greene (2008) investigated the disruptive effect of irrelevant speech on working memory (WM) by analyzing the effects of vocal music, equivalent instrumental music, and irrelevant speech on WM performance. The study recruited 60 students who completed WM tests (digit span task similar to one used by Salame & Baddeley, 1989) in the presence of each of the three auditory conditions noted above. Two popular songs (gauged by a high ranking on world and U.S. singles charts) familiar to most of the students were used as the vocal component: *When I'm Gone,* by Three Doors Down, and *I'm With You,* by Avril Lavigne. Standard karaoke versions of these two pop songs served as instrumental music stimuli. The irrelevant speech was provided by an excerpt from a recording of Jane Austen's *Northanger Abbey*. Participants listened to the auditory stimuli via headphones set at a comfortable volume. The results not only demonstrated that speech and vocal music disrupt WM performance, but also that irrelevant speech is less distracting than vocal music and more distracting than instrumental music. Based on the combined results from rated questionnaires about music familiarity and perceived level of distractions, the authors concluded that familiarity with song lyrics produces a small but non-significant effect on performance and that people have poor assessments of the degree of WM performance degradation resulting from irrelevant background noise.

Consistent with the above study, Avila, Furnham, and McClelland (2012) assessed the effects of familiar vocal and instrumental music on the cognitive performance in verbal, numerical, and logic tests of 58 subjects. Instrumental and vocal versions of music pieces were identical except for the absence of vocals in the instrumental version. The songs were chosen based on familiarity and tempo ratings – *Umbrella*, by Rihanna featuring Jay-Z, *So Sick*, by Ne-Yo, and *Let Me Love You*, by Mario. The results indicated the lyrical information present in vocal music interfered with verbal information processing in verbal tasks for all the participants. The instrumental music also caused impairment in verbal performance as compared to the condition of silence. The study showed that any form of music causes detrimental effects on a task where verbal information processing is involved and that working on a complex task or processing complex material is best accomplished in silence.

In a reading comprehension task where semantic information processing is involved, it is logical to expect that background vocal music can be the most detrimental to performance. To test this hypothesis, Stroupe (2005) focused on the differences between the effects of lyrical music, non-lyrical music, and silence on the performance of a reading comprehension task as measured by accuracy and speed of response. Lyrical music was hypothesized to be the most detrimental, and longer reaction times were expected due to slower processing caused by the added complexity of lyrics. Indeed, accuracy in lyrical conditions was found to be significantly lower than for non-lyrical and silent conditions, whereas non-lyrical and silent conditions did not differ significantly. Moreover, the processing times for the lyrical condition were significantly longer than for the other two conditions. Collectively, the results supported the hypothesis that listening to vocal music is the most detrimental of the three conditions in the performance of a reading comprehension task.

In summary, the studies investigating the effects of background music, whether instrumental or vocal, on the performance of cognitive tasks are inconsistent. A recent extensive review of music and cognitive abilities by Schellenberg and Weiss (2013) concluded that the effect is dependent on numerous factors. These factors range from the type of cognitive task, context, choice of background music, tempo, intensity, and presence or absence of vocals, to individual differences. Individual differences such as personality, music experience or training, preference, and study or work habits play a significant role in the way in which background music impacts performance.

In addition to factors explored here, the linguistic content in background music may also have an impact on the performance of semantic cognitive tasks. There are two questions: Is linguistic content present in both speech and in background music processed by a common mechanism, and do they share a common semantic system?" When the answer to both of these questions is "yes," background vocal music is clearly detrimental to the task. However, research dealing with these questions is in initial stages.

Syntax, Semantics, and Melody in Language and Music

Both music and speech fall in the category of meaningful auditory stimuli processed during listening. When listening, a person must use cognitive processes to sort through the incoming information and process what is being heard. The term "listening effort" refers to the attention and cognitive resources required to understand speech and/or other meaningful stimuli (Gosselin & Gagné, 2010). Listening effort may be regarded as a component of cognitive effort when considering how information is processed. Therefore, meaningful noise could be considered competition for other simultaneous cognitive tasks such as semantic categorization.

The degree to which these cognitive demands interfere with semantic categorization is believed to depend on the degree of overlap between the mechanisms for semantic categorization and those utilized by the distracting speech or music (Allport, Antonis, & Reynolds, 1972; Friedman & Polson, 1981; Martin, Wogalter, & Forlano, 1988; Navon & Gopher, 1979). An integrated form of linguistic and musical information is received by the ears when words are sung. However, beyond this first sensory level of analysis, it is still unclear whether the semantic and melodic aspects of song are processed as whole or separate components. Reasoning through dual task paradigm and resource theory, the results from the study conducted by Bonnel, Faita, Peretz, and Besson (2001) suggested that the semantic and melodic aspects of language are processed by independent systems. Their study involved 48 French-speaking students from a mixed pool of musicians/non-musicians, who were asked to detect the semantic or melodic incongruity (single task) or both (dual task) present in the excerpts from French operatic songs. Semantic and melodic incongruity were introduced by making a final word of each excerpt either semantically congruous or incongruous in relation to the preceding linguistic context and sung either in or out of key.

While the right hemispheric dominance for music and the left hemispheric dominance for language have been demonstrated in many cognitive tasks, it also has been shown that similar neural regions and/or mechanisms for processing both music and speech engage at the syntactic and pre-semantic level (Koelsch, 2005; Koelsch, Gunter, Wittfoth, & Sammler, 2005; Koelsch et al., 2004).

Recent research suggests that the lyrics and tunes of unfamiliar songs are processed at different degrees of integration along the axis of the superior temporal sulcus (STS) and the left precentral gyrus (PrCG), with the greatest integration occurring at the pre-semantic level. A study by Sammler et al. (2010) incorporated fMRI scanning in which 12 right-handed, native French speakers were asked to listen attentively with closed eyes and without humming or singing along with 168 short unfamiliar songs having different tunes and meaningful lyrics. These songs were based on a collection of 19th century French folk songs and constructed by a professional composer. Melodies were presented via E-Prime software in four types of blocks corresponding to the four experimental conditions, namely (1) songs with the same tunes and same lyrics, (2) songs with the same tunes but different lyrics, (3) songs with different tunes but same lyrics, and (4) songs with different tunes and different lyrics. In order to confirm that participants followed the instructions, they were asked to rate the degree of attention paid to the songs and also whether they sang overtly or covertly during the scan on a nine-point scale. Imaging results showed interactions for lyrics and tunes at left mid-STS and lack of interactions and stronger adaptations for lyrics towards more anterior regions of left STS. According to the authors, the results suggested an integrated processing of the two at the pre-lexical level and an independent processing of lyrics at the semantic level.

In an ERP study conducted by Koelsch et al. (2004), the authors suggested that evidence of a similar type of N400 effect (semantic priming effect) between language and music processing indicates an influence of language, present in spoken sentence as well as in musical excerpt, on the semantic processing of words. In this study, forty participants were presented with a spoken sentence or a musical excerpt as a prime stimulus followed by a visual presentation of a target word. Prime stimuli were either semantically related or unrelated to the target word. Prime stimuli were constructed in the form of sentences and short musical excerpts (recorded from commercially available CDs), and the target words were in the form of concrete and abstract German nouns. A combination of prime stimuli was chosen for each target word: (1) a semantically related sentence, (2) a semantically unrelated sentence, (3) a semantically related musical excerpt, and (4) a semantically unrelated musical excerpt. A clear semantic priming effect (N400 ERP peak component) was observed when the target word was unrelated to the prime sentence and when it was unrelated to the prime musical excerpt.

A study by Poulin-Charronnat, Bigand, Madurell, and Peereman (2005) showed the interactive effects between semantic and harmonic relatedness, which implies that music may modulate semantic priming in vocal music. Forty-two students - musicians and non-musicians – participated in the experiment in which stimuli were in the form of 48 8-chord sentences sung by professional French singers. In half of the sentences, the last word was semantically related to the previous linguistic context, and in the other half, the sentences were identical except that they ended on a non-word. Harmonic function was manipulated when the last word was sung on either a referential tonic chord or a congruent but less referential subdominant chord. Participants were asked to judge whether the last sung lyric was a word or a non-word. A significant interaction was observed between semantic and harmonic relatedness, suggesting that interference of musical and linguistic processing likely happens at some unspecified, higher level of processing.

Another study by Schön, Gordon, and Besson (2005) involving ERP measurements also revealed the overlapping nature of musical and linguistic processing when linguistic and melodic components of songs were present. An experiment involved participants who were non-musicians listening to pairs of sung words in different blocks of trials; their attention was directed to the words in order to judge whether they were same or different (lexical processing), and to the melody to determine whether the notes were same or different (pitch processing). Thus, two dimensions were associated with the task. Four experimental conditions of different combinations of these two dimensions were used: (1) same language and music, (2) different language same music, (3) same language/different music, and (4) different language and music. The results showed that in linguistic and musical tasks linguistic processing and pitch processing were not processed independently. An earlier ERP study carried out by Patel, Gibson, Ratner, Besson, and Holcomb (1998) comparing syntactic incongruities in language and music had indicated that processes giving rise to P600 (a positive component of the ERP elicited by words that are difficult to integrate structurally into meaningful sentences) may not be language specific but may involve a common mechanism shared by both linguistic and musical processes for the same ERP component. Fifteen musically educated adults participated in this experiment in which sequences were created using principles of phrase structure for language and principles of harmony and key-relatedness for music. Musical sequences were based on Western European tonal music, constructed in such a way that an element was congruous, moderately incongruous, or highly incongruous with the preceding structural context. The results revealed statistically indistinguishable positivity (P600 component) for linguistic and musical structural incongruities.

A review of comparative data on musical and linguistic processing has summarized the studies involving syntax in language and music. An analysis of the review suggests a testable prediction about the lack of language specificity regarding syntactic comprehensions and existence of deficits in music perception in Broca's aphasia (Patel, 2003). Moreover, a series of experiments carried out by Besson and Schön (2001) suggested that when some of the components of semantic processing in language are compared with the melodic and harmonic components of music, language specificity seems to be evident at the semantic level, whereas language and music share similar effects at the syntactic level. Thus, studies that involved a comparison of language and music have hinted that linguistic and melodic processing may occur at various degrees of integration at the pre-semantic level.

In the context of music and speech stimuli, intentional efforts are required to attend to sounds similar to one another. According to Bregman (Bregman, 1978; 1990), the auditory system unfolds complex patterns of incoming acoustic information for the purpose of better cognition. Its goal is to perceptually organize sounds into one or more components, called "streams." The phenomenon of organizing sounds into different streams is commonly referred as auditory stream segregation. According to this hypothesis, the process that looks for any known representations, patterns or schemas in incoming auditory information is referred to as a schema-driven process. Listeners' voluntary attention is thought to be involved in schema-driven or top-down processes. Thus, familiarity with the auditory stimulus plays a major role in the execution of schema-driven processes. Familiarity can stem from acquired learning, knowledge, and prior experiences of a sound source (including a musical instrument or a human voice). Schema-driven processes may be involved in the segregation of language, speech, melody, music, timbre, or any acoustic event of a known environment. Timbre, in particular, is a complex, multidimensional property that enables us to discriminate between two musical instruments playing the same note with the same frequency, intensity or duration. Similarly, it helps us to differentiate between the two speakers speaking the same words. Timbre is the property that gives musical instrument or voice a typical tone or texture (Iverson & Krumhansl, 1993; Menon et al., 2002).

Bregman has argued that recognition of a familiar timbre in a particular tone from the mixture of tones depends on the schema-driven process of segregation. Researchers have conjectured that it may require several other mechanisms, such as selective attention, short-term memory based comparisons and working memory, to enable selective listening and tracking of one of the instruments from the mixture of different timbered instruments, with selective attention paid to timbre selection causing an additional load (Alain & Bernstein, 2008; Cusack, 2005; Deike, Gaschler-Markefski, Brechmann, & Scheich, 2004; Janata, Tillmann, & Bharucha, 2002; Kondo & Kashino, 2009).

Along similar lines with auditory stream segregation, one study (Vaidya-Mairal, 2015) that investigated the effect of a number of sound sources contained in the auditory stimulus reported the disruptive effect of two sound sources (vocal + piano) on accuracy of responses when coupled with linguistic content in the background auditory stimulus. The study involved the cognitive task of visual semantic picture categorization and measured reaction time and accuracy of responses made during the categorization task while participants listened to the auditory stimulus at the background.

The evidence summarized in this section overall suggests that the processing of content and melody that are present in the background music may have an impact on cognitive performance. Past studies focusing on the effect on cognitive tasks of background music or meaningful auditory stimulus used a number of semantic tasks such as reading comprehension, proofreading, and semantic memory recall. However, a task of visual semantic word categorization has not yet been tested in a similar setting.

The Cognitive Task of Categorization

Categorization is a complex process utilizing basic cognitive skills and may be defined as an allocation of objects or events to various classes. As described by Medin and Smith (1984), categorization refers to deciding whether a particular object belongs to a particular class or not. It is achieved by taking into consideration mental representations of various categories and then finding a way to decide which provides the most appropriate fit to the objects under consideration. In the context of category naming, Smith and Osherson (1995) explained that categorization is the crucial way in which human beings code their experiences, and the coding aspect of categorization affects why human languages possess simple terms or names for categories. Another viewpoint was presented by Rosch, Mervis, Gray, Johnson, and Boyes-Braem (1976), who argued that objects belonging to a category are equivalent to one another.

Theories of Categorization

Several theories attempt to explain how we classify and organize objects within our mental lexicon. Classical theory assumes that categorization of objects is based on a fixed set of individually necessary and jointly sufficient defining features; however, a major problem with this view is that many categories do not have clear-cut boundaries and may be vague with unclear distinctions. The prototype theory postulates that the potential members of semantic categories are classified based on degree of similarity with a corresponding prototype (Hampton, 1995; Rosch, 1973; 1975). As explained further by Rosch (1975), objects in the real world can be grouped together on a number of associated features. This group of inter-connected features directs to the information of prototype concepts, prototype being the category member constituting all of the features in the respective group. Inclusion in the prototype concept category is decided by determining how similar any object is to this prototype, where similarity is defined in terms of the weight and number of the prototype features that the object constitutes (Hampton, 1998). Kruschke (2005; 2008) further developed the prototype model by concluding that a summary representation of many objects is stored together in the categories instead of storing the information about each and every object.

The exemplar theory of categorization operates analogously to the prototype theory with certain different representations and presenting individual exemplars. The main assumption is that individual exemplars of a category are stored in memory while classification decisions are made based on the similarity of stimuli to the stored exemplars (Medin & Schaffer, 1978; Murphy & Medin, 1985; Nosofsky, 1986). In this model of categorization, each distinct instance of a stimulus and its category label are stored in memory. Similarity of the stimulus to all the previous known exemplars is included and combined, and then the category of the stimulus is determined. Thus, the notion of similarity plays a critical role in this type of model.

Categorization tasks are performed with a variety of stimuli such as pictures, letters, digits, objects, and printed words. While the categorization of pictures and printed words is the most common form, the current study specifically used printed words to make it more challenging with a background of vocal music. Before we explore the facts related to the categorization of printed words, we need to understand the way in which printed words are read.

Processing of Printed Words

Accessing the meaning of printed words is one of the most complex and important skills in the process of reading acquisition. The experimental models describing recognition of printed words indicate that the stimuli of printed words contain information at different levels and that there are several stages of cognitive processing involved in printed word recognition. A word stimulus carries information at levels such as the appearance of letters or spelling (graphemic and orthographic representation), pronunciation or articulation (phonetic representation), and meaning (semantic representation) (Bentin, Mouchetant-Rostaing, Giard, Echallier, & Pernier, 1999; Ellis, Flude, Young, & Burton, 1996; McClelland & Rumelhart, 1981; Seidenberg & McClelland, 1989; Smith & Magee, 1980). Thus, it becomes crucial in word learning and recognition to build associations between grapheme-phoneme representations and, in turn, between printed and spoken language (Blomert, 2011; Grainger & Holcomb, 2009;

Jost, Eberhard-Moscicka, Frisch, Dellwo, & Maurer, 2013). Although the concept of processing levels of printed words has been accepted by most of the theories of printed word processing (Ellis , Flude, Young, & Burton, 1996; McClelland & Rumelhart, 1981; Seidenberg & McClelland, 1989), there is a lack of consensus regarding the interactions between those levels of processing of printed words. The traditional view proposes a series of processing stages in which the orthographic stage is the first level of processing, followed by a phonetic stage, which is followed by semantic processing of a printed word (Morton, 1969). As a result, naming printed words may appear as a faster process than categorization or classification, the latter of which requires access to semantic information. Another view proposes a cascade pattern of processing levels in which the processing of a particular stage can begin before the processing of a previous stage has ended (McClelland, 1979). A more recent view of printed word reading proposes that parallel processing of stimulus takes place at all levels (Carr & Pollatsek, 1985; Jared & Seidenberg, 1991; McClelland & Rumelhart, 1981; Seidenberg & McClelland, 1989).

Horn and Manis (1987) conducted a set of experiments to explore the process of recognition of printed words, particularly the development of automaticity and speed in accessing the meanings of printed words. In their study, the ability to identify a printed word automatically without focusing on individual letters or letter-sound connections was termed “automaticity.” College students as well as school children (1st through 5th grade) took part in the study, which administered dual task procedures in order to assess automaticity in terms of the degree of attention paid to reading and comprehending printed words. The participants matched a pair of words for the same/different semantic category while monitoring a tone. Exemplar words from each of the four categories – animals, colors, body parts, and clothes – were chosen as word stimuli. In the second experiment, the speed of word reading and recognition was assessed via identification and categorization tasks. In an identification task, the subjects were asked to make speedy decisions about whether pronounced and printed words were the same. In a categorization task, subjects made binary yes/no decisions about printed word categories. The authors claimed that the identification condition provided a measurement of time for word recognition without accessing meaning, whereas the categorization condition provided a measurement of time for access to meaning. The results revealed a significant drop in time and degree of attention paid to recognizing and categorizing words from 1st to 2nd grade children. The results also revealed that adults do allocate some attentional processing resources to word reading and accessing meaning, thus making the word reading process not fully automatic.

In a very recent study, the time course of reading visual words was studied through the use of electrophysiological measures (Eddy, Grainger, Holcomb, Mitra, & Gabrieli, 2014). In particular, researchers looked into the temporal measurement of automaticity in children and adults processing and accessing meaning in visual word forms. They used the method of masked priming in which two words were presented at very short intervals so that processing the first word is assumed to be influential in processing of the second word. The study’s authors deduced that in children automaticity for visual word form processing takes time to develop.

As described by Yum, Holcomb, and Grainger (2011), another approach to understanding the semantic aspect of printed word recognition is to look at the processing differences between printed words and objects (pictures). Individual features of objects convey a great deal of information or meaning about the object, whereas the individual features (e.g., letters) of printed words fail to convey meaning of the word. This may be why the semantic categorization of printed words takes longer than that of pictures or objects.

Categorization of Printed Words

An investigation of the storage, organization, and retrieval of semantic information from memory store can be done using a binary semantic decision task. In binary task of semantic categorization, a subject is asked whether a printed word (or a picture of an object) belongs to a previously specified semantic category, and whether two printed words (or pictures) belong to the same semantic category (Collins & Loftus, 1975; Guenther & Klatzky, 1977; Meyer, 1970). Guenther and Klatzky (1977) carried out a study involving a binary yes/no semantic categorization task where subjects had to indicate whether two simultaneously presented words belonged to the pre-specified superordinate target category. The superordinate target categories were carpenter's tools, kitchen utensils, mammals, and birds. Printed words were the six subordinate words chosen from each of the above superordinate categories (for example: hammer, screwdriver, pliers, wrench, wedge, crowbar; fork, spoon, cup, glass, toaster, burner; dog, cat, bear, lion, mouse, rabbit; blue jay, sparrow, eagle, hawk, chicken, and turkey). All the stimuli were chosen from Battig and Montague (1969) frequency norms. The authors also used different graphemic presentations of printed words. The reaction time was measured from the time when two printed words were displayed simultaneously on the screen until the recording of a yes/no response by subjects. As seen in these experiments, as well as those of a other studies (Collins & Loftus, 1975; Meyer & Schvaneveldt, 1971), reaction times were shorter for the pair of words that were semantically related than for those that were not.

In another experiment by Smith and Magee (1980), four superordinate categories – animals, food, clothing, and household furniture – were incorporated to elicit judgments on whether an item belongs to a particular category. An incongruent category picture was displayed during a word categorization task, and an incongruent category word was displayed during a picture categorization task as a slight variation in method. The study findings indicated more disruption in case of word categorization than in that of a picture.

In a previously mentioned study by Horn and Manis (1987), binary yes/no semantic categorization for a pair of words was performed by children and college-going adults. Eight stimuli words were selected from each of the four categories. Stimuli words were chosen from a separate study in which 140 children were asked to write down as many items from each of the categories as they could in one minute (method adopted from Horn, 1985). The authors claimed that the speed with which meanings of the printed words were accessed was reflected in categorization times. As stated earlier, the results revealed a significant drop in time and degree of attention paid to recognizing and categorizing words from 1st to 2nd grade children. The results also revealed that adults do allocate some attentional processing resources to word reading and accessing meaning, thus making the word reading process not fully automatic.

Potter and Faulconer (1975) explained that word and picture categorization can be thought of as a two-step process of visual discrimination and semantic decision. As a result, visual similarity and semantic relatedness play significant roles in the word-picture categorization process. Visual surface similarity, typically described as a condition where objects have common visual features/attributes, or similarity in shapes and sizes, is greater among pictures belonging to the same category than among pictures belonging to different categories. A pair of categories like fruits and vegetables possesses a higher visual similarity than categories like fruits and animals. Experiments where word-picture differences for binary yes/no semantic category decisions have been studied found that, in general, if pictures are visually dissimilar reaction times are shorter for pictures than for words (Hogaboam & Pellegrino, 1978; Pellegrino, Rosinski, Chiesi, & Siegel, 1977; Potter & Faulconer, 1975). However, another finding from these experiments suggested that it may take longer to categorize pictures if they are visually similar. Since words do not have an extra factor of visual similarity or dissimilarity, semantic relatedness holds more importance in the case of word categorization.

Snodgrass and McCullough (1986) explained the picture superiority effect in categorizing tasks with the visual similarity hypothesis. In general, pictures are categorized at a superordinate level (e.g., vehicle) with the help of visual surface similarity and not through internal semantic rules. Subjects were asked to categorize pictures/names (words) for visually similar and dissimilar categories. The categories were fruits, vegetables, and animals. The results showed that the categorization time for pictures was affected by visual similarity. Longer reaction times were observed for pictures of visually similar categories, whereas shorter reaction times were observed for pictures of visually dissimilar categories. Snodgrass and McCollough interpreted these results to explain that since pictures from the same category are usually visually more similar to each other than pictures from two different categories, study participants might have used visual cues as a means of categorizing pictures at the initial step.

Job, Rumiati, and Lotto (1992) observed longer categorization times for words and pictures belonging to semantically and visually related categories than for words and pictures belonging to two semantically and visually nonrelated categories. Extended findings from their studies (Lotto, Job, & Rumiati, 1999) suggested that reaction times for semantically related conditions were longer than for unrelated conditions for words, as well as for pictures. Strong effects of visual similarity were observed only in the case of pictures and not for words when semantic relatedness was held constant.

To further investigate these inconsistent findings about picture categorization times from previous studies, Viswanathan and Childers (2003) designed a new methodology to test word-picture categorization. By controlling for visual similarity and semantic relatedness, they asked participants to make binary yes/no judgments about categories. Words chosen for their experiment were based on the standardized norms created by Snodgrass and Vanderwart (1980). The categories from which words were selected were animals, parts of the human body, clothing, fruits, vehicles, sporting items, and insects. Results revealed an advantage for pictures over words for a binary task of categorization. The authors stated that semantic relatedness plays a bigger role than visual similarity in categorization for both words and pictures and that visual features in pictures can activate many facets of meaning; therefore, pictures can simultaneously access features (and, in turn, meanings) and concepts, whereas words only have access to meaning because they lack information from visual features. This effect might lead to longer categorization times for words than for pictures because the process of categorization is believed to be mediated by semantic processing.

Most of the studies focusing on word-picture categorization involve comparisons between individual categorization tasks for words and pictures. However, Greene and Fei-Fei (2014) carried out a categorization task in which they used a Stroop-like paradigm to compare basic-level (forest or street) and superordinate (natural or urban) categories. Printed words for objects or scenes were congruently or incongruently superimposed with images of objects or scenes. Their findings revealed two insights: first, categorization performance suffered more in incongruent settings; second, basic-level categorization for scenes seemed to be automatic. The authors further explained that if we saw a novel scene we tended to label it automatically only at a basic level (forest or street) but not at a superordinate level (natural or urban setting).

In order to check whether widely used Battig and Montague's standardized category norms for younger adults were also valid for use in research with middle-aged and older adults, Howard (1980) carried out an experiment with younger (20-39 years), middle-aged (40-59 years), and older adults (60-79 years). The subjects were required to produce as many category exemplars as possible for each of the categories chosen from the Battig and Montague norms. He confirmed that it is appropriate to use the same category norms in experiments that deal with middle-aged and older adults for most of the categories.

In an attempt to gain more understanding about how categorization in different sensory modalities is represented in the neural system, Adams and Janata (2002) used a type of a binary yes/no categorization task, which they termed a "name verification task," for picture and auditory sound stimuli. A printed word label was presented on a screen simultaneously with a picture or a sound stimulus. A word label either matched or mismatched the category of presented stimulus. The participants had to indicate with yes/no whether the word label category and stimulus was a match. Results revealed that reaction times for visual objects (pictures) were lower than those for auditory objects (sound stimuli). In conjunction with further analyses, fMRI imaging data provided interesting insights about brain regions that might be engaged in a common semantic representation of visual and auditory objects.

In a recent study consistent with that of Adams and Janata (2002), Simanova, Hagoort, Oostenveld, and van Gerven (2014) performed fMRI imaging of participants who performed semantic categorization tasks. Input stimuli were presented in four different input modalities: spoken (auditory) and written (visual) words, photographs (visual), and natural sounds (auditory). The participants indicated out-of-category exemplars in a given block. The categories were animals and tools. Simanova et al. were able to decode semantic information from fMRI data and, with the help of a source localization technique, revealed similar frontal lobe areas engaged in the semantic task irrespective of the input modality. Further validation is necessary in this regard; however, the combined results of these two studies may suggest the possibility of accessing similar semantic resources in audio-visual dual-processing where the processing of semantic information is taking place.

Categorization research provides a general understanding that categorization task is primarily a semantic processing task and semantic relatedness between objects or words plays a bigger role than visual similarity that is present between them. Reaction time research tied to this topic emphasizes on the fact that processing and categorization of words may not necessarily be fully automatic in case of adults.

As seen above, the reaction time measurement is the most critical part of categorization experiments. Researchers have proposed that the reaction time in categorization experiments may reflect the speed with which semantic information is accessed from the semantic memory stores. As a result, the speed and accuracy of responses in categorization tasks tell us how fast information is being processed. The speed at which information is processed is a crucial factor in evaluating cognitive abilities, which are believed to be affected by aging. It would be interesting to see how normal older adults respond to the categorization of printed words in both control and background music conditions.

Cognitive Processing with Aging

Speed of Processing

A significant number of researchers have tried to explain the causes of age-related changes in cognitive ability. The explanations broadly focused on two approaches: the efficiency of task-specific structural or processing elements, and global or general factors such as a reduction in processing speed, working memory capacity, or inhibitory efficiency (ability to ignore irrelevant information). Reviews of the early literature reveal a greater focus on the global factors, specifically a decrease in processing speed with an increase in age, as the primary factor (Baddeley, Logie, Bressi, Sala, & Spinnler, 1986; Birren & Fisher, 1995; Hasher & Zacks, 1988; Salthouse, 1996).

A study by Hartley, Stojack, Mushaney, Annon, and Lee (1994) suggested that threshold reading and recall time was significantly longer in older than younger adults. Twenty four younger adults (20-39 years) and 24 older adults (60-83 years) took part in the experiment, in which one of the two tasks was reading a list of sufficiently long and semantically complex sentences containing between 11 and 16 words, with 5 to 7 propositions. The participants were asked to recall a sentence after it was presented. Older adults who recalled the text more effectively have also been shown to pause more frequently than younger adults in organizing new information while reading three narratives.

Pfütze, Sommer, and Schweinberger (2002) studied behavioral and electrophysiological performance on age-related slowing by asking participants to recognize names and faces. Three groups of 16 participants each took part in the study; the groups were divided into young (mean age: 25.4 years), middle-aged (mean age: 45.4 years), and older (mean age: 64.6 years) individuals. They were instructed to sort each name and face displayed into the categories of famous and unfamiliar persons. Mean reaction time measurements revealed that the group of older participants exhibited longer response times to visual stimuli.

The speed-induced processing impairment of cognitive function in older adults can occur either because operations cannot be successfully performed within the available time ("limited time mechanism") or because the outcomes of early processing are already lost when later processing takes place ("simultaneity mechanism"). The limited time mechanism is believed to take place when cognitive operations are executed too slowly relative to the time available for processing; the simultaneity mechanism occurs because not all the information that is needed for higher level processing is available simultaneously as a result of a slower processing speed (Salthouse, 1996). A key assumption in the processing-speed theory is that the speed of processing is a critical constraint in cognitive processing. The underlying assumption is that the cognitive abilities of an individual are not only a function of the nature of processes involved in the cognitive task, but also of the speed at which the processes can be performed. The reduction in the speed of processing is thus assumed to be a major factor in the effect of age on measures of cognition (Salthouse, 1980, 2000).

Despite the focus on processing speed as a primary factor in age-related cognition impairment, there is some evidence that working memory and inhibition do play key roles in the decline and that the relative contribution of these three factors depends on the type of cognitive task at hand (Kliegl, Maayr, & Krampe, 1994; Mayr & Kliegl, 1993). A study by Van der Linden et al. (1999) sought to establish the relative contribution of processing speed, working memory capacity, and inhibition capability to the effects of aging on language performance. The study consisted of 151 participants in a broad age range of 30-80 years divided into 5 age categories (30-39, 40-49, 50-59, 60-69, and 70-80 years). A number of different tests were administered, and the participants were tested for processing speed, working memory, and interference (the capacity to inhibit irrelevant information); a letter comparison task was also incorporated into the study. In a letter comparison task, which is the most commonly used task for the measurement of processing speed, participants decide if two letters from a pair are same or different. Color naming was another task used to measure processing speed; in this task, participants were asked to name the ink color with which strings of letters were presented. Measuring working memory involved an updating task in which strings of consonants were presented at a certain rate and participants were asked to recall them. The interference task was administered in the form of the Stroop color-word task where participants had to name the color in which the presented word was printed. Significant decrements in processing speed, interference, and working memory performance were seen in 60-69 year-old and 70-80 year-old age groups than in the other three groups. The study confirmed that language performance is correlated with age-related reductions in speed, resistance to interference, and working memory. One implication of this result is that older adults in the age group of 60-80 years may display significantly poorer performance in dual-processing paradigms where a primary reaction time task is coupled with secondary (voluntary or involuntary) processing of irrelevant background stimulus.

Attention

As discussed earlier, aging is associated with declines in cognitive functions such as processing speed, working memory capacity, and inhibitory control (Van der Linden et al., 1999). The decline is most apparent when older adults encounter complex tasks with multiple simultaneous stimuli, and they are more easily distracted by task-irrelevant stimuli than are younger adults. This limitation means that an older adult is less efficient in attending to a stimulus while ignoring another in a dual task (Craik & Salthouse, 2011). It is hypothesized that older adults may develop an ability to enhance the focus of their attention on a target stimulus to compensate for increased distractibility (Horváth, Czigler, Birkás, Winkler, & Gervai, 2009). According to this so-called decline-compensation hypothesis, older adults must spend more attentional effort than young adults to achieve the same level of performance (Dennis & Cabeza, 2008).

In an experiment carried out by Horváth et al.(2009), three groups of participants – children (6 years), young adults (19-24 years), and elderly adults (62-82 years) – performed a go/no go duration auditory discrimination task. Their study revealed a surprising finding. A group of children was found to be significantly different from the other two groups in terms of reaction time and distractibility however; no significant difference was found between young and elderly adult groups for reaction time and distractibility. Indeed, neurophysiological studies show that high-performing older adults employ additional cognitive resources in demanding listening situations, demonstrated by activation of frontal brain areas, than do the low-performing older adults (Getzmann, 2012; Getzmann & Falkenstein, 2011). In a Getzmann and Falkenstein (2011) study, comprehension of spoken language understanding was tested in natural language setting with younger listeners (19-25 years) and older listeners (54-64 years). Results of their study revealed that older listeners did not miss more responses than younger listeners and did not take longer time to respond than younger listeners. Event-related potential activity showed a difference in cortical processing for both age groups. High performing older adults seemed to engage more amounts of frontal lobe areas to compensate for increased distractibility. In another study by Getzmann (2012), he looked into spoken language comprehension in a natural setting and added a demanding listening setting. The same age groups of listeners were incorporated as those in Getzmann and Falkenstein (2011). Word (target) detection task was used and results revealed that older adults performed better than younger adults in terms of missed responses. Event-related potential results once again showed frontal lobe activation exclusively in case of older adults and Getzmann concluded that high performance of older adults was related to an extra engagement of neural resources

In a very recent study, Getzmann, Gajewski, and Falkenstein (2013) studied involuntary shifts in attention to task-irrelevant deviant stimuli and subsequent reorientation using older adults in the age range of 63-88 years and younger adults in the range of 19-33 years. Performance data on an auditory distraction task revealed that older high-performing adults showed a pronounced frontal activation. This implies that high-performing older adults were recruiting extra attentional resources to perform at the same level as younger adults, providing additional evidence for the decline-compensation hypothesis.

Information processing research on cognitive aspects of aging has predominantly revealed a finding that processing speed, working memory, and inhibitory efficiency are few of the areas that get affected with aging. Inhibitory efficiency, this ability to inhibit or ignore irrelevant background information becomes more important in cases where dual or multi-tasking is required. Interestingly, the latest neurophysiological techniques have also shown that this decrease in ability to inhibit irrelevant information may get compensated by allocating extra cognitive neural resources in case of some high performing adults.

Both voluntary and involuntary forms of attention paid to task-irrelevant stimuli cause distraction from the task relevant stimuli and hence impair the performance of cognitive tasks due to some degree of involuntary processing of task-irrelevant stimuli. The word “background” in “background music” suggests that it can be task-irrelevant to the primary task. Although in the current study the performance of listening to background music was not measured directly as a secondary task performance, it still involved a secondary processing that may take resources away from the primary task and can lead to degradation in performance. However, the performance of a so-called “secondary task” in the current study is gauged in terms of degree of attention by presenting a questionnaire. Even though it is not a case of dual task in the sense that performance on a secondary task of listening to background music is not measured in real time, it certainly is the case of dual-processing and hence is necessary to cover the literature on dual tasks (in which dual-processing takes place).

The Cognitive Aspects of Dual-Processing Tasks

The dual task paradigm refers to a methodology in which two tasks are performed simultaneously, and the result is compared to that when a single task is performed. The investigation of a dual task performance provides insights into the human system and its processing capacities.

The human system has finite capacities, called resources, to perform tasks, and the level of one's performance is directly related to the resources available. Data quality (including the parameters related to stimuli, level of practice, and response complexity) determines the characteristics of the tasks, called subject-task parameters, for human beings (Navon & Gopher, 1979; Norman & Bobrow, 1975). The level of performance intended in tasks with pre-defined subject-task parameters requires a particular level of resources. The more difficult a task and the higher the level of intended performance, the greater the demand placed on the resources. The human system provides resources depending on the demand but also subject to the availability of resources. If the demand is greater than the resources available, then the system cannot supply sufficient resources. When more than one task is being performed, the resource allocation becomes even more complex, depending on the objective demands of the tasks and the subjective preferences of the person. When the difficulty or parameter of task changes, the productivity of a unit of resource changes. During the performance of multiple tasks, the nature of the effect of one task over the others has an impact on the cumulative demand on the resources (Navon, 1985; Navon & Gopher, 1979; Norman & Bobrow, 1975; Wickens, 2002). Evidence for this was seen in a study by Just, Keller, and Cynkar (2008). Using the fMRI technique, they investigated the brain activity associated with a simulated driving task in two settings: an undisturbed driving task and a driving task coupled with a simultaneous auditory sentence comprehension task. The participants judged the sentences as true or false during the second setting while virtually driving on a curved path. The driving accuracy observed in case during performance of the dual tasks was lower compared to the performance during undisturbed conditions and was accompanied by a decrease in the activation of parietal lobe associated with spatial processing. Just et al. interpreted those findings as reflecting a capacity limit on resources required by two tasks and, as a result, mental resources are drawn away from driving by an auditory language task that causes impairment in driving performance.

Another example of how increased cognitive load affects performance in a dual task is found in the study by Gosselin and Gagne (2011), which revealed poorer performance by older participants in a sentence recognition task that was performed simultaneously with a secondary task of pattern recognition in the presence of noise. In the sentence recognition task, the participants were asked to denote the three key words after listening to each of the sentences. The study's authors interpreted the poorer performance among older participants in terms of a limited capacity of available resources and argued that fewer cognitive resources are available for older participants in case of a dual task. The literature suggests that if tasks only compete for resources, then the total resources needed are the sum of those needed for each task performed individually. However, if the tasks interfere or conflict in some way, then the jointly performed tasks demand more resources than sum of those needed for separately performed tasks. If dual tasks are presented, and the subject is asked to ignore one task and attend to the other, the resources required are still more than those when the attended-to task was presented by itself; some resources are required for the involuntary processing of the task to be ignored (Navon & Gopher, 1979; Norman & Bobrow, 1975; Wickens, 2002).

An fMRI study by Mayer, Bittner, Nikolic, Bledowski, Goebel, and Linden (2007) presented an example of conflicting tasks causing more load on processing capabilities. The study was based on a hypothesis that visual selective attention and visual working memory share common neural resources and, as a result, the ability to memorize visual information over short periods of time is limited. The participants were instructed to perform a visual search and to encode one of the three complex objects into visual working memory. The results indicated overlapping activation of visual working memory and visual search, suggesting a sharing of resources and thus a limitation of processing capabilities.

In the context of ignoring one task and attending to the other, the subjects in another study involving dual-processing were instructed to attend to auditory sentence comprehension, or to mental rotation of visual objects, or to both. The fMRI imaging results showed a high level of activation in the language-processing regions when the subjects attended to auditory sentences and low activation in visuospatial regions even when they ignored the mental rotation task. Similarly, a lower activation in language processing regions was observed even when subjects ignored the auditory sentences. The activation of brain areas associated with ignored tasks indicated that some quantity of resources was still allocated to process the to-be-ignored stimuli (Newman, Keller, & Just, 2007).

On the other hand, if the two tasks presented are both attended to, then there are two possibilities. First, it is likely that the performance of one task is negatively affected at the expense of the other. In such situations, the two tasks may be using the same resources. Mayer et al. (2007), the study described above, also provided support for the view that visual working memory is affected by visual attention; common resources are shared for processing. The second possibility is that performing one task has no bearing on the performance of the second task, suggesting that the resources used in the two tasks may be independent of one another (Kahneman, 1973; Keele, 1973; Kerr, 1973; Wickens, 2002). A study by Alais, Morrone, and Burr (2006) showed independence of resources for vision and audition when dual tasks contained dual-processing of these two different modalities. They used a visual contrast discrimination task and an auditory tone pitch discrimination task as the two concurrent tasks and found no effect on the performance of each task in the presence of the other. The authors argued that the results revealed that these sensory modalities are not shared by the same attentional control as in the case of low-level discrimination tasks.

Another example of distinct resources was established in an earlier fMRI imaging study by Adcock, Constable, Gore, and Goldman-Rakic (2000). They used a dual task paradigm with auditory (verbal categorization noun task) and visual (space rotation or face identification task) components. Activation scans showed that areas that were activated under dual task conditions were also activated in single task conditions for respective components. Based on these findings, Adcock et al. proposed the existence of different specialized information processing systems in the human brain involved in multitasking. This view of independent processing resources, and these two examples of studies (Adcock, Constable, Gore, and Goldman-Rakic, 2000; Alais, Morrone, and Burr, 2006), may not be considered to be entirely consistent with the widespread views about processing resources and performance in dual tasks.

Navon (1985) proposed another view on performance in two (or more) concurrent tasks in addition to his view about the number of resources available in concurrent tasks. According to this view, task interference may not result from the scarcity of resources, but rather from the outcome or side effects of one of the tasks interfering with the processing required for the second task, referred to as outcome conflict or cross-talk (Navon & Miller, 1987). An example would be singing a waltz and dancing in a tango style. Shaffer (1975) illustrated an example of this notion in his experiment. When two tasks, such as typing to dictation and reading aloud were performed simultaneously, performance was observed to deteriorate significantly. In case of typing to dictation, processing auditory words generated task-inappropriate speech response presentations in addition to a task-appropriate typing response. This created interference for the verbal response required of reading aloud. Similarly, reading printed material aloud created a task-inappropriate typing response in addition to a task-appropriate verbal response.

Performance Measures Obtained in Dual-Processing Tasks

Reaction Time in Categorization Tasks

Reaction time measurements are one of the most popular measures for processing semantic memory research within human information processing. A simplified definition of reaction time can be stated as the speed with which subjects can judge statements or make decisions about category membership (Rosch, 1999).

In the study carried out by Ashby and Maddox (1994), categorization response time (RT) was studied in three different experiments that involved three different types of stimuli: (1) horizontal and vertical line segments of varying length that were joined at an upper left corner, (2) rectangles of varying width and height, and (3) circles or semicircles of varying size with a radial arm of varying orientation. The study findings concluded that stimulus familiarity or category prototype were not significant factors in determining categorization RT.

Dick (1971) performed an experiment to study the relationship between naming and categorization in terms of reaction time measurements. The experiment involved either naming or categorizing an item as a letter or number where the size of the stimulus set was systematically manipulated across participants. The results indicated the precedence of naming over categorization.

The findings from a study by Landauer and Freedman (1968) revealed that reaction times were higher when object names were categorized into larger categories than smaller ones. Category size was considered to be a governing factor in the result. On the other hand, a series of experiments conducted by Collins and Quillian (1970) revealed no evidence that larger categories require longer categorization times than smaller ones but suggested that semantic relatedness is one of the determining factors of categorization time. The subjects in this study performed a binary yes/no categorization task for categories such as animal, dog, and bird.

Kiefer (2001) administered an electrophysiological study in which picture-word categorization differences were assessed. The subjects indicated whether a superordinate picture or word stimulus belonged to a natural or an artificial category. Consistent with the literature, categorization times showed the effect of picture superiority, that is, pictures were categorized faster for natural and artificial categories. In another study referred to earlier, reaction times for basic-level and superordinate categories were investigated in a Stroop-like paradigm (Greene & Fei-Fei, 2014) by superimposing words and objects/scenes. Categorization times for incongruent trials (a mismatch between a word and a superimposed image) were longer than for congruent trials for both word and object/scene stimuli. Moreover, basic-level categorization times for scenes were shorter than that of the superordinate level, which suggested that basic level categorization is automatic.

Reisenauer and Dreisbach (2013) sought to address the question; if distractors (irrelevant stimuli) are present in a categorization task, then are task instructions pertaining to relevant stimuli also automatically followed for the distractor stimuli? Again, a Stroop-like paradigm was used by superimposing target words and distractor picture stimuli. The authors found shorter categorization times for the trials where distractor and target stimuli were in the same category and thus proposed that distractor stimuli are automatically processed by the same set of rules as that of relevant stimuli.

Behavioral data from an fMRI study (Adams & Janata, 2002) using audio and visual forms of stimuli for binary yes/no categorization tasks revealed a main effect of sensory modality in reaction time. Specifically, categorization times for visual stimuli were faster than for auditory ones. Also, similar to the findings of Greene and Fei-Fei (2014), longer response times were observed for subordinate levels.

Reaction Time in Dual-Processing

Reaction time is also the most widely used measure for understanding the nature of performance in tasks where dual-processing is taking place. In the context of these tasks, reaction time signifies the time it takes subjects to respond to a certain stimulus by either making a decision or carrying out a task according to instructions.

One of the early studies that looked into the physiological basis for dual-processing interference engaged two types of auditory and visual tasks (Klingberg & Roland, 1997). The auditory tasks consisted of a go/no-go task where subjects were asked to report whether the frequency of a previous tone was lower than the last one, and a short term memory task (STM) where subjects were presented with a series of high pitched tones and asked to compare each target tone with the previous one in order to report whether the last target tone was lower. The visual tasks consisted of a similar go/no go task in which subjects reported a decrease in the luminance of a circular field, and an STM task in which subjects reported a target luminance level if it was lower than the previous level. A significant increase in reaction times was reported when the two tasks occurred concurrently.

Just, Carpenter, Keller, Emery, Zajac, and Thulborn (2001) also investigated the concurrent performance of two tasks in different sensory modalities. The study used a mental rotation task of 3-D figures as a visual task and a sentence comprehension task as an auditory task. The underlying rationale was to test the prevailing assumption that two sensory systems are independent in terms of processing resources. In a mental rotation task, total response times increased significantly (from 2440 ms to 2792 ms) from single to dual tasks. Similarly, in an auditory sentence comprehension task, total response times had a reliable increase (from 532 ms to 740 ms) going from single to dual task conditions.

In another study by Loose, Kaufmann, Auer, and Lange (2003), individual tasks were composed of identifying target stimuli in the form of two tones of identical frequency and patterns of four crosses forming a square for an auditory-visual dual task. The subjects underwent a dual task paradigm in which reaction time and accuracies were calculated while they were being scanned with fMRI imaging for the activation patterns. In a divided attention condition, reaction times were longer than in a selective attention condition for visual and auditory modalities. In addition, visual stimuli produced longer reaction times than auditory stimuli for both selective and divided attention conditions. Capacity limitations on resources for the two sensory stimuli in the divided attention condition were reflected in increased reaction times.

In order to explore effective learning styles in multimedia learning, Brünken, Plass, and Leutner (2004) administered a knowledge acquisition test of learned multimedia material while secondary processing took place in a task of auditory tone detection. Learning material was presented to ten undergraduates in visual only (pictures), audio-visual (verbal narration and pictures) and audio-visual plus background music (verbal narration and pictures with the background of instrumental music) formats. An interesting finding of higher test scores in the audio-visual condition was compromised by an increase in reaction time in a secondary task of tone detection. Reaction times for visual only and audio-visual plus background music conditions were comparable (231.60 ms and 235.61 ms respectively) but, as previously noted, reaction times for the audio-visual condition (with no background music) were significantly higher than the other two conditions (285.37 ms).

Newman, Keller, and Just (2007) investigated the behavioral and neural bases of ignoring one task while attending to another in auditory sentence comprehension and the mental rotation of visual objects. Behavioral results indicated significant increases in reaction times for a dual task condition. For sentence comprehension task, reaction times increased from 465 ms to 762 ms whereas for the mental rotation task, the increase was from 2835 ms to 3067 ms.

Accuracy in Dual-Processing

Along with reaction time, accuracy is another measurement widely used to understand the nature of performance where dual-processing is taking place. When a subject is asked to perform two tasks, there are two options: to divide his or her attention between the stimuli or focus on one and ignore the other stimulus. Performance can be measured using the accuracy of responses during such parallel-processed tasks relative to those with attention to one task (Treisman, 1969).

The literature suggests that the human system is complex, possessing multiple resource channels. The performance of a subject on tasks where dual-processing is involved is lower when inputs are in the same modality than when inputs are in two different modalities. Treisman and Davies (1973) showed that interference during dual task monitoring was substantially higher when the same sensory modality stimuli, either audio or visual, were presented than when stimuli were in different sensory modalities. Six undergraduate students participated in the study; they received the stimuli in the form of auditory words, auditory tones, visual words, and visual positions presented over two channels in combinations of visual and auditory V(A), visual and visual V(V), auditory and auditory A(A), and auditory and visual A(V) modalities. For both the channels, the subjects were asked to indicate the initial letter of visual words by writing, repeating auditory words by speaking them loudly, repeating the tones in the form of singing, and marking the visual positions. The results indicated a high (nearly 90%) percentage of accuracy for visual items when they were paired with auditory items. On the other hand, the study found low accuracies for the visual items in the second channel when they were paired with other visual items. Similarly, a greater loss in accuracy was reported in case of auditory items in the second channel when paired with other auditory items. The results further revealed that when words and spatial positions were both visually presented, there was a substantial interference between the stimuli, confirming that perception is severely affected when two inputs involve the same processing mechanism. In a subsequent monitoring task, the subjects were shown two simultaneous lists of words and asked to look or listen for a target word in both. The target words were in the form of words containing either the letters “end” or the sound “end” (physically defined target words) and all animal names (semantically defined target words). The results suggested that the subjects found it easier to look for a target word containing “end” in the visual presentation. In the case of the auditory presentation, they found it easier to look for a semantic target word. It was further revealed that the subjects were able to detect appreciably more targets with focused attention than with divided attention within the same modality, while they were able to divide their attention much more effectively when the two inputs were in different modalities. The results demonstrated that a greater processing capacity is available for two-modality dual tasks than for single-modality dual tasks. The authors suggested that with a complicated interplay of multiple resource channels, each with a finite capacity for processing information, each channel may be shared by several concurrent tasks and one task may involve multiple channels.

Norman and Bobrow (1975) elaborated on the role of resource constraints and data limitations in performance with multiple concurrent processes. According to their study, the performance of a process can be limited by either the quantity of processing resources or by the quality of input data. When the performance is unchanged even when additional resources are made available, the process is data-limited. Conversely, when the performance depends on the number of resources available, the process is resource-limited. In a data-limited process, where the input data is of inadequate quality, reaction time (RT) is inversely proportional to accuracy. However, when input data is of good quality and the processes are resource-limited, RT and accuracy have a direct relationship. In other words, there is a RT-accuracy tradeoff in a resource-limited environment (Norman & Wickelgren, 1969).

Numerous studies have shown that the nature of inputs affects performance in dual-processing situations. Massaro and Warner (1977) compared the performance of subjects with various combinations of input modalities – both auditory, both visual, or one auditory and one visual. Their study included two experiments that involved test tones (at 800 Hz and 880 Hz) presented at approximately 80 dB SPL and test letters (U and V). In the first experiment, four subjects identified the test tones as low or high and the test letter as U or V. In a divided attention condition, the subjects were cued to attend to both stimuli simultaneously and were required to identify both in a trial. In a selective attention condition, the subjects were cued to attend to a tone or a letter in each trial; they recorded their responses by pressing one of the four-push buttons in both the conditions. The results of the first experiment indicated poorer performance levels in divided attention conditions as opposed to over-selective attention conditions (about 4% better in the selective attention condition). In the second experiment, the performance during the divided attention condition was similar to that of the first experiment. The results of the second experiment indicated significantly poorer performance in simultaneous or divided attention conditions in comparison to the sequential or successive presentation conditions. The authors claimed that the study results showed evidence of the role of limited-capacity and selective attention during visual and auditory perception.

In the course of the above study, the participants performed auditory sentence comprehension and mental rotation tasks in a set of single and dual task experiments, indicating whether two 3-D figures were the same or mirror images of each other. Their performance in the mental rotation task showed degradation occurring under divided conditions. The error rate from a single to a dual task went up, from 7.8% to 12.3%. However, a performance drop from single to dual tasks of auditory sentence comprehension tasks resulted in negligible error rates (Just et al., 2001).

In their subsequent study, Just, Keller, and Cynkar (2008) analyzed the brain activity associated with the performance of a simulated driving task with and without a simultaneous auditory sentence comprehension task. The participants judged the sentences to be true or false while they virtually drove on a curving path. While driving in the listening condition, impairment on driving performance was observed in terms of significant errors such as hitting the curb and deviations from an ideal path. The single task driving condition had fewer errors than when performed in a listening condition. In addition, performance measures on the sentence comprehension task showed high accuracy (92%), which implied that participants did pay attention to background auditory stimuli while driving.

As described in a previous section on reaction time, Brünken, Plass, and Leutner (2004) administered a knowledge acquisition test on learned multimedia material in the presence of a secondary processing of auditory tone detection. The learning material was presented in visual only (pictures), audio-visual (verbal narration and pictures) and audio-visual plus background music (verbal narration and pictures with the background of instrumental music) formats. One interesting finding was the higher test scores in the audio-visual condition. The students had significantly higher mean score value of 15.6 in the audio-visual presentation than in the visual only presentation (mean value of 8.60). The authors argued that learners do grasp the learning material in dual task conditions; moreover, it may be that they do better with audio-visual presentations because more sensory information is available to acquire. However, the addition of background music to the audio-visual presentation of learning material reduced the test scores because, while it did not have learning content, it served as a distraction by impairing the performance of a single task.

Another experiment where the performance of a visual task was evaluated in the presence of an auditory task was carried out by Pizzighello and Bressan (2008). Ninety participants watched a dynamic display while they listened to verbal material; they were then asked to comprehend and recall the verbal material while the answers were measured for accuracy. At the same time, the subjects were asked to select an unexpected visual object from a display. The scores indicated that the number of correctly recalled words decreased significantly only when comparing auditory only to auditory-visual conditions. Also, the performance of a visual task – detecting an unexpected target – was lowered when auditory and visual tasks were coupled.

During an investigation of the behavioral and neural bases of ignoring one task and attending to another, Newman, Keller, and Just (2007) found impairments in each task under dual task conditions. The error rate increased from 8.3% to 19.2% in a sentence comprehension task and increased from 4.6% to 12.8% in a mental rotation task.

The Role of Capacity Limitation and Attention in Dual-Processing of Auditory and Visual Tasks

Treisman (1969) suggested that the perceptual system consists of several relatively independent subsystems, or “analyzers” (Sutherland, 1959), which code different aspects of stimuli. The ability to parallel process or divide attention is dependent upon whether different tasks share the same analyzing system or use different systems. Sharing a single analyzer is believed to make dual-processing performance relatively more difficult.

To investigate capacity limitations and attentional control during simultaneous visual and auditory inputs, Massaro and Warner (1977) conducted two experiments with test tones and test letters. In the first experiment, the subjects were asked to attend to one or both of the two simultaneous stimuli. In the second experiment, the subjects were presented with stimuli either sequentially or concurrently, with no specific instructions. Tone recognition was found to be compromised in a divided attention condition. Similarly, a letter was recognized more readily in a selective attention condition than when tone recognition was also required. The results showed a finite, but not large, effect of capacity limitations and attentional control during visual and auditory perceptions.

Another study by Bonnel and Haftser (1998) focused on the role of capacity limitation on dual-processing performance with auditory and visual inputs. Six undergraduate students took part in identification and detection experiments. Auditory and visual signals appeared 440ms after the onset of the constant stimulus called the "pedestal." An auditory channel signal in the form of a 500 Hz tone at 80dB was presented binaurally through headphones. A visual channel signal in the form of 3 cm lighted circle made with red phosphor was located at the center of a monitor with 1.64 mL luminance. In the divided attention condition for detection, subjects were asked to report any change in the pedestals; in the divided attention condition for identification, subjects were asked to report the direction of change in the pedestals as either incremental or decremental. The responses were recorded with the help of two computerized 6-point rating scales for auditory and visual channels, and the results showed that detection in a divided condition was as efficient as when each task was presented individually. However, identification in a divided condition involved a tradeoff in performance, likely due to a limited capacity. The study's authors suggested that resource limitations become important at a central level of processing (involved in identification) rather than in the auditory and visual peripheries (involved in detection).

In the dual task of auditory sentence comprehension and mental rotation of visual objects, fMRI imaging showed less activation of sensory and association areas in a dual-processing condition than the sum of the activation of two individually performed tasks. In the visual task, participants performed a mental rotation task by indicating whether two 3-D figures were the same or mirror images of each other. In the auditory task, they performed a sentence comprehension task where they indicated whether general knowledge sentences were either true or false. Behavioral measures in terms of response time and accuracy showed a decline in the performance of a mental rotation of visual objects in dual tasks, whereas the sentence comprehension task showed decline only in case of response times in dual tasks. The authors presented the possibility of interdependence of otherwise independent, non-overlapping areas of sensory and association cortex engaged in a dual cognitive task that involved different sensory modalities. Another interpretation offered by the authors focused on the capacity limitation placed on the total amount of cortical activation and attention available for each task.

These results raised a general concern in a real-life situation pertaining to driving regarding an individual's ability to drive in the presence of distracting auditory stimuli (Just et al., 2001). Just, Keller, and Cynkar (2008) addressed this concern in their next study in which they focused on the brain activity associated with a simulated driving task in conjunction with a simultaneous auditory sentence comprehension task. The participants judged sentences as true or false while they virtually drove on a curving path. The results revealed decreased activation of the parietal lobe associated with spatial processing in a dual task and interpreted it as a limit of the amount of attention or resources required by two tasks, which means that mental resources are drawn away from driving by auditory language tasks causing impairment in driving performance.

Another experiment where limits on capacity of resources or attention were witnessed in terms of behavioral measures was also based on the performance of a visual task in the presence of an auditory task (Pizzighello & Bressan, 2008). In that study, 90 subjects listened to verbal material (auditory), counted the number of bounces of moving objects (visual), or did both (dual) while they watched a dynamic display. The subjects were required to comprehend and recall the verbal material as the accuracy of their responses was measured and recorded. At the same time, the subjects were expected to select an unexpected visual object from display; the findings indicated that only one third of subjects detected an unexpected object while they listened to verbal material. An inability to notice these unexpected objects, termed "inattentional blindness" by the authors, was equally likely in auditory only and dual conditions. The study proposed that the auditory task might have used all the resources, exhausting the available capacity, by giving all the attention to verbal material. The study also offered further practical implications about the possibility of impairment of our reactions to unexpected objects during driving while listening to the radio.

Klingberg and Roland (1997) used the PET imaging technique to investigate the effect of divided attention and its physiological basis. They used both auditory and visual go/no go tasks and short term memory tasks to test the dual-processing interference. In doing so, they observed activations of overlapping areas of cortex and postulated that limitations in processing capacities for two simultaneous tasks were reflected in the increased reaction times. Another PET imaging study (Anderson, Iidaka, Cabeza, Kapur, McIntosh, & Craik, 2000) focused on brain activation as related to the effect of divided attention on encoding and retrieval in memory. The study utilized visual tasks consisting of a memory task of lists of moderately related (semantically) word pairs and an encoding task of those visually presented word pairs by making a visual image connecting them. A secondary auditory task involved randomly presented high and low tones, and the participants were instructed to press the buttons corresponding to high or low tones. Younger and older adult groups were included in the study and compared for their brain activity while in conditions of divided attention. Activation patterns showed reduced activation of the prefrontal cortex (involved in memory encoding) during an encoding task in a divided attention condition followed by disruption in encoding performance (measured as mean proportion of words correctly recalled) for both groups. The authors suggested that divided attention impaired elaborate encoding of semantic information by reducing the amount of available attentional resources.

Newman, Keller, and Just (2007) carried out an fMRI imaging study in which the subjects either attended to auditory sentence comprehension, or to the mental rotation of visual objects, or to both. The sum of activation areas associated with auditory sentence comprehension and visual mental rotation conditions was greater than the activation areas for dual task conditions. The authors provided explanation of this finding by maintaining that limited resources in the case of dual tasks might cause interdependency of brain regions in terms of activations at any given point. Similarly, a decrease in activation of sensory areas was observed in divided attention conditions in another auditory-visual dual task study (Loose, Kaufmann, Auer, & Lange, 2003). In that case, the dual task was composed of identifying target stimuli in the form of two tones of identical frequency and patterns of four crosses forming a square. The subjects underwent the dual task paradigm while they were being scanned with fMRI imaging for the activation patterns. Loose et al. conjectured that the limited capacity of a resource system for controlled processing may have caused this decrease in brain activation during a dual task.

Consistent with Loose et al., Johnson and Zatorre (2006) found significantly less activation of sensory areas during divided attention conditions. In this study, the subjects were scanned with fMRI while they attended to auditory novel, tonal melodies or abstract, novel, closed, 2-D shapes, or attended to both, or passively observed both as a baseline. At the end of the experiment, the subjects were tested on a recognition memory task to check whether attention instructions were followed. The authors claimed that a decrease in sensory activity during divided attention is a case of neural resource limitation between sensory modalities. Furthermore, they added that equivalent sensory cortex activation for divided attention and baseline conditions (passive observation of auditory and visual stimuli) suggests saturation of between-modality resources in these two bimodal conditions.

In an earlier study, Jolicoeur (1999) also attempted to demonstrate capacity limitations in processing mechanisms in an experiment with auditory and visual sensory modalities. In particular, the attentional blink effect was studied when visual stimuli were presented as letters in a rapid series and the subjects were asked to identify pre-specified visual targets. Auditory stimuli were presented in the form of pure tones, and the subjects were required to record a speeded-choice response regarding the pitch of the tone in the successively presented auditory stream stimuli. Decrements in mean accuracy measures in the visual task for the experimental group suggested that the attentional mechanisms required for the visual task were engaged in the processing of successive auditory tasks.

A vast quantity of behavioral and physiological evidence has established that the brain has a limited processing capacity. The alterations in brain activations of certain cortical regions as a result of the increasing difficulty of task-related conditions is a way to accommodate task-relevant processing by relocating processing resources in such a capacity-limited environment. Examples of this can be found in the studies by Pomplun, Reingold, and Shen (2001) and Hairston et al. (2008). In the latter study, the researchers investigated the effect of increasing difficulty in an auditory temporal order judgment task on the amount of deactivation associated with visual cortex when subjects performed a similar visual temporal order judgment task. The results showed a substantial degree of deactivation in the visual cortex with the increasing difficulty of the auditory tasks. The authors explained that these deactivations in cross-modalities were due to interactions between sensory processing systems compensating for task difficulty (Hairston et al., 2008). In the earlier study, Pomplun, Reingold, and Shen (2001) varied the difficulty of an auditory task with a simultaneous visual task. The visual span of the subjects was measured while they memorized numbers they listened to and indicated the occurrence of a target number. The results showed reductions in the size of visual span as the attentional and resource demands of an auditory task increased.

The Role of Semantic Processing and Attention in Auditory and Visual Tasks

One of the important questions that researchers have investigated, with mixed results, is whether the limits to attention in a dual-processing with auditory and visual inputs occur only at higher levels of language processing. Treisman and Davies (1973) attempted and failed to establish that the limit to attention arises only at the semantic level of language processing. In the monitoring task, the subjects were shown two simultaneous lists of words and asked to look or listen for a target word in both the lists. Target words were in the form of words containing either the letters "end" or the sound "end" (physically defined target words) and all animal names (semantically defined target words). The results indicated that the subjects found it easier to look for a target word containing "end" in the visual presentation. In the case of auditory presentation, the subjects found it easier to look for a semantic target word. Treisman and Davies conjectured two possible reasons for not reaching the perceptual limits in dual task performance. The first possibility is that vision and hearing indeed share a single semantic system, but the semantic classification tasks in their study were too easy to reach the limits. Alternatively, each of the dual tasks in two modalities actually had its own separate semantic system. In either of the scenarios, the implication of divided attention was that performance was still worse with divided than with focused attention.

On the other hand, Oswald, Tremblay, and Jones (2000) reported a disruption in comprehension due to the presence of meaningful and meaningless speech, with greater impairment occurring with meaningful speech. Sixty undergraduates participated in their study, listening to meaningful speech in the form of a recording of news and meaningless speech in the form of the same recording played in reverse while they performed two visual tasks. Specific instructions were given to participants as to ignore the irrelevant speech background. The visual tasks involved an acquisition task where the subjects were presented with sentences and asked questions about the content. The second visual task involved a recognition task of 35 sentences; the subjects were asked to decide whether they had seen each of the sentences before. The results indicated that significantly more errors were made in the meaningful speech than in the meaningless speech condition. The authors concluded that performance of a cognitive task that involves semantic processing can be hindered by the presence of an irrelevant sound containing meaning or semantics.

In another study, the cognitive tasks of proofreading, reading comprehension, and computer use were performed by 36 subjects in the presence of different auditory backgrounds such as speech, masked speech, and continuous noise (Venetjoki, Kaarlela-Tuomaala, Keskinen, & Hongisto, 2006). Considerable impairments were observed in proofreading when it was performed in combination with intelligible speech, whereas performance of the other two tasks remained unaffected. Proofreading was believed to be sensitive to meaning and the most demanding task of all those presented. The findings of the study suggested that an intelligibility of background speech may have interfered with the proofreading task. These results were found to be consistent with the ones documented by Jones, Miles, and Page (1990) in a similar proofreading experiment. Sorqvist and his colleagues (2010) expressed concern about the presentation of traditional reading comprehension (RC) tests and argued that in traditional comprehension tests questions are presented after the whole passage is presented, thus involving a long retention interval. As a result, irrelevant speech may be interfering with long-term memory rather than the comprehension or semantic aspect of it. In order to overcome this methodological complexity, they designed an experiment (Sörqvist, Halin, Hygge, 2010) where an RC task involved short texts, each followed by a question. The authors claimed that this methodological improvement was able to test the immediate effect of irrelevant speech (if any) on semantic processes. They found a disruptive effect, in terms of number of errors in the presence of irrelevant speech consisting of a story about a fictitious cultural performance.

As mentioned earlier, an experiment carried out by Pizzighello and Bressan (2008) tested their participants' ability to detect an unexpected visual object in a display while listening to verbal material consisting of five short stories and five lists of Italian words. The subjects were instructed to pay attention to verbal stimuli in order to comprehend and recall the information; the results indicated that only one third of the subjects detected an unexpected object while they listened to verbal material. Therefore, the authors argued, the auditory task might have used all the resources by demanding all the attention for the verbal material. The possibility of our reactions being impaired by unexpected objects during driving while listening to the radio was raised by the authors. Further support for this implication was highlighted in a study by Just, Keller, and Cynkar (2008), which investigated the brain activity and performance associated with a simulated driving task while participants listened to factual sentences. The participants then judged the sentences as true or false, requiring the processing of semantic knowledge, while they virtually drove on a curving path. The lower driving accuracies that were observed than during the control condition were believed to be due to the higher resource demand for sematic language processing, resulting in impaired driving.

Although memory tasks are not a direct form of a visual task, experiments testing the memory or serial recall in the presence of intelligible speech generally involve a visual presentation of digits, letters, or objects to be memorized. One such study found irrelevant meaningful speech had a strong impact on word fluency tests in a semantic memory task (Enmarker, 2004). The word fluency test consisted of three sets of meaningful words. Irrelevant meaningful speech also hampered the performance of a face and name recognition task in the same experiment. Another recent study by Schlittmeier, Hellbruck, Thaden, and Vorlander (2008) also examined the effect of irrelevant background speech on verbal short memory and mental arithmetic tests. The participants in their experiment were explicitly instructed to ignore the background speech. When the participants were presented with sequences of digits that they were subsequently asked to recall, there was found to be a detrimental effect of highly intelligible speech on recall performance. In an earlier memory recall experiment, researchers (Neely & LeCompte, 1999) tested the effect of semantic similarity on recall performance. A semantic similarity between background auditory words and the visual words to be remembered was controlled for, and the findings indicated that semantic similarity was a significant factor in the disruption of performance on recall.

These studies collectively indicate that voluntary or involuntary attention paid to the verbal material impairs the performance on a concurrent visual cognitive task, possibly by engaging a significant number of resources and degree of attention to the processing of verbal, semantic information contained in the stimulus.

There are few studies that focus on the semantic processing of dual audio and visual tasks. Lewis (1970) used a dichotic listening paradigm with simultaneous pairs of words to determine the level of semantic processing of an unattended message. The subjects were asked to accurately shadow (repeat) the attended words and their reaction time was monitored as the class of simultaneous unattended words was changed (from associatively related, to semantically related, to unrelated). While the subjects were unable to recall the unattended words, the pattern of reaction times as a function of class of unattended words exhibited selective interference. Lewis concluded that even though the subjects were unable to reproduce the unattended message words, those words were not being filtered at the perceptual periphery but were being processed at a semantic level. Treisman, Squire, and Green (1974) sought to replicate and clarify the results of the Lewis (1970) study, and they confirmed that reaction time for a message word was increased when a semantically related word was presented on the unattended channel. However, they found that the results held true only for semantically related words in an early list position and only in a small proportion of trials. Lewis' (1970) conclusions were validated by Mackay (1973), who presented the subjects with two auditory word messages, one in each ear, simultaneously. He asked the subjects to shadow (repeat) the message presented to one ear and to ignore the one presented to the other ear. The interpretation of the attended message was influenced by the semantic properties of unattended words, suggesting a semantic level in the processing of the non-target words.

Experiments by Johnston and Wilson (1980) further validated the results of Lewis (1970) in dual auditory tasks. The researchers presented the subjects with series of word pairs binaurally: pairing target words with non-target words that were "appropriate, inappropriate, or neutral". The detection of target words was facilitated by "appropriate" non-target words and hindered by "inappropriate" non-target words. The authors concluded that semantic properties of non-target words can improve accuracy, as well as reduce the latency, of target detection.

Inhoff and Briihl (1991) carried out experiments with dual visual tasks that explored the role of semantic processing. Their subjects were asked to read and comprehend a target passage in the presence of a second passage that they were asked not to attend to. The attended and unattended passages were presented with alternating lines of text. As an additional measure, the eye movements of the subjects were tracked. The overall results showed that there was an acquisition of semantic information from both attended and the unattended text. However, a closer look at the eye movement tracking data showed that the subjects occasionally (but not always) shifted attention to unattended text as well. When those instances of attention shifting were excluded from the analysis, the semantic processing of unattended text did not appear to be present. The study raises an important question underlying all the previous studies: How successful are subjects in not paying attention to the stimuli they are asked to ignore and to what extent does semantic processing of unattended stimuli affect the performance on attended stimuli?

The literature covering behavioral and physiological experiments illustrates that in some cases participants are instructed to pay attention to the auditory stimulus while they perform certain tasks, whereas in others they are instructed to not pay attention to the auditory stimulus while they perform certain cognitive tasks or are being scanned. As a result, in addition to a type of an auditory stimulus, the nature of a cognitive task and attentional instructions can also play a major role in such experiments. Data from studies investigating musical and linguistic features of auditory stimulation suggest that vocal musical stimuli may evoke a similar type of semantic effect as that of linguistic stimuli. An overview of research based on dual tasks proposes the possibility of processing not to-be-attended auditory stimulus at the semantic level when a visual stimulus is being attended.to. As you age, this ability to inhibit or ignore not to-be-attended stimulus decreases even further. Evidence from studies investigating the cognitive functioning of older adults suggests slowing of speed of processing and reduction in inhibition capacity with age.

Statement of the Problem

The collective inference of all of this literature hypothesizes that factors like the nature of a cognitive task, the type of background auditory stimulation, the level of attention paid by an individual, and the age of an individual can influence the performance of a cognitive task. The current study is an attempt to evaluate the effect of the content of background auditory stimulus and the age of an individual on the performance of a visual semantic word categorization. Part of the underlying rationale is that the evidence suggests that the content of background music – instrumental versus vocal – may have an impact on cognitive performance. The second part of the rationale lies in the fact that a task involving the visual semantic categorization of printed words has not yet been explored in the setting of background music, particularly a vocal form of music. In such a setting, a task can become more challenging to perform with the semantic processing of printed words and the voluntary/involuntary semantic processing of background vocal music taking place simultaneously. The third part of the rationale is based on the age factor. The literature states that how fast and accurately an individual responds to categorization tasks will be determined by how fast semantic information is processed. Evidence also suggests that the ability to respond faster to cognitive tasks decreases as age increases. Therefore, the performance of older adults in cognitive tasks of visual semantic word categorization would yield more insights on the topic. The current study will seek to answer the following research questions.

Research Questions and Hypotheses

Research Question 1

Will there be any effect of a background auditory condition that contains vocal music on the performance of a visual word categorization task in terms of reaction times and accuracies of responses for both older and younger adults?

Hypothesis 1

Reaction times will be longer and response accuracies for a visual word categorization task will be lower during the background auditory condition that contains vocal music for both age groups.

Research Question 2

Will there be any effect of age on the performance of a visual word categorization task in terms of both reaction times and accuracies of responses in all of the background auditory conditions?

Hypothesis 2

Reaction times and accuracies of responses for older adults will be longer and lower, respectively, than for younger adults in the visual word categorization task in all of the background auditory conditions.

CHAPTER 3. METHODOLOGY

Study Design

Participants

The participants in this study consisted of 40[1] adult native speakers of English with normal speech and language, divided into two groups: a group of 18 older adults (63-79 years) and a group of 22 young adults (18-33 years) (**Table 3-1**). All participants had normal or corrected vision. The younger group had normal hearing, and the older group had normal to near-normal hearing. All participants had no history or diagnosis of attention deficit hyperactivity disorder (ADHD), brain injury, mental illness, or cognitive or communication impairment per their self-report.

All participants were recruited based on their voluntary interest in participating in the study. The older adults were recruited from John T. O'Connor Senior Citizen's Center, Knoxville and the Office on Aging, Knoxville. The younger adults were recruited from the Department of Audiology and Speech Pathology at the University of Tennessee Health Science Center, the population of the University of Tennessee, Knoxville students and staff, and the Knoxville community through the use of an approved advertising flyer (**Appendix A**). Before the experiment, all participants were required to review and sign an informed consent (**Appendix B**) previously approved by the University of Tennessee Health Science Center Institutional Review Board. In addition, each participant was required to complete a history questionnaire (**Appendix C**) for any known brain injuries, psychiatric, hearing, or vision problems. The participants were assessed for handedness as per the standard Edinburgh Inventory Test. Apart from 18 older adult participants, another older adult who expressed interest in participation in the study did not qualify based on age and several other inclusion criteria and was excluded from the study before the actual experimental part was performed.

[1] It was found that three participants in the older group did not enter a response for one or more conditions, which showed up in the calculated results as 0% accuracy. It is possible that they did not understand the word categorization task. Another participant in the older group did not meet the criteria for passing cognitive testing. As a result, four of the participants from the older group were excluded from further data analysis.

Table 3-1. Age, gender, and education level distribution of two groups of participants.

Demographic Category	Level	Older Group *(n=18)*	Younger Group *(n=22)*
Age (years)	Range	63-78	19-33
	Mean	69.83	24.68
Gender	Male	2	10
	Female	16	12
Education level (years)	Range	12-22	12-18
	Mean	15.89	15.09

Participant Screening Measures

Hearing Screening Measures

Prior to the experiment, each participant had to pass a hearing screening in the Voice and Speech Science laboratory where the experiment took place. The older adults went through a screening at 500 Hz, 1000 Hz, 2000 Hz, 4000 Hz, and 8000 Hz at 35 dB HL, whereas younger adults went through the same set of frequencies at 25 dB HL. The screening results showed that most of the older adults, who were in their late 60s to 70s, were able to hear the pure tones up to 4000 Hz well but had difficulty hearing tones in the higher frequency range. Because most of the energies in human voice, piano, and violin spectra that are part of the auditory stimuli in the current study are below 4000 Hz, those individuals were included in the study.

Cognitive Testing and Reading Efficiency Measures

Prior to the experiment, all participants were also required to pass an assessment of cognitive functioning using the standard Cognitive Linguistic Quick Test (CLQT) and an assessment of word reading efficiency using the standard Test of Word Reading Efficiency (TOWRE) (**Table D-1** and **Table D-2** in **Appendix D** for individual domain scores). The tests were administered by student clinicians from the Department of Audiology and Speech Pathology in the Neurocognitive Linguistics Laboratory. The cognitive domains evaluated by the CLQT were attention, memory, executive functions, language, and visuospatial skills. An elimination criterion for CLQT was followed as per severity ratings described by Nancy Helm-Estabrooks, Sc. D., CCC-SLP in the CLQT's examiner's manual (**Table 3-2**). The manual also states the criteria for those individuals who do not have any known neurological dysfunction but are found to be low-scoring on CLQT performance in their age range. If a participant scored above the Criterion Cut Scores on three or more domains, he/she was included in the study.

The test of TOWRE included evaluations of sight word efficiency, phonemic decoding efficiency and total word reading efficiency. A total word reading efficiency score in the range of 70-130 or individual scores on two or more evaluations above the cut scores was used as an inclusion criterion to represent a typical population (**Table 3-2**). Exclusion from the study occurred either at the request of the participant or if any of the inclusion criteria was not met.

Table 3-2. Pre-experimental CLQT and TOWRE test ratings for two age groups of participants as a function of age and education level.

Group	Participant	Age (years)	Education Level (years)	CLQT	TOWRE
Older Group	1	75	16	WNL	WNL
	2	73	12	WNL	WNL
	3	66	16	WNL	WNL
	4	76	14	WNL	WNL
	5	65	18	WNL	WNL
	6	63	18	WNL	WNL
	7	67	17	WNL	WNL
	8	78	18	WNL	WNL
	9	64	15	MILD	WNL
	10	72	14	WNL	WNL
	11	75	12	WNL	WNL
	12	68	16	WNL	WNL
	13	85	18	WNL	WNL
	14	65	16	WNL	WNL
	15	67	18	WNL	WNL
	16	78	22	WNL	WNL
	17	70	14	WNL	WNL
	18*	70	12	MILD-MOD	LOW
	**	52	16	WNL	WNL
Younger Group	1	24	18	WNL	WNL
	2	24	16	WNL	WNL
	3	22	16	WNL	WNL
	4	25	16	WNL	WNL
	5	19	12	WNL	WNL
	6	20	12	WNL	WNL
	7	23	16	WNL	WNL
	8	31	14	WNL	WNL
	9	31	12	WNL	WNL
	10	24	16	WNL	WNL
	11	23	16	WNL	WNL
	12	24	16	WNL	WNL
	13	24	12	WNL	WNL
	14	22	12	WNL	WNL
	15	21	12	WNL	WNL
	16	20	12	WNL	WNL
	17	23	18	WNL	WNL
	18	27	16	WNL	WNL
	19	23	16	WNL	WNL
	20	28	18	WNL	WNL
	21	32	18	WNL	WNL
	22	33	18	WNL	WNL

Table 3-2. (Continued).

Notes: WNL - within normal limit, * - a participant with mild-moderate (MILD-MOD) cognitive impairment, LOW - score below the level specified by an inclusion criterion to represent a typical population, ** - a participant who did not meet age and several other criteria.

Stimuli and Materials

Auditory Experimental Stimuli

The auditory experimental stimulus consisted of the Adele's song, "*Someone like You*," from the commercial CD recording. The song was selected on the basis of its popularity as indicated by its position on the Billboard Chart. The song also had an added advantage that it did not have extended instrumental portions or pauses, thereby simulating a purely vocal condition. The experimental stimuli consisted of three different auditory conditions, and a quiet control condition during which no auditory stimulus was presented.

The conditions were as follows:

1. The song with Words (duration: 4 minutes 45 seconds)
2. Piano Melody of the song with the piano instrumental background (duration: 4 minutes 45 seconds)
3. Violin Melody of the song with the piano instrumental background (duration: 4 minutes 45 seconds)
4. Quiet: No Sound (control condition)

Instrumental recordings for conditions 2 and 3 were constructed using the music notation software program Finale as well as sampled instruments.

Visual Experimental Stimuli

Visual stimuli consisted of mono- and di-syllabic printed words from superordinate categories such as tools, utensils, animals, food, clothing, furniture, body parts, vehicles, toys, instruments, and insects (Guenther & Klatzky, 1977; Horn & Manis, 1987; Smith & Magee, 1980; Viswanathan & Childers, 2003). Each auditory condition was presented with 26 sets of printed word stimuli, with each set presented in a form of a three-word row. Printed words were balanced for number of syllables, phonemic distribution, high/low frequency, and number of sets per category. Prior to the actual experiment, printed word sets were also tested in a pilot experiment for inter-judge reliability. Ten individuals took part in a pilot experiment that rated word sets for semantic category membership and provided a common category for the set. Individuals were distributed across the population of two students, two administrative staff members, and two clinical faculty members from the Department of Audiology and Speech Pathology, as well as two apartment housing community staff members and two members of Knoxville community. Included in the study were the words sets for which 80% or more respondents agreed upon category membership (**Table E-1**, **Table E-2**, **Table E-3**, and **Table E-4** in **Appendix E**).

Post-Experiment Questionnaire

A questionnaire consisting of 21 questions on different topics was presented at the end of the experiment (**Appendix F**). Some of the questions were designed to gauge participants' attention and perception during the visual word categorization task. The remaining questions were designed to obtain information on participants' music preferences and learning/studying/working habits associated with music in general (adopted from Jones, 2010). Of the 21 questions, 20 were designed on a 5-point Likert scale. Question 21 elicited a description of the participants' musical training, if any. The questionnaire was approved by the University of Tennessee Health Science Center Institutional Review Board prior to participant recruitment in the study.

Instrumentation

All visual word stimuli were presented via the SuperLab Pro (Version 4.5) computer program (Abboud, Heller, Schultz & Zeitlin, 2010) on an Apple Mac Pro computer placed outside of a sound booth. SuperLab Pro is an experimental psychological software that controls the inter-stimulus interval and the rate of stimulus presentation in order to present the same conditions to all the participants. The program uses a multimedia timer to record reaction times and also records the accuracy of responses after receiving input from the participant. The SuperLab computer was attached to a flat screen monitor placed in a sound booth for presenting the visual word stimuli to the participants. A response pad on which the participants recorded their responses was attached to the SuperLab Mac Pro computer and placed in the sound booth in front of the flat screen monitor. Each participant was seated approximately 60 centimeters (cm) away from the flat screen monitor and symmetrically with respect to the position of the two speakers. The auditory stimuli were played continuously on a Windows compatible laptop computer located outside the sound booth, and the output was presented via speakers placed inside the sound booth in the range of 65-72 dB SPL (approximate sound level of speech) (**Figure 3-1**).

Procedure

The experimental task consisted of two parts: visual word categorization and category selection. The participants were provided with written instructions (**Appendix G**) and asked to respond as quickly and accurately as possible. Practice training was provided to ensure that participants understood the task.

The experiment consisted of two parts: Part 1, word categorization, and Part 2, category selection (**Figure 3-2**) which were interleaved. In Part 1 of the experiment (word categorization), an initial blank screen was shown to the participants for 1500 ms and a fixation cross was presented. The participants were instructed to focus their attention on the cross, which remained on the screen for 1000 ms. The next set of stimuli (a word set) would appear on the screen soon after the offset of the fixation cross. The

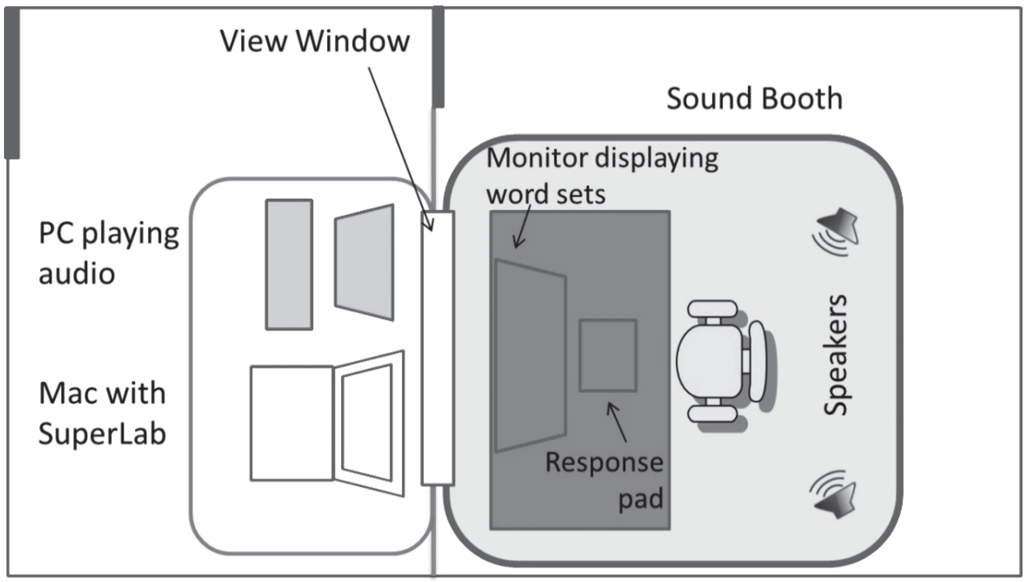

Figure 3-1. The schematic diagram of the experimental set-up.

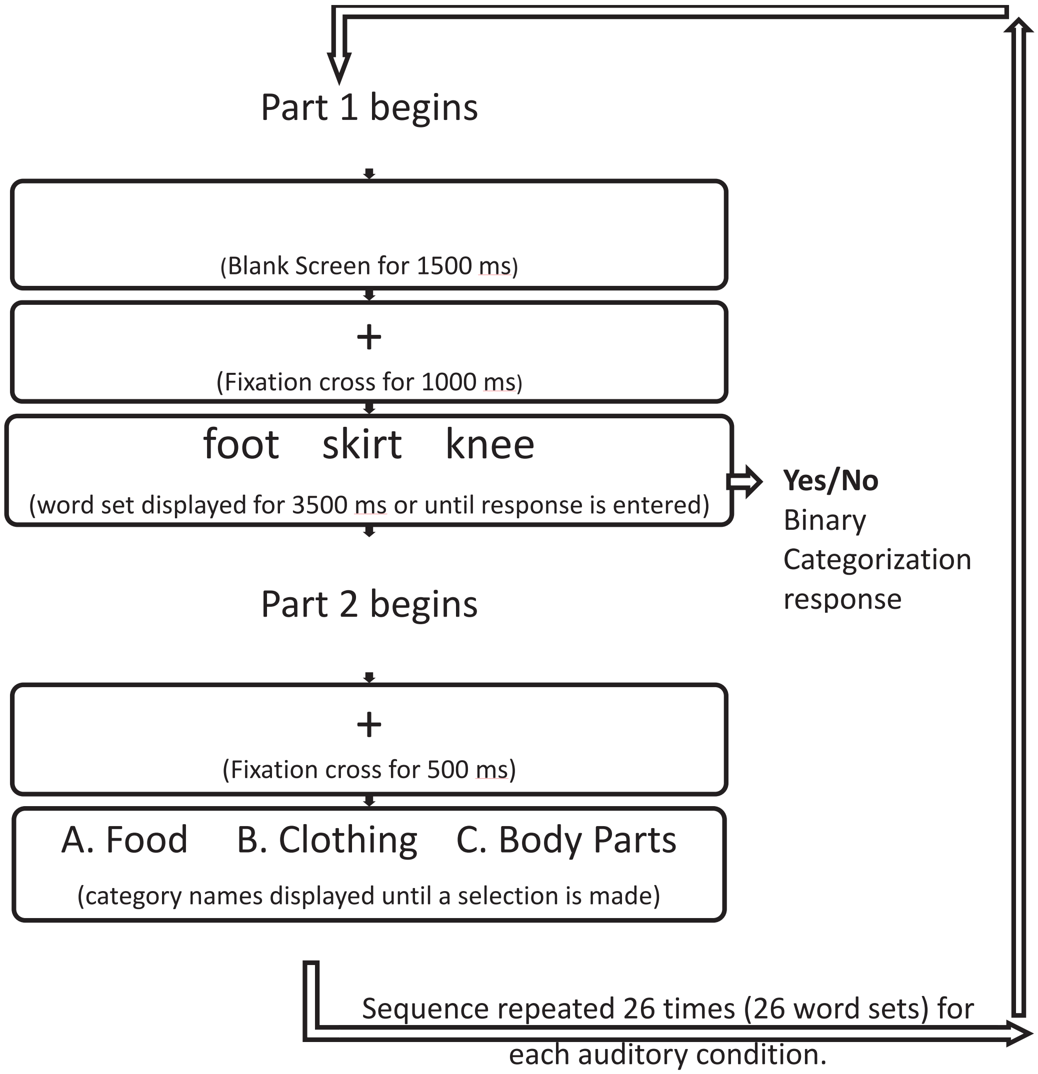

Figure 3-2. The sequence of stimuli presentation in part 1 (word categorization) and part 2 (category selection) of the experiment.

timer was started at the onset of each word set. The participants were asked to perform a binary (yes/no) semantic categorization task in which they had to determine whether all three words belonged to the same semantic category. Word sets were designed in such a way that, in some cases, all the words belonged to the same superordinate category while in others, a pair of words belonged to one common superordinate category and the third word belonged to a different superordinate category. Each word set was programmed to remain on the screen for 3500 ms unless the participant responded before this time period. At this point, the timer was indicated the end of that part. On the offset of the word set, another fixation cross appeared on the screen for 500 ms. In cases where participants took the full 3500 ms, participant response was allowed to be recorded in this extra time period of 500 ms. In the case of such a situation, a provision was made to add this extra time to the reaction time measurement in the program.

Part 2 (category selection) of the experiment began at the offset of last fixation cross at which point the participants were presented with three superordinate categories. A timer was set to record the second reaction time. The participants were asked to choose a common category of three words for the word set that was presented to them on the previous screen. The timer was stopped after the participant's response and accuracy was recorded. The main reason for including Part 2 in the experiment was to capture the participants' real-time thinking regarding category membership. This in turn helped to identify any ambiguity in word sets.

In order to record their responses, the participants pressed buttons on a response pad indicating "yes" or "no" in Part 1 and A, B, or C to select a category in Part 2. Each auditory condition consisted of 26 word sets, and this whole experimental task was repeated four times for four auditory conditions. The order of auditory conditions, order of 26 word sets within a condition, and the position of three words within a set were randomized by the software. The position of three category names in Part 2 was randomized using a random generator available on the web.

Statistical Analysis

Error responses found in Part 2 (category selection) of the experiment were studied further for any common error pattern (caused by possible ambiguity) in a word set. No such pattern was observed for any of the word sets across participants in both groups. After this initial error analysis, means and standard deviations were generated for the reaction times (ms) and accuracies of responses (percentage) for four background auditory conditions for the two groups. Accuracy scores in percentage were then transformed using angular transformation (arcsine) to accuracy scores in radians. These transformed accuracy measurements were then used for the rest of the statistical analyses. Analysis of Variance with repeated measures (between-subjects factor – age group and within-subjects factor – condition) was conducted to test the main effects and/or interactions between the two age groups and within each group. Paired sample T-tests were computed to test for comparisons of any significant differences among conditions within each group.

For analysis of the responses to the questionnaire administered at the end of the experiment, correlations on a subset of questions relating to reaction time and accuracy measurements were calculated. In addition, a covariate analysis was performed on the subset of questions treated as the covariate on reaction time and accuracy measurements for four conditions.

CHAPTER 4. RESULTS

Descriptive Statistics

The results summarize the means and standard deviations (SD) of the reaction time in milliseconds (ms) and accuracies of responses in radians for 4 conditions for the two age groups for the task of visual word categorization (**Table 4-1**). It was found that three participants in the older group did not enter a response for one or more conditions, and it showed up in the calculated results as 0% accuracy. It is possible that they did not understand the word categorization task. Another participant in older group did not meet the criteria for passing cognitive testing. As a result, four participants from the older group were excluded from further data analysis, either because they did not pass cognitive testing or because they possibly did not understand the word categorization task or both. Individual measurements of reaction time and accuracy of responses for two groups were recorded (**Appendix H** and **Appendix I**).

Reaction Time

Mean reaction times in the older group for conditions Song with Words, Piano Melody, Violin Melody, and Quiet were 2179.08 ms (SD = 562.57 ms), 2103.99 ms (SD = 522.24 ms), 2209.78 ms (SD = 468.92 ms), and 2224.88 ms (SD = 386.51 ms), respectively. For the younger group, mean reaction times for conditions Song with Words, Piano Melody, Violin Melody, and Quiet were 1858.79 ms (SD = 340.29 ms), 1871.29 ms (SD = 299.75 ms), 1812.34 ms (SD = 305.06 ms), and 1849.38 ms (SD = 344.65 ms), respectively (**Table 4-1**).

Accuracy of Responses

Mean accuracies of responses (radians) for the older group in conditions Song with Words, Piano Melody, Violin Melody, and Quiet were 2.48 rad. (SD = 0.30 rad.), 2.55 rad. (SD = 0.15 rad.), 2.51 rad. (SD = 0.16 rad.), and 2.52 rad. (SD = 0.21 rad.), respectively. Mean accuracies of responses (radians) for the younger group in conditions Song with Words, Piano Melody, Violin Melody, and Quiet were 2.68 rad. (SD = 0.31 rad.), 2.61 rad. (SD = 0.25 rad.), 2.63 rad. (SD = 0.24 rad.), and 2.65 rad. (SD = 0.25 rad.), respectively (**Table 4-1**).

Table 4-1. Descriptive statistics for the reaction time (ms) and accuracy of responses (% and radians) as a function of the age group and the condition.

Age Group	Statistic	Song with Words	Piano Melody	Violin Melody	Quiet
Older Group	Mean RT (ms)	2179.08	2103.99	2209.78	2224.88
(n=14)	S.D.	562.57	22.24	468.92	386.51
	Mean Accuracy				
	%	87.91	91.21	89.84	89.84
	rad.	2.48	2.55	2.51	2.52
	S.D.				
	%	10.54	4.11	4.67	6.68
	rad.	0.30	0.15	0.16	0.21
Younger Group	Mean RT (ms)	1858.79	1871.29	1812.34	1849.38
(n=22)	S.D.	340.29	299.75	305.06	344.65
	Mean Accuracy				
	%	92.83	91.78	92.31	92.81
	rad.	2.68	2.61	2.63	2.65
	S.D.				
	%	7.44	6.31	5.81	4.94
	rad.	0.31	0.25	0.24	0.25

Notes: RT - reaction time, S.D. - Standard deviation.

Inferential Statistics

Within-Subjects Differences

Reaction Time

Mixed design 2x4 ANOVA were performed to evaluate the effects of the repeated measures condition (Song with Words, Piano Melody, Violin Melody, and Quiet) within-subjects on the reaction time across all participants in the two age groups. No significant main effect of condition ($F_{(3,102)} = .283$, $p = .838$) or significant interaction between condition and the age group ($F_{(3,102)} = .905$, $p = .442$) was found. **Table 4-2** summarizes overall within-subjects results for main effect of condition and interaction between condition and age group on reaction time in visual word categorization task (**Table 4-2**). The results of paired sample T-tests showed no significant difference for any of the six paired comparisons among conditions ($p > .05$) for both the groups (**Table 4-3**).

The reaction times for the older and younger groups were recorded as distribution data (**Figure 4-1** and **Figure 4-2**). The box-plot for the older group (**Figure 4-1**) illustrates that the mean reaction time (dotted line in the box) for the Piano Melody condition is the lowest (fastest response), whereas the reaction time mean is the highest (slowest response) for the Quiet condition, which also exhibits the least degree of variability for reaction time values across participants. The variability for reaction time values is found to be greatest in case of Song with Words condition. The box-plot for the younger group (**Figure 4-2**) illustrates that the reaction time mean for the Violin Melody condition is the lowest (fastest response), which has the least degree of variability across participants, whereas the mean reaction time is the highest (slowest response) for the Piano Melody condition. Similar to the older group, the variability in reaction time values is found to be the greatest in case of Song with Words condition for the younger group. There are few data points labeled with numbers (representing specific participants) that are outside of the whisker bars (**Figure 4-1**, **Figure 4-2**, and **Figure 4-3**). It is important to note that these data points are not outliers based on inter-quartile range rule for outliers (**Appendix J**).

Accuracy of Responses

Mixed design 2x4 ANOVA were performed to evaluate the effects within-subjects of the repeated measures conditions (Song with Words, Piano Melody, Violin Melody, and Quiet) on the accuracy of responses (radians) across all participants in the two age groups (**Table 4-4**). No significant main effect of condition ($F_{(3,102)} = .036$, $p = .991$) or significant interaction between condition and group ($F_{(3,102)} = .599$, $p = .617$) was found. Again, there are few data points labeled with numbers (representing specific

Table 4-2. Results of 2x4 ANOVA for overall within-subjects and between-subjects differences for reaction time (ms) in visual word categorization task.

Effect	F	df	Sig.	Partial Eta Squared	Observed Power
Condition	.283	3	.838	.008	.103
Group	7.970	1	.008*	.190	.783
Condition x Group	.905	3	.442	.026	.242

Notes: df – degrees of freedom, * - Significant at .05 level.

Table 4-3. Results of paired sample T-tests for reaction time (ms) for two age groups in visual word categorization task.

Age Group	Pair of Conditions	Mean	S.D.	t	df	Sig.
Older Group ***(n=14)***	Song with Words–Piano Melody	75.08	349.10	.805	13	.435
	Song with Words–Violin Melody	-30.69	349.24	-.329	13	.747
	Song with Words–Quiet	-45.80	438.38	-.391	13	.702
	Piano Melody-Violin Melody	-105.78	355.37	-1.11	13	.286
	Piano Melody-Quiet	-120.86	351.82	-1.29	13	.221
	Violin Melody-Quiet	-15.10	379.65	-.149	13	.884
Younger Group ***(n=22)***	Song with Words–Piano Melody	-12.50	346.29	-.169	21	.867
	Song with Words–Violin Melody	46.44	281.19	.775	21	.447
	Song with Words–Quiet	9.41	311.35	.142	21	.889
	Piano Melody-Violin Melody	58.95	213.19	1.29	21	.209

Table 4-3. (Continued).

Age Group	Pair of Conditions	Mean	S.D.	t	df	Sig.
Younger Group ***(n=22)***	Piano Melody-Quiet	21.91	297.43	.346	21	.733
	Violin Melody-Quiet	-37.03	215.01	-.808	21	.428

Notes: S.D. - Standard deviation, df – degrees of freedom, * - Significant at .008 (after applying Bonferroni correction on alpha = .05).

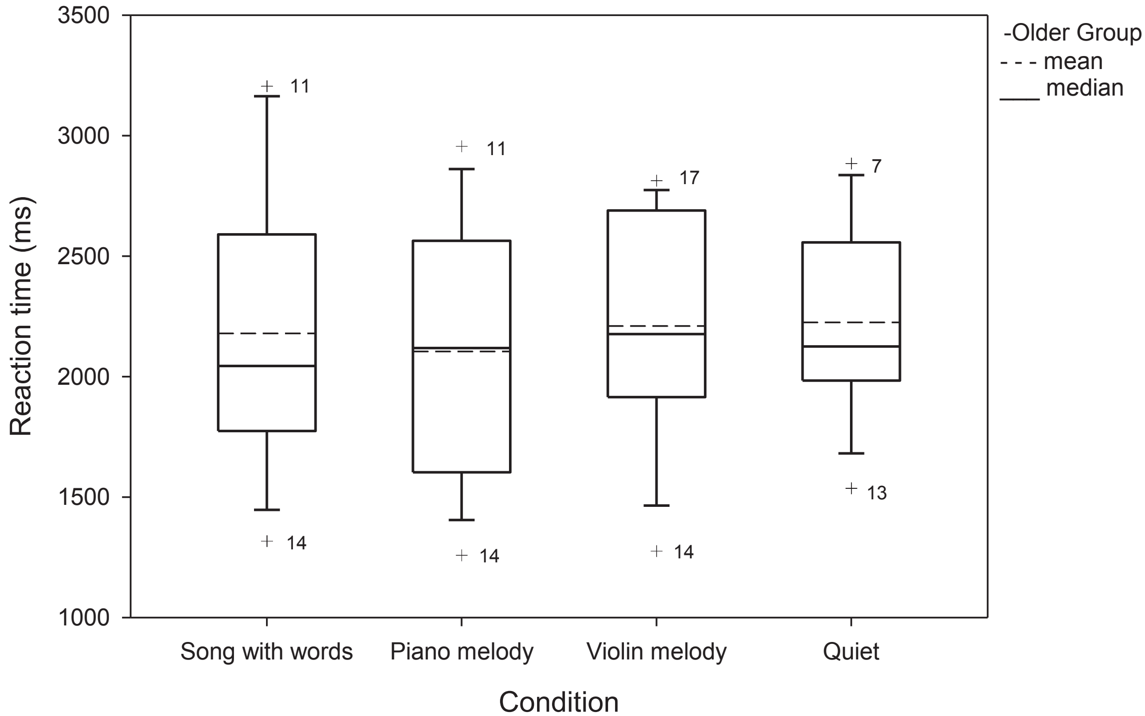

Figure 4-1. Box-plot of the distribution of data for the older group for reaction time (ms) as a function of auditory condition.

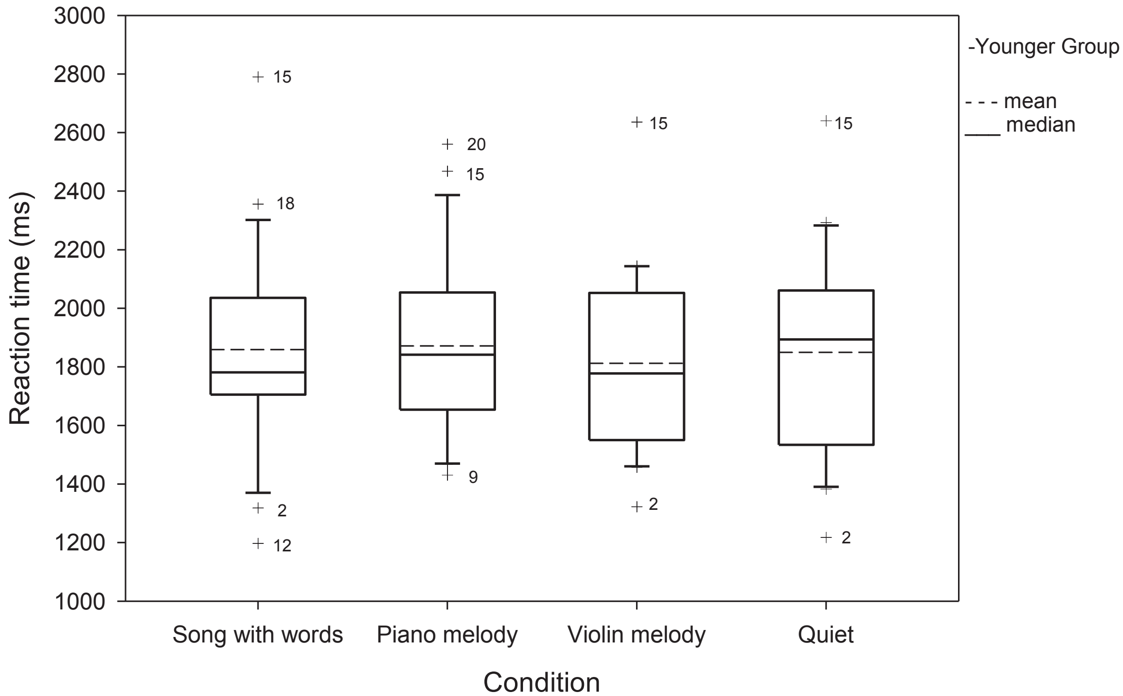

Figure 4-2. Box-plot of the distribution of data for the younger group for reaction time (ms) as a function of auditory condition.

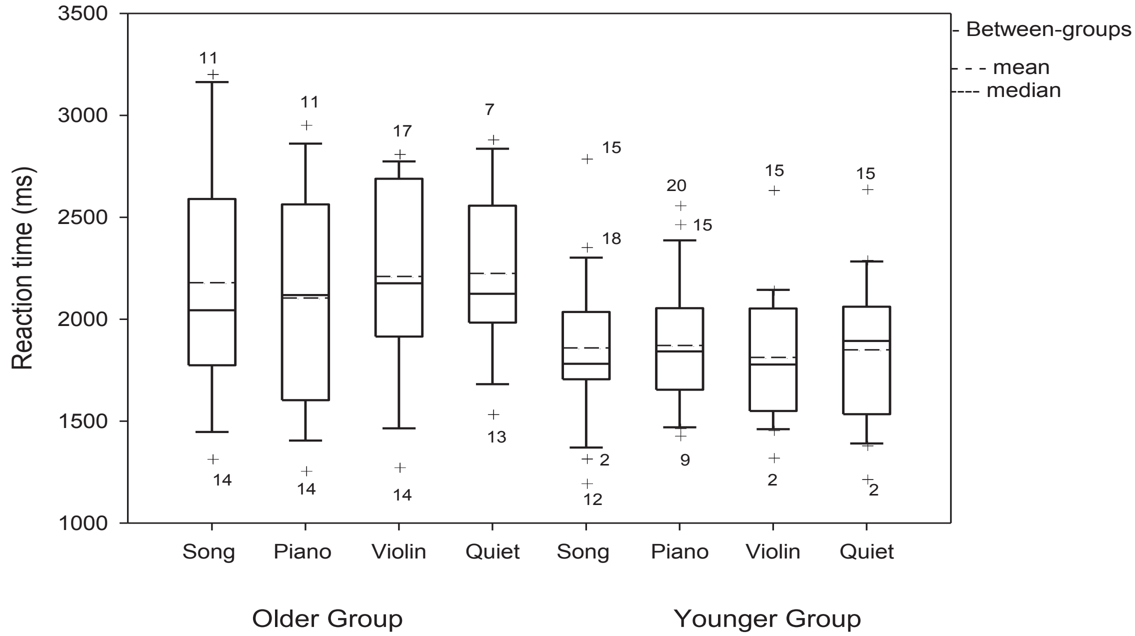

Figure 4-3. Box-plot of the distribution of data for two age groups for reaction time (ms) as a function of auditory condition.

Table 4-4. Results of 2x4 ANOVA for overall within-subjects and between-subjects differences for accuracy of responses (radians) in visual word categorization task.

Effect	F	df	Sig.	Partial Eta Squared	Observed Power
Condition	.036	3	.991	.001	.056
Group	6.950	1	.013*	.170	.726
Condition x Group	.599	3	.617	.017	.171

Notes: df – degrees of freedom, * - Significant at .05 level.

participants) that are outside of the whisker bars (**Figure 4-4**, **Figure 4-5**, and **Figure 4-6**). It is important to note that none of these data points are extreme outliers based on inter-quartile range rule for outliers (**Appendix K**). In fact, there are only three data points (participants 9, 13, and 20) in the younger group (**Figure 4-5**) that are barely outside of the lower inner fence, making them minor outliers. Further review of individual domain evaluations in cognitive testing and reading efficiency of these participants revealed within-normal results (**Table 3-2**; **Table D-1**, and **Table D-2** in **Appendix D**). As a result, these data points have been included in all of the statistical analyses.

The results of paired sample T-tests showed no significant difference for any of the 6 pairwise comparisons among conditions ($p > .05$) for both the groups as summarized in the results for paired sample T-tests for accuracy of responses for two groups (**Table 4-5**).

The accuracy of responses (radians) for the older and the younger group is illustrated as distribution of data (**Figure 4-4** and **Figure 4-5**). The box-plot for the older group (**Figure 4-4**) illustrates that accuracy mean (dotted line in the box) for the Piano Melody condition is the highest with the least degree of variability, whereas the accuracy mean is the lowest for the Song with Words condition with the greatest degree of variability across participants. The box-plot for the younger group (**Figure 4-5**) illustrates that the accuracy mean for the Song with Words condition is the highest with the greatest degree of variability, whereas the accuracy mean for the Piano Melody condition is the lowest. The Quiet condition has the least degree of variability across participants.

Between-Subjects Differences

Reaction Time

Mixed design 2x4 ANOVA were performed to evaluate the effects of age group (older group, younger group) and the repeated measures condition (Song with Words, Piano Melody, Violin Melody, and Quiet) on subjects in their reaction time. The between-subjects factor showed a significant overall main effect of age group on the reaction time ($F_{(1,34)} = 7.976$, $p = .008$) (**Table 4-2**).

Post-hoc comparisons (adjusted for Bonferroni corrections) within ANOVA revealed differences between mean reaction times for two age groups for three conditions (**Table 4-6**). Significant differences were found for Song with Words ($p = .04$), Violin Melody ($p = .004$), and Quiet conditions ($p = .005$), respectively. No significant difference was found for reaction time between two age groups for the Piano Melody condition ($p = .098$). Overall, the older group had higher values of reaction time means (dotted lines in box plot) than those for the younger group (**Figure 4-3** and **Figure 4-7**). In general, the response times of the older group were significantly slower for Song with Words, Violin Melody, and Quiet conditions than that of the younger group. For the

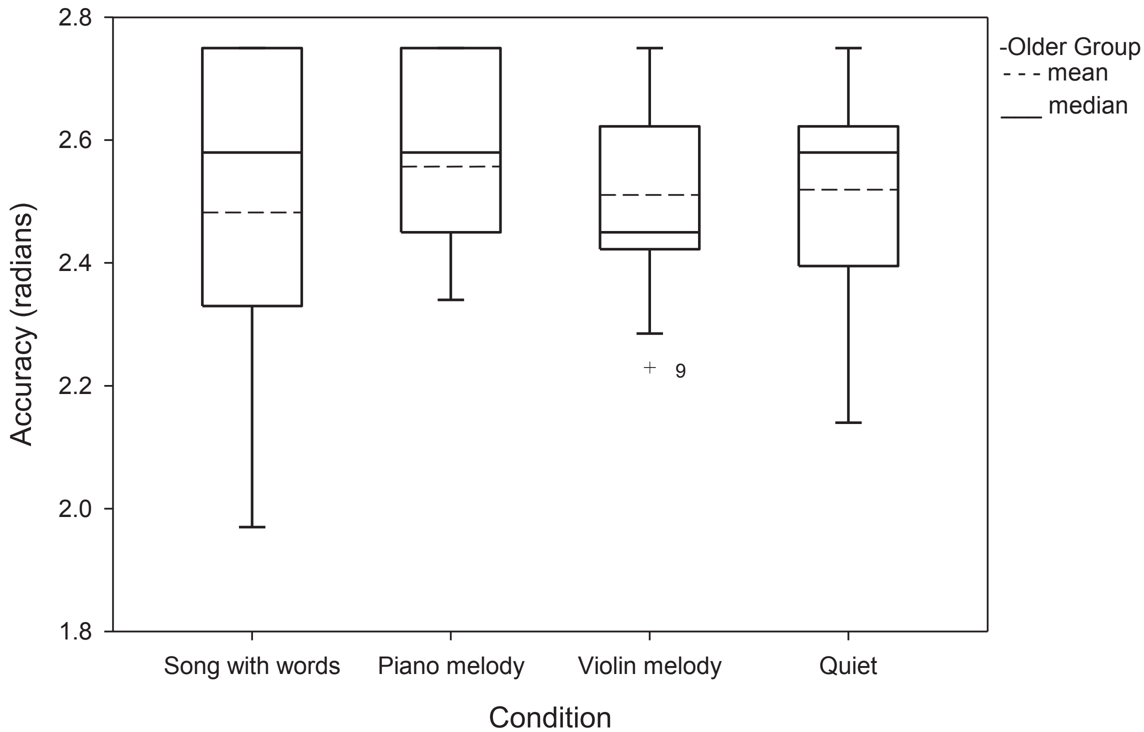

Figure 4-4. Box-plot of the distribution of data for the older group for the accuracy of responses (radians) as a function of auditory condition.

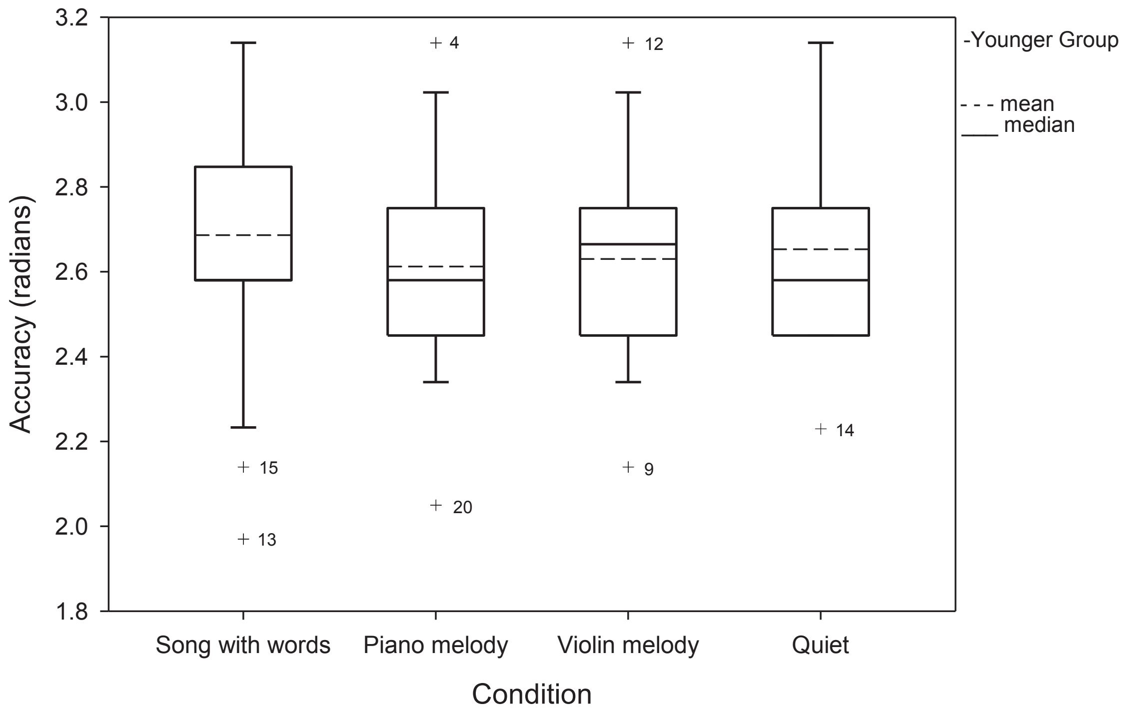

Figure 4-5. Box-plot of the distribution of data for the younger group for the accuracy of responses (radians) as a function of auditory condition.

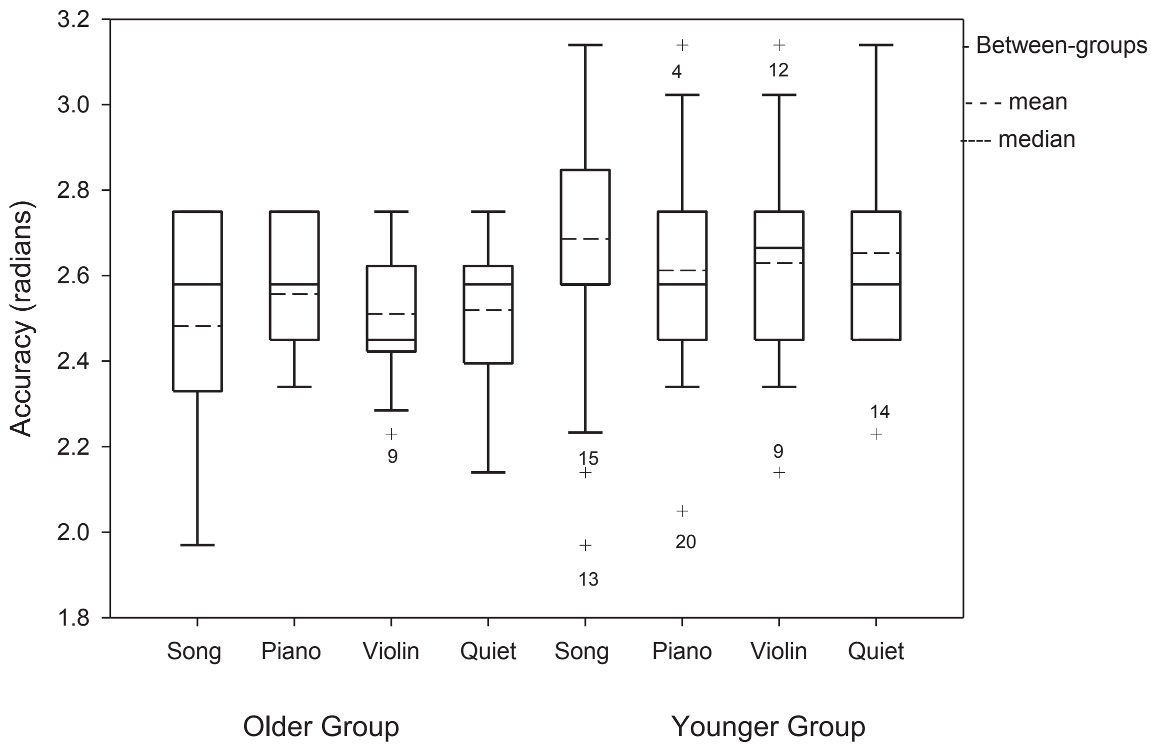

Figure 4-6.   Box-plot of the distribution of data for two age groups for accuracy of responses (radians) as a function of auditory condition.

Table 4-5. Results of paired sample T-tests for accuracy of responses (radians) for two age groups in visual word categorization task.

Age Group	Pair of Conditions	Mean	S.D.	t	df	Sig.
Older Group ***(n=14)***	Song with Words–Piano Melody	-.075	.276	-1.04	13	.318
	Song with Words–Violin Melody	-.029	.281	-.392	13	.702
	Song with Words–Quiet	-.039	.388	-.375	13	.714
	Piano Melody-Violin Melody	.046	.191	.901	13	.384
	Piano Melody-Quiet	.036	.281	.486	13	.635
	Violin Melody-Quiet	.009	.294	-.145	13	.887
Younger Group ***(n=22)***	Song with Words–Piano Melody	.075	.394	.896	21	.381
	Song with Words–Violin Melody	.058	.367	.735	21	.470
	Song with Words–Quiet	.033	.356	.442	21	.663
	Piano Melody-Violin Melody	-.017	.396	-.208	21	.837

Table 4-5. (Continued).

Age Group	Pair of Conditions	Mean	S.D.	t	df	Sig.
Younger Group ***(n=22)***	Piano Melody-Quiet	-.042	.257	-.760	21	.456
	Violin Melody-Quiet	-.024	.353	-.319	21	.753

Notes: S.D. - Standard deviation, df – degrees of freedom, * - Significant at .008 (after applying Bonferroni correction on alpha = .05).

Table 4-6. Results of post-hoc comparisons within ANOVA for differences between mean reaction times (ms) for two age groups for each condition.

Condition	Mean Difference (ms) (Older Group - Younger Group)	Sig.
Song with Words	320.294	.040*
Piano Melody	232.709	.098
Violin Melody	397.437	.004*
Quiet	375.507	.005*

Notes: * - Mean difference significant at .05 level, adjustment for multiple comparisons – Bonferroni.

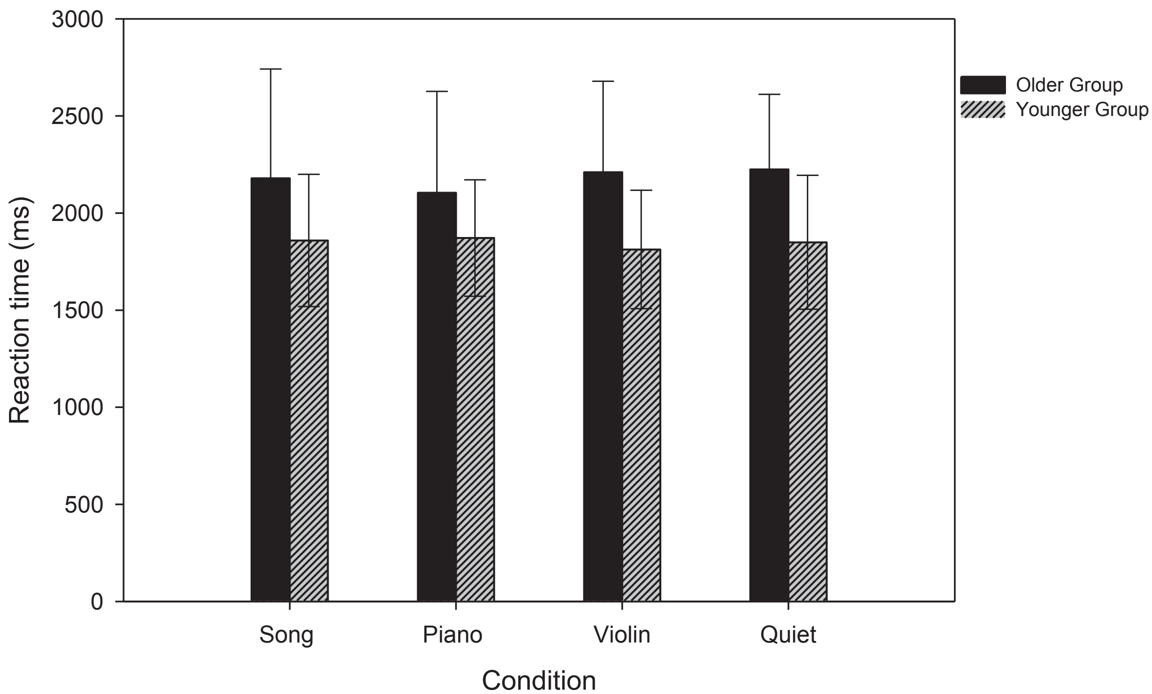

Figure 4-7. Bar-graph of the distribution of data for two age groups for reaction time (ms) as a function of auditory condition.

Piano Melody condition, responses of the older group were slower than that of the younger group; however the difference was not found to be statistically significant.

Accuracy of Responses

Mixed design 2x4 ANOVA were performed to evaluate the effects of age group (older group, younger group) and the repeated measures conditions (Song with Words, Piano Melody, Violin Melody, and Quiet) between-subjects on the accuracy of responses. In contrast with the within-subjects analysis, the between-subjects ANOVA showed a significant overall main effect of age group on the accuracy ($F_{(1,34)} = 6.948$, $p = .013$) across all conditions (**Table 4-4**).

Post-hoc comparisons (adjusted for Bonferroni corrections) within ANOVA revealed no significant differences between mean accuracies for Song with Words ($p = .060$), Piano Melody ($p = .468$), Violin Melody ($p = .118$), or Quiet conditions ($p = .101$) for the two age groups (**Table 4-7**). In the between-subjects differences for accuracy of responses for two age groups, the older group had overall lower accuracy means (dotted lines in box plot) for Song with Words, Violin Melody, Piano Melody, and Quiet conditions than those for the younger group (**Figure 4-6** and **Figure 4-8**). However, the mean differences were not found to be statistically significant (**Table 4-7**). In the distribution of data for reaction time as a function of accuracy of responses for participants across two age groups, it can be observed that participants in the older group had higher reaction times (slower responses) than those in the younger group (**Figure 4-9**). In addition, participants in the older group had a lower accuracy of response than those in the younger group. Thus, results of the current study reveal that the younger group of participants performed more quickly in a visual word categorization task.

Questionnaire Statistics

Descriptive Statistics

Means and standard deviations across the participants' responses within two age groups to questions are summarized in **Table 4-8**. **Table 4-9** and **Table 4-10** display the means and standard deviations for responses to questions from participants in each of the two age groups separately.

Covariate Analysis

Results from the covariate analysis in which a set of questions was treated as a covariate variable on reaction times and accuracies for the four conditions across the

Table 4-7. Results of post-hoc comparisons within ANOVA for differences between accuracy of responses (radians) for two age groups for each condition.

Condition	Mean Difference (rad.) (Older Group - Younger Group)	Sig.
Song with Words	-.206	.060
Piano Melody	-.055	.468
Violin Melody	-.119	.118
Quiet	-.133	.101

Notes: * - Mean difference significant at .05 level, adjustment for multiple comparisons – Bonferroni.

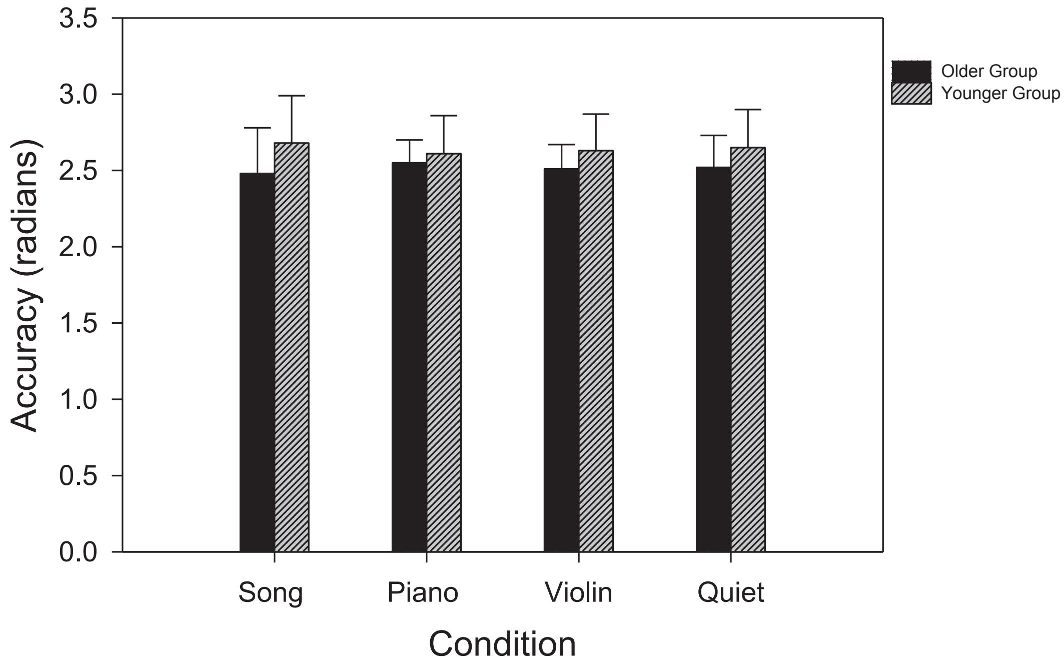

Figure 4-8. Bar-graph of the distribution of data for two age groups for accuracy of responses (radians) as a function of auditory condition.

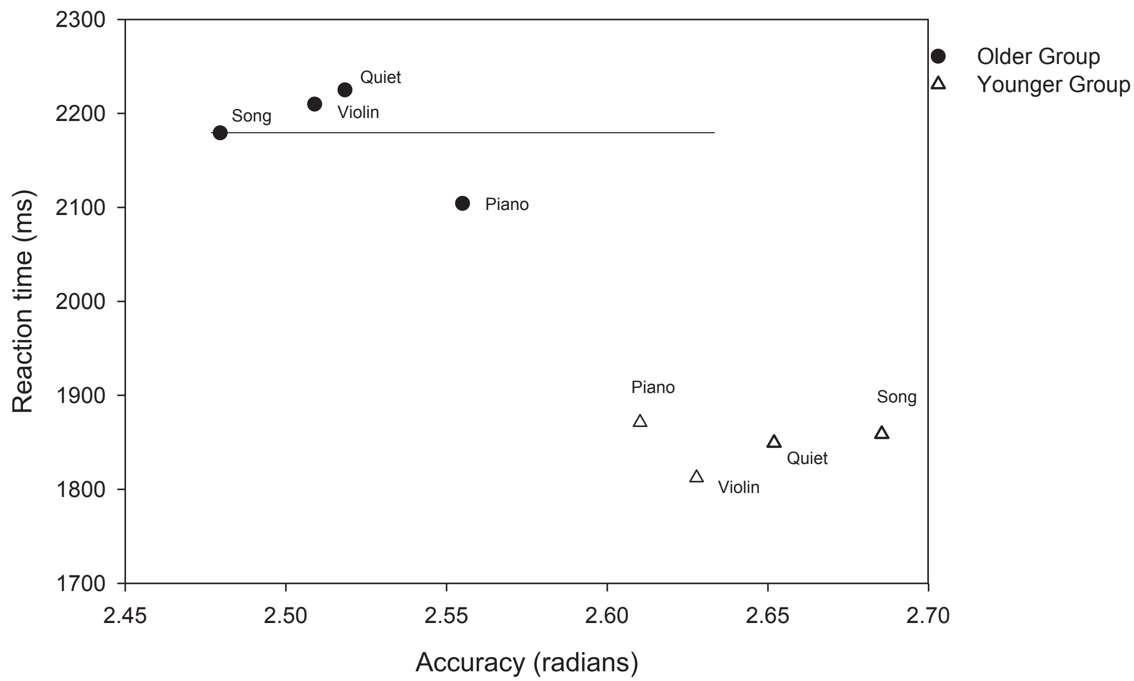

Figure 4-9. Scatter-plot of the distribution of data for reaction time (ms) as a function of accuracy of responses (radians) for two age groups.

Table 4-8. Descriptive statistics across all participants as a function of question for the questionnaire presented at the end of the experiment.

Question Number	*N*	Mean	S.D.
1	35	2.46	1.120
2a	35	3.97	0.954
2b	35	2.34	0.968
2c	36	3.56	1.297
3	36	3.67	1.604
4	36	3.17	1.781
5	36	1.97	1.108
6	36	3.39	1.379
7	36	3.03	1.055
8	36	3.06	1.511
9a	36	4.72	0.513
9b	36	3.36	0.990
9c	36	3.28	0.974
10	36	4.42	0.937
11	36	2.94	1.413
12	36	2.69	1.451
13	35	3.80	1.052
14	36	4.14	0.723
15	36	3.39	1.315
16a	36	1.92	1.180
16b	36	3.19	1.261
16c	36	2.81	1.215
16d	36	2.44	1.403
16e	36	3.06	1.330
17a	26	3.62	0.804
17b	26	3.92	0.796
17c	26	3.19	0.939
18	36	3.17	1.298
19a	36	2.94	1.393
19b	36	3.14	1.268
19c	35	3.89	0.796
20	36	2.36	1.268

Notes: S.D. - standard deviation, Strongly disagree – 1, Disagree – 2, Undecided – 3, Agree – 4, Strongly agree – 5.

Table 4-9. Descriptive statistics for the older group as a function of question for the questionnaire presented at the end of the experiment.

Question Number	*N*	Mean	S.D.
1	13	2.38	.961
2a	13	3.69	1.109
2b	13	2.92	1.038
2c	14	2.50	1.225
3	14	2.21	1.311
4	14	1.50	.941
5	14	2.07	1.141
6	14	3.29	1.590
7	14	3.29	1.139
8	14	2.00	1.240
9a	14	4.71	.469
9b	14	3.29	.994
9c	14	3.36	1.151
10	14	4.29	1.069
11	14	2.07	.997
12	14	1.93	1.385
13	13	3.69	1.032
14	14	3.79	.893
15	14	3.14	1.512
16a	14	1.50	.855
16b	14	2.64	1.393
16c	14	2.71	1.326
16d	14	1.71	1.267
16e	14	2.93	1.439
17a	9	3.67	.707
17b	9	3.89	.782
17c	9	3.11	1.167
18	14	3.14	1.562
19a	14	2.64	1.550
19b	14	3.00	1.617
19c	13	3.92	.641
20	14	2.00	1.038

Notes: S.D. - standard deviation, Strongly disagree – 1, Disagree – 2, Undecided – 3, Agree – 4, Strongly agree – 5.

Table 4-10. Descriptive statistics for the younger group as a function of question for the questionnaire presented at the end of the experiment.

Question Number	*N*	Mean	S.D.
1	22	2.50	1.225
2a	22	4.14	.834
2b	22	2.00	.756
2c	22	4.23	.813
3	22	4.59	.959
4	22	4.23	1.307
5	22	1.91	1.109
6	22	3.45	1.262
7	22	2.86	.990
8	22	3.73	1.279
9a	22	4.73	.550
9b	22	3.41	1.008
9c	22	3.23	.869
10	22	4.50	.859
11	22	3.50	1.371
12	22	3.18	1.296
13	22	3.86	1.082
14	22	4.36	.492
15	22	3.55	1.184
16a	22	2.18	1.296
16b	22	3.55	1.057
16c	22	2.86	1.167
16d	22	2.91	1.306
16e	22	3.14	1.283
17a	17	3.59	.870
17b	17	3.94	.827
17c	17	3.24	.831
18	22	3.18	1.140
19a	22	3.14	1.283
19b	22	3.23	1.020
19c	22	3.86	.889
20	22	2.59	1.368

Notes: S.D. - standard deviation, Strongly disagree – 1, Disagree – 2, Undecided – 3, Agree – 4, Strongly agree – 5.

participants from two groups revealed significance for two of the six questions: Questions 2b, 5, 6, 7, 8, and 15 (**Table 4-11**; **Appendix F**). Question 8 was found to be a significant covariate ($F_{(1,27)} = 5.4$, p = .028) on reaction time for the Violin Melody condition. Question 8 asked participants whether they subvocalized or sang along to themselves during the task. It was also found that Question 6 was a significant covariate ($F_{(1,27)} = 4.49$, p = .043) on reaction time for the Piano Melody condition. Question 6 asked participants whether Song with Words was the most distracting music. Additionally, Question 6 was found to be a significant covariate ($F_{(1,27)} = 5.52$, p = .027) on accuracy for the Quiet condition. Although Questions 6 and 8 were significant covariates, the significant effect of age group on reaction time and accuracy was nullified in the case where these questions acted as significant covariates. It can be summarized that none of the questions was a significant predictor of reaction time or accuracy for any of the auditory conditions.

Correlation Analysis

To evaluate whether any of the questions is correlated with reaction time and accuracy, correlation analysis was performed on a set of questions: 1, 5, 6, 7, 8, and 15 (**Appendix F**). Due to the fact that the significant main effects on reaction time and accuracy were found for the age factor but not for listening condition, the correlations were computed for the two age groups (**Table 4-12** and **Table 4-13**). However, correlations computed across listening conditions are also summarized for reference (**Appendix L**).

For the older group, Question 1 was found to be significantly negatively correlated with the accuracy for the Violin Melody condition. Question 1 asked participants whether they paid exclusive attention to the background music. The results suggest that when they paid exclusive attention to the Violin Melody then their accuracy was lowered. Question 6 was found to be significantly positively correlated with the accuracy for Quiet condition. Question 6 asked participants whether the Song with Words was the most distracting music. The correlation result suggests that if they did feel that Song with Words was the most distracting music, their accuracy of response in the Quiet condition was higher (**Table 4-12**).

For the younger group, Question 1 was found to be significantly negatively correlated with the accuracy for the Song with words condition. Question 1 asked participants whether they paid exclusive attention to the background music or not. The results reveal that if they paid exclusive attention to the Song with Words then their accuracy was lowered. Question 5 was found to be significantly negatively correlated with the reaction time for the Quiet condition. Question 5 asked participants whether the instrumental music was the most distracting; the result suggests that when they did feel that instrumental music was the most distracting music to work with, their reaction times in the Quiet condition were lower (faster response) (**Table 4-13**).

Table 4-11. Significant covariates across the participants from two age groups for a subset of questions for the questionnaire presented at the end of the experiment.

Condition/ Measure	Covariate Source	F	df	Sig.	Partial Eta Squared	Observed Power
Violin Melody/RT	QN 2b	.238	1	.630	.009	.076
	QN 5	.030	1	.864	.001	.053
	QN 6	4.170	1	.051	.134	.503
	QN 7	.009	1	.927	.000	.051
	QN 8	5.400	1	.028*	.167	.610
	QN 15	2.150	1	.154	.074	.293
	Group	1.390	1	.249	.049	.206
Piano Melody/RT	QN 2b	.215	1	.647	.008	.073
	QN 5	.238	1	.629	.009	.076
	QN 6	4.490	1	.043*	.143	.533
	QN 7	.318	1	.577	.012	.085
	QN 8	2.410	1	.132	.082	.322
	QN 15	.048	1	.829	.002	.055
	Group	.062	1	.805	.002	.057
Quiet/ Accuracy	QN 2b	.641	1	.431	.024	.120
	QN 5	1.310	1	.262	.048	.197
	QN 6	5.520	1	.027*	.175	.619
	QN 7	1.270	1	.270	.047	.192
	QN 8	.190	1	.666	.007	.071

Table 4-11. (Continued).

Condition/ Measure	Covariate Source	F	df	Sig.	Partial Eta Squared	Observed Power
Quiet/ Accuracy	QN 15	.430	1	.518	.016	.097
	Group	1.610	1	.215	.058	.231

Notes: df – degrees of freedom, RT - reaction time, QN - Question Number, * Significant at .05 level, results from the covariate analysis in which a subset of questions (question numbers 2b, 5, 6, 7, 8, and 15) was treated as a covariate variable on reaction times and accuracies for 4 conditions (6 questions*4 reaction times*4 accuracies of responses) across the participants from two groups revealed significance only for two of the six questions. Only the significant results are summarized here.

Table 4-12. Correlations calculated on a set of questions relating to reaction time (ms) and accuracy of responses (radians) for the older group.

Condn.	Measure	R	Sig.	r	Sig.	r	Sig.
		QN 1		**QN 5**		**QN 6**	
Song with Words	RT	.164	.593	.094	.749	-.230	.429
	Accuracy	-.508	.076	.052	.861	-.229	.432
Piano Melody	RT	-.039	.899	-.022	.942	-.416	.139
	Accuracy	.067	.828	.215	.461	-.017	.955
Violin Melody	RT	.233	.443	.125	.670	-.334	.243
	Accuracy	-.587*	.035	-.267	.357	-.069	.815
Quiet	RT	.009	.978	-.118	.608	-.411	.144
	Accuracy	-.018	.953	.370	.193	.587*	.027
		QN 7		**QN 8**		**QN 15**	
Song with Words	RT	.360	.207	-.292	.312	-.016	.958
	Accuracy	-.411	.144	-.325	.257	-.148	.613
Piano Melody	RT	.219	.451	-.235	.419	-.121	.681
	Accuracy	-.294	.307	.079	.789	-.251	.387
Violin Melody	RT	.155	.598	-.422	.132	-.243	.402
	Accuracy	-.066	.823	-.043	.883	.229	.431
Quiet	RT	.152	.605	-.160	.585	.190	.515
	Accuracy	.169	.563	.322	.262	-.187	.522

Notes: Condn. – condition, r – Pearson's correlation coefficient, QN – question number, * Sig. – 2-tailed significance level at .05, RT – reaction time.

Table 4-13. Correlations calculated on a set of questions relating to reaction time (ms) and accuracy of responses (radians) for the younger group.

Condn.	Measure	R	Sig.	r	Sig.	r	Sig.
		QN 1		QN 5		QN 6	
Song with Words	RT	.361	.098	.028	.900	-.160	.477
	Accuracy	-.479*	.028	.499	.021	-.428	.053
Piano Melody	RT	-.131	.560	.024	.917	-.278	.211
	Accuracy	-.014	.951	.228	.319	.104	.654
Violin Melody	RT	.024	.914	-.076	.738	-.317	.151
	Accuracy	.065	.780	-.222	.334	.214	.351
Quiet	RT	.146	.518	-.432*	.045	.147	.515
	Accuracy	-.326	.178	.080	.731	.213	.353
		QN 7		QN 8		QN 15	
Song with Words	RT	.077	.733	.009	.968	.033	.884
	Accuracy	.373	.096	-.051	.827	-.079	.734
Piano Melody	RT	-.133	.556	-.335	.128	.230	.304
	Accuracy	.235	.306	.215	.350	-.353	.117
Violin Melody	RT	-.101	.656	-.359	.101	.102	.650
	Accuracy	-.342	.129	.195	.398	.161	.485
Quiet	RT	-.281	.205	-.162	.471	.209	.351
	Accuracy	.335	.137	-.158	.495	-.018	.940

Notes: Condn. – condition, r – Pearson's correlation coefficient, Sig. – 2-tailed significance level at .05, QN – question number, RT – reaction time.

CHAPTER 5. DISCUSSION

Studies have yielded contradictory results regarding the effect of listening to music on our ability to work. The evidence has illustrated that while in some cases instrumental and vocal music do not affect the performance of a cognitive task, in other instances they do affect the performance. Earlier studies that indicated detrimental effects of listening to meaningful auditory stimuli have experimented with the tasks of reading comprehension, memory recall, or proofreading. However, the task of semantic categorization has not yet been studied in this context. Adequately performing the task of semantic categorization in the presence of background music requires efficient processing time and an ability to inhibit irrelevant information, both of which are thought to decline with increasing age.

The present study investigated the effects of content of background auditory stimuli and age of an individual on the performance of semantic word categorization. The experimental research questions in this study addressed within-subjects differences as well between-subjects differences. The particular research questions that were raised were whether vocal linguistic content present in the background auditory condition (within-subjects differences) and the age of an individual (between-subjects differences) have any detrimental effect on semantic word categorization tasks. The reaction time and accuracy for each participant's response to word categorization tasks were analyzed.

Within-Subjects Differences: The Effect of Content of Background Music

The first research question considered whether vocal music has a detrimental effect on reaction time and accuracy in a word categorization task for both age groups. The results revealed no overall significant main effect of auditory conditions on both reaction time (**Table 4-2**) and accuracy (**Table 4-4**). The results also revealed no significant differences for pairwise comparisons among four conditions for reaction time (**Table 4-3**) and accuracy of responses (**Table 4-5**) within each age group. Therefore, performance of word categorization was similar for all auditory conditions within both age groups. This further indicates that vocal music (the Song with Words condition) did not significantly slow down the performance of word categorization within both age groups. Similarly in terms of accuracy, it suggests that vocal music did not make participants commit more errors in word categorization within both age groups. However, variability across the participants in both age groups is seen to be greatest for the Song with Words condition for reaction time (**Figure 4-1** and **Figure 4-2**) and accuracy (**Figure 4-4** and **Figure 4-5**). Moreover, a similar degree of variability is seen above and below the mean values for this condition. An inconclusive response (mean = 3.37) was observed for Question 6: "Listening to a song with words was the most distracting while working on the computer." The participants' perception of their own performance on that particular condition is consistent with the actual variability seen in the data (**Appendix F**; **Table 4-8**). The response for Question 1, "I paid exclusive attention to the background music," is significantly negatively correlated with accuracy in the Song with Words condition (**Appendix L**). It means that the participants that thought that they paid exclusive attention to the song had lower accuracies.

While designing the stimuli, it was expected that the Song with Words condition will negatively affect the performance of word categorization task the most because of the presence of semantic content in the condition. It was also expected that the performance on categorization task for the Piano Melody and Violin Melody conditions would be similar. The fact that the performance across all three conditions was found to be similar was a surprising finding.

In fact, the current findings are inconsistent with most of the studies that compared the effect on cognitive performance of vocal and instrumental music to that of silence. Cassidy and MacDonald (2007) reported a decline in performance for a variety of memory recall tasks in the presence of background vocal music as compared to silence. Similarly, Alley and Greene (2008) reported differences in disruptions in working memory performance when conducted in the presence of speech, instrumental music, and vocal music. In that study, unlike the current one, background auditory stimuli were presented via headphones, and a working memory task was used. The detrimental effect of listening to vocal music during the performance of a verbal task was documented by Avila, Furnham, and McClelland (2012). Both instrumental music and vocal conditions caused significant impairment when compared to the performance of the task during silence. Stroupe (2005) reported significantly longer reaction times and lower accuracies in a reading comprehension task when the task was coupled with background lyrical music. All these studies have a common element: the instrumental music that they used was exactly same as those accompanying vocals in the vocal condition but was without a melody. All stimuli in the current study had exactly the same piano accompaniment, but also had a common melody present in them. Another difference between these studies and the current study is in the nature of the cognitive tasks that were used. These studies used working memory, memory recall, reading comprehension or verbal tasks. The task in the current study was based on semantic processing and retrieval of single word presented in a set of three words in semantic categorization. The difference in tasks is important. The tasks used in the other studies did not necessarily involve semantic processing (or did not require processing of each and every word), whereas the current categorization task required the subject to access the semantic memory store to process the meaning of each and every word from the set.

A few recent neurophysiological studies (Adams & Janata, 2002; Simanova, Hagoort, Oostenveld, & van Gerven, 2014) show that a common semantic representation of visual and auditory stimuli may exists. Results from their studies revealed that a number of frontal lobe areas are engaged in the semantic processing task (more specifically, a categorization task), regardless of the input modality (visual or auditory stimuli). If this is true, then the Song with Words condition in the current study would be expected to affect the performance of a visually presented semantic task. Two possible explanations, described below, may account for why no significant variation in the task performance as a function of auditory condition appeared in the current study.

One possible explanation relates to the melody contained in the auditory conditions. Three conditions – Song with Words, Piano Melody, and Violin Melody – contained a common melody. The piano accompaniment in all the three stimuli was also exactly the same, making the stimuli more similar to each other. The categorization task performances under those conditions did not differ significantly. This suggests that the melody contained in the music was a more dominant factor in the overall processing of music, even if an involuntary one, than the processing of vocal (linguistic) content. In other words, it might be conjectured that a musical song is stored and retrieved from the memory more as a melody than as just the string of words contained in it.

Studies that investigated the processing of lyrics and tunes of a song arrive at contradictory conclusions. One conclusion suggests that the melodic (tunes/sequence of tones) and linguistic (lyrics) aspects of a song (Bonnel, Faita, Peretz, & Besson, 2001; Racette & Peretz, 2007) are processed independently. The other conclusion suggests that the two aspects of a song undergo dependent or integrated processing (Lebedeva & Kuhl, 2010; Schön, Gordon, & Besson, 2005). These studies have found that it is easier to recognize a given tune or lyrics of a song when they are presented in the same, original combination of tune and lyrics. A third conclusion suggests that the processing of melodic and linguistic aspects of the songs is partially integrated and partially separated, meaning that the two are integrated at the pre-semantic level but subsequently separated (Peretz & Coltheart, 2003; Sammler et al., 2010). In the case of the current study, even if it is assumed that processing was integrated at the pre-semantic level, the results indicate that the processing of linguistic stimulus (words in a song) did not interfere with the semantic task of word categorization. Thus, the presence or absence of linguistic content in music did not make a significant difference; however, the commonality of tonal patterns did make a difference in results when a secondary processing of music was involved and where the main primary focus was on the processing of a different linguistic task. This finding does not fully explain why the task performance during the Quiet auditory condition was not different from that during the other three auditory conditions.

The second possible explanation, which may help explain the similarity in task performance across all conditions, relates to the difficulty of the categorization task. The current task involved categorizing sets of monosyllabic and disyllabic words chosen to control for frequency and familiarity of words across all participants. The task of semantic word categorization is thought to be a higher-level linguistic task, and previous research has shown that limits to attention arise at the semantic level of linguistic processing when another auditory task also involving meaningful content is played in the background (Oswald, Tremblay, & Jones, 2000; Venetjoki, Kaarlela-Tuomaala, Keskinen, & Hongisto, 2006). Therefore, it is quite likely that the current stimuli or task was not complex enough to engage the semantic system as would a more complex stimulus (in the form of multiple sentences or difficult tri-syllabic words or words chosen from subordinate categories) or a more complex task (difficult decisions based on semantic content in the stimulus). This may have made it possible for the participants to easily compensate for any interference from a background auditory stimulus.

Indeed, according to the literature on dual-processing, compromise in performance can be observed as the complexity or difficulty of a task increases (Hairston et al., 2008; Pomplun, Reingold, & Shen, 2001). In a study where dual tasks of auditory sentence recognition and pattern recognition were performed simultaneously in the presence of increasing noise, a poorer performance was exhibited by older adults (Gosselin & Gagne, 2011). However, the current results did not show a similar limit on attentional resources with increasing difficulty in background auditory condition. It is important to note that the current task involved dual-processing, but it was not a typical case of dual task where performance of both the primary and secondary task is measured; the performance of a background auditory task (secondary processing task) was not measured in real-time. As a result, a lack of performance pressure on the secondary background auditory task may have prevented it from imposing an additional demand on cognitive resources. This in turn may have caused similarity in performance on word categorization task for all of the background auditory conditions.

Between-Subjects Differences: The Effect of Age

The second research question addressed the effect, if any, of age on reaction time and accuracy measurement in a word categorization task under each of the background auditory conditions.

The Effect of Age on Reaction Time

The results revealed an overall significant main effect for reaction time. The older group was significantly slower than the younger group (**Table 4-1** and **Table 4-2**; **Figure 4-3**, **Figure 4-7**, and **Figure 4-9**). The results are consistent with the significant amount of evidence that suggests that processing speed (Baddeley, Logie, Bressi, Sala, & Spinnler, 1986; Birren & Fisher, 1995; Hartley, Stojack, Mushaney, Annon, & Lee, 1994; Hasher & Zacks, 1988; Pfütze, Sommer, & Schweinberger, 2002; Van der Linden et al., 1999) and inhibitory efficiency, which is an ability to inhibit/ignore irrelevant information, decline with an increase in age (Craik & Salthouse, 2011; Kliegl, Maayr, & Krampe, 1994; Mayr & Kliegl, 1993; Van der Linden et al., 1999).

Further support for this explanation comes from the results of the cognitive testing and reading efficiency performed prior to each experiment in the current study (**Table D-1** and **Table D-2** in **Appendix D**); the results show a lower mean for the total word reading efficiency score (for older = 78.35 and for younger = 100.68) in TOWRE and a lower mean for attention (for older = 185.57 and for younger = 202.23) scores in CLQT for older adults than those for younger adults.

It was also found that the average reaction time for each of the conditions was higher for older adults than that for the younger adults (**Table 4-1**). However, the reaction time differences between the two age groups went from statistically non-significant to statistically significant as the complexity of sound stimulus increased from Piano Melody (single sound source) to Violin Melody and Song with Words (two sound sources each with familiar but different timbres: violin + piano and vocal + piano) (**Table 4-2** and **Table 4-6**; **Figure 4-3**, **Figure 4-7**, and **Figure 4-9**). Prior research has shown that stream segregation may occur when two sounds differ in timbre (Cusack & Roberts, 2000; Roberts, Glasberg, & Moore, 2002; Singh & Bregman, 1997; Snyder & Alain, 2007). This may have caused the participants listening to a stimulus with multiple sound sources of familiar but different timbres to spend a conscious attentional effort in segregating two sound sources from each other. An increased load on cognitive resources due to spending more attentional effort may lead to a decline in performance (Alain & Bernstein, 2008; Cusack, 2005; Deike, Gaschler-Markefski, Brechmann, & Scheich, 2004; Janata, Tillmann, & Bharucha, 2002; Kondo & Kashino, 2009; Vaidya-Mairal, 2015). Thus, it can be proposed that in the current study the older adults may have experienced an overload of cognitive demand that is explained as follows. It is widely accepted research that there exists a baseline of inherent decline in cognitive performance with increase in age. If the processing of melody is added to the total processing, then it would further add to the load on available resources. On top of that, if stream segregation occurs, it would increase the cognitive load even further. Hence, it is possible that the older adults were more significantly affected by the increased cognitive load on available resources in order to filter out two sound sources during conditions with two sound sources (Violin Melody and Song with Words), leading to an increase in statistical significance for those two conditions as compared to the single-sound source condition (Piano Melody). On the other hand, the younger adults were able to cope with the cognitive load more easily across all conditions. This still leaves a question as to why the performance during the Quiet condition was statistically different for both age groups.

The reaction times for the older adults are higher than those for the younger adults in the Quiet condition; moreover, the differences between the reaction times are statistically significant, making the Quiet condition results similar in nature to the results for Violin Melody and Song with Words conditions. It is conjectured that many of the participants filled the silence during the Quiet condition, which occurred after at least one other auditory condition for nearly 75% of the participants (based on the randomization patterns used) with sub-vocalizing or recalling the song. That recall may have had a negative effect on the attention paid to the categorization task and on the task performance; the effect was more pronounced for the older adults. However, further studies are needed to test this conjecture.

The Effect of Age on Accuracy

The results revealed an overall significant main effect for accuracy, indicating that the older group was significantly less accurate than the younger group (**Table 4-4**; **Figure 4-6** and **Figure 4-8**). It was also observed that the effect size for reaction time between the two age groups was greater than that for the accuracy (**Table 4-2** and **Table 4-4**; **Figure 4-9**), which was not an unexpected finding. In past studies, high-performing older adults have been shown to compensate for the decline in inhibitory efficiency that accompanies increasing age by using additional attentional resources to increase performance while taking longer to carry out cognitive tasks (Dennis & Cabeza, 2008; Getzmann, 2012; Getzmann, Gajewski, & Falkenstein, 2013; Getzmann & Falkenstein, 2011; Horváth, Czigler, Birkas, Winkler, & Gervai, 2009). In the current study, it was also seen that while the mean accuracy for each of the conditions was higher for younger adults than that for the older adults, the mean accuracy differences between the two age groups were not statistically significant for any of the auditory conditions. In terms of cognitive testing and reading efficiency performance, although there was a difference between means for cognitive testing evaluations (**Table D-1** and **Table D-2** in **Appendix D**) for the two age groups, all of the older adults performed within normal limits based on the severity ratings described in the examiner's manual for testing. Therefore, as discussed above, it is likely that these average-to-high performing older adults spent additional cognitive resources in order to perform the task adequately while taking longer to do so. As a result, the difference in accuracies for the two age groups was not statistically significant for any of the auditory conditions, but the difference in reaction times was.

Limitations and Implications for Future Research

Contrary to a number of prior studies that reported the detrimental effect of background instrumental or vocal music on cognitive performance, the current study did not show any significant effect of background auditory condition across participants. The task did not cause participants to reach a perceptual load limit on cognitive resources. There might be several reasons for this, but the main reason likely stems from the fact that the task was not sufficiently challenging.

The current categorization task used mono-and di-syllabic words from superordinate categories. The word categorization task could have been made more difficult with the use of more complex stimuli, such as a set of multiple sentences or difficult tri-syllabic words or words from a subordinate category. Some studies (Adams & Janata, 2002; Greene & Fei-Fei, 2014) have reported longer reaction times when words from subordinate categories were used. Although semantic categorization is considered to be a higher level linguistic task, a slightly more difficult semantic task such as a semantic decision or processing task like that used in Smith's (1985) study could be used, especially in the case where the experiment participants are drawn from a population of normal adults.

As mentioned earlier, the current task involved dual-processing but did not involve a secondary task as such. The performance of the background auditory task was not measured in real-time. This lack of performance pressure may have caused participants to perform better in the categorization task. The demand imposed by the dual-processing task on cognitive resource capacity can be increased by measuring the performance of the background auditory task simultaneously. More investigation is needed to appropriately design such a measure without causing any disturbance or discontinuity in the auditory stimulus. One possibility is to ask participants to count the number of times a particular word appeared in the stimulus and to report it at the end of the experiment.

Regarding the experiment format, each set of words was displayed on the screen for 3,500 milliseconds unless the participant responded before the end of that time period. The task could have been made more challenging by displaying the word set for a brief period, taking it away, and leaving the participant the rest of the time to respond with a blank screen in front of him/her. If the length of time for which the word set was displayed was reduced by making the rest of the time available for participant to respond, then the task may be more challenging.

Apart from increasing the difficulty of the task, balancing for few other factors could control for variability in the data. Despite the effort of the study, familiarity with the song used as an auditory stimulus was not controlled across participants. It is possible that some of the older adults were not familiar with the song while a large proportion of younger adults were. Future studies should ensure control for the familiarity of the song.

The participants in the two age groups were not matched in gender or education level, which may have introduced an additional degree of variability in the data. Therefore, it would also necessary in a future study to match the participants in two age groups in gender and education level to reduce possible variability. Last, the history questionnaire information that was collected prior to the experiment was per self-report, meaning that the participants themselves may not have been aware of any vision problem or any injury that they may have had that could have interfered with their responses.

Conclusion

It was hypothesized that vocal music and an increase in age will have a detrimental effect on the performance of a visual word categorization task. The findings of the study revealed that categorization task performance during vocal music was not significantly different from that during quiet or instrumental conditions. This concluded that vocal music did not interfere with semantic word categorization across participants. It was also found that an increase in age did have a detrimental effect on categorization task performance; more particularly, older adults were found to be significantly slower and less accurate than younger adults.

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APPENDIX A. THE ADVERTISING FLYER

THE UNIVERSITY of TENNESSEE
HEALTH SCIENCE CENTER

VOLUNTEERS NEEDED FOR RESEARCH STUDY

ENTITLED

Background Music and Categorization of Printed Words in Normal Younger and Older Adults

Younger (18-33 years) and
Older Adults (63-79 years) needed

We are conducting research to find out how listening to background music affects listener's ability to process printed words and categorize them.

To participate: Participants must be native speakers of English, have normal or near to normal hearing, and normal or corrected (glasses or contacts) vision, and have NO history of brain injury, ADHD, or speech and language impairment.

A complimentary hearing screening and cognitive screening will be provided at no cost.

Contact: Sukhada Mairal at **(865) 335-2276** or **svaidya1@uthsc.edu** for more information and to participate.

This research has been approved by the UTHSC Institutional Review Board, and is conducted under the supervision of Dr. Kristin King and Dr. Molly Erickson in the Department of Audiology and Speech Pathology.

Sukhada Mairal svaidya1@uthsc.edu (865) 335-2276 Categorization-Music Study	Sukhada Mairal svaidya1@uthsc.edu (865) 335-2276 Categorization-Music Study	Sukhada Mairal svaidya1@uthsc.edu (865) 335-2276 Categorization-Music Study	Sukhada Mairal svaidya1@uthsc.edu (865) 335-2276 Categorization-Music Study	Sukhada Mairal svaidya1@uthsc.edu (865) 335-2276 Categorization-Music Study	Sukhada Mairal svaidya1@uthsc.edu (865) 335-2276 Categorization-Music Study	Sukhada Mairal svaidya1@uthsc.edu (865) 335-2276 Categorization-Music Study	Sukhada Mairal svaidya1@uthsc.edu (865) 335-2276 Categorization-Music Study

IRB NUMBER: 14-03169-XP
IRB APPROVAL DATE: 06/20/2014

APPENDIX B. THE CONSENT FORM

Main Consent Form

THE UNIVERSITY of TENNESSEE HEALTH SCIENCE CENTER

TITLE: The Effect of Background Music on Visual Categorization of Printed Words in Normal Younger and Older Adults

PRINCIPAL INVESTIGATOR: Sukhada Vaidya Mairal
547 South Stadium Hall
University of Tennessee
Knoxville, TN 37996

CO-PRINCIPAL INVESTIGATOR(S): Kristin King, Ph.D., Molly Erickson, Ph.D.

1. INTRODUCTION:

You are being given the opportunity to participate in this research study. The purpose of this consent form is to help you decide if you want to be in the research study. This consent form may contain words that you do not understand. Please ask the study doctor or the study staff to explain any words or information that you do not clearly understand. We encourage you to talk with your family and friends before you decide to take part in this research study. Please tell the study doctor or study staff if you are taking part in another research study.

The purpose of this study is to investigate how listening to background music affects our ability to process words and categorize them. Subjects between 18-79 years of age will be recruited from the population of university students and the local community center of the Office on Aging.

Approximately 60 subjects will participate in this study. The study will take place at the Voice and Speech Science Laboratory on the campus of the University of Tennessee, Knoxville. This laboratory is located at 427 South Stadium Hall.

Your participation in this study will last for one visit and will take about one-and-one-half hours (90 minutes). However, if there is an unexpected problem, such as problems with the computer that will you will use to complete the study, we may ask you to come back another day to complete the study.

2. PROCEDURES TO BE FOLLOWED:

If you agree to take part in the study, you will have several screening tests to make sure that you will be able to complete the experiment part of the study.

First, you will have a hearing screening, which will be provided at no charge to you. The hearing screening is similar to those you may have had while in elementary or high school. You will listen to some sounds through headphones and let the investigator know when you hear the sounds. **If you do not pass the hearing screening, your participation in the study will stop at this point and you will not complete the rest of the study.**

Next, you will be asked some simple questions about your speech and language abilities; your abilities for thinking, processing, and remembering; and your psychological and emotional status. **If you have any conditions related to these abilities that might affect whether or not you can complete the rest of the study, your participation in the study will stop at this point. You will not complete the rest of the study.**

Your "handedness" (whether you are right-handed or left-handed) will then be tested using a standard Edinburgh Handedness Inventory test. You will be asked some questions about which hand you use to do different tasks. The results of this test will not affect whether you are able to complete the study. Instead, this test will give us information that will be used later for analysis of the data (the information we collect from all the study tests and evaluations) after all the study subjects have completed the study.

Finally, you will have a cognitive screening, which will also be provided at no charge to you. This screening will take place using two tests. The first one is the standard Test of Word Reading Efficiency. For this test, you will read a list of words for the investigator. The second test is the Cognitive Linguistic Quick Test. For this test, you will do simple tasks like drawing a line through a maze, drawing a clock face so that it shows a certain time, and finding certain shapes (like a star) on a page with different types of shapes on it. , **If you do not pass this screening test, your participation in the study will stop at this point. You will not complete the rest of the study.**

In the event that you do not pass a screening test, you will be advised to see a specialist if you wish to have further testing or treatment.

If you pass all the screening tests and agree to continue in the study, you will complete the experiment part of the study while listening to music. The following steps are involved in the experiment:

- You will enter a sound booth and be seated in front of a computer and a response pad. You will be fitted with headphones.
- A plus sign will appear on the computer monitor. This lets you know that the experiment is about to begin. Over the headphones you may hear nothing or you may hear some background music. Very quickly after that (about a half a second), you will see 3 printed words. They may all three belong to the same category of words, or one or more of them may belong to different categories of words. You will be asked to quickly decide if all

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three of them belong to the same category or not. You should try to answer as quickly and as correctly as possible.

- When you have made your decision, you will hit a "yes" or "no" button on a response pad. Once you have answered yes or no, you will see another plus sign, letting you know that the next set of 3 printed words is about to be presented.
- You will do this experiment 4 different times.
- After you finish the experiment, you will answer a short written questionnaire with 21 questions about your attention during the experiment, as well as your studying or working habits.

Completion of the screening procedures and the experiment will take approximately one-and-one-half hours.

All of the procedures are being completed for research purposes only.

3. RISKS ASSOCIATED WITH PARTICIPATION:

There is a potential risk of loss of confidentiality. Every effort will be made to keep your information confidential; however, this cannot be guaranteed.

There is a possible risk of tiring as the experiment takes about one-and-one-half hours to complete. There is also a potential risk of troubling feelings or emotions concerning the sensitive nature of some of the screening questions and the cognitive functioning assessments.
You will be allowed to take a break if needed.

The research may involve risks to you which are currently unforeseeable. You will be told about any new information that might change your decision to be in this study. You may be asked to sign a new consent form if this occurs.

4. BENEFITS ASSOCIATED WITH PARTICIPATION:

There are no direct benefits associated with participation in this study. There is a potential benefit in undergoing the hearing test that is used to screen enrolled participants for normal hearing. There is another potential benefit in undergoing the cognitive functioning test that is used to screen enrolled older adult participants. Findings from this study may help determine optimal music listening environments for the processing of visually printed words.

5. ALTERNATIVES TO PARTICIPATION:

All of the procedures described in this consent form are being done for research purposes only. You will not have to undergo these procedures if you do not participate in this study.

6. CONFIDENTIALITY:

Research records/specimens
All your paper research records will be stored in locked file cabinets and will be accessible only to research personnel.
All your electronic research records will be computer password protected and accessible only to research personnel.

Presentations/Publications
You will not be identified in any presentations or publications based on the results of this research study.

Authorization to Use and Disclose Information for Research Purposes
Under federal privacy regulations, you have the right to decide who can review and copy your personal health information (called "protected health information" or PHI). PHI collected in this study may include information such as:

- Past and present medical records
- Records about your study visits
- Records about phone calls made as part of this research
- Research records

By signing this consent form, you are giving your permission for the study doctor and the study staff at the University of Tennessee to get your PHI from your doctor and/or facilities where you have received health care. They may also share your PHI with:

- The Institutional Review Board (IRB) at the University of Tennessee Health Science Center

Your PHI will only be used and/or given to others:

- To do the research
- To study the results
- To see if the research was done correctly

Your PHI will be used until the study is completed.

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You may withdraw or take away your permission to use and disclose your PHI at any time. You do this by sending written notice to the study doctor. If you withdraw your permission, you may not be able to stay in the study.

When you withdraw your permission, no new PHI will be gathered after that date. However, information that has already been gathered may still be used and given to others. The federal regulations allow you to review or copy your PHI that is used in this study.

7. COMPENSATION AND TREATMENT FOR INJURY:

You are not waiving any legal rights or releasing the University of Tennessee or its agents from liability for negligence. In the event of physical injury resulting from research procedures, the University of Tennessee does not have funds budgeted for compensation for medical treatment. Therefore, the University of Tennessee does not provide for treatment or reimbursement for such injuries.

If you are injured or get sick as a result of being in this study, call the study staff immediately. The study doctor will provide you with a subsequent referral to appropriate health care facilities.

If you are injured or get sick as a result of being in this study, you and/or your insurance will be billed for the costs associated with this medical treatment.

No compensation will be available to you for any extra expenses that you may have as the result of research related physical injuries, such as additional hospital bills, lost wages, travel expenses, etc.

No compensation will be available to you for any non-physical injuries that you may have as a result of research participation, such as legal problems, problems with your finances or job, or damage to your reputation.

8. QUESTIONS:

Contact Sukhada Vaidya Mairal at (865) 335-2276 if you have questions about your participation in this study, or if you have questions, concerns, or complaints about the research.

If you feel you have had a research-related injury, contact the Co-Principal Investigator, Mary L (Molly) Erickson, Ph.D., CCC-SLP at office number (865) 974-9895 or Ashley Harkrider, Department Chair, Ph.D., CCC-A at office number (865) 974-1819.

You may contact Terrence F. Ackerman, Ph.D., UTHSC IRB Chairman, at 901-448-4824, or visit the IRB website at http://www.uthsc.edu/research/research_compliance/IRB/participant_complaint.php if you have any questions about your rights as a research subject, or if you have questions, concerns, or complaints about the research.

9. PAYMENT FOR PARTICIPATION:

You will not be paid for participating in this research study.

If you are a University of Tennessee student, you may be able to receive credit point(s) toward participating Psychology courses for research participation, but this is not guaranteed. Students in participating Psychology courses do not have to participate in this study to receive credits, but may, instead, complete written assignments as described in their course syllabi. Students in the Audiology and Speech Pathology Research Design course may also be able to receive credit point(s) for research participation, but this is not guaranteed. Students participating in this research study should consult their course syllabi and, if applicable, their course instructor to verify availability of course credit for participation in this research study.

University of Tennessee employees will not be paid for participating in this research study.

10. COSTS OF PARTICIPATION:

There are no costs to you for participating in this study

11. VOLUNTARY PARTICIPATION AND WITHDRAWAL:

Your participation in this research study is voluntary. You may decide not to participate or you may leave the study at any time. Your decision will not result in any penalty or loss of benefits to which you are entitled.

If you are a student of the University of Tennessee, participating or not participating in this study will in no way influence your grade in any course, other than any extra credit your course instructor may approve for participation.

If you are an employee of the University of Tennessee, participating or not participating in this study will not affect your employment status.

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12. CONSENT OF SUBJECT:

You have read or have had read to you a description of the research study as outlined above. The investigator or his/her representative has explained the study to you and has answered all the questions you have at this time. You knowingly and freely choose to participate in the study. A copy of this consent form will be given to you for your records.

____________________________________ _________ ________
Signature of Research Subject (18 years +) **Date** **Time**

____
Printed Name of Adult Research Subject

____________________________________ _________ ________
Signature of Person Obtaining Consent **Date** **Time**

____
Printed Name of Person Obtaining Consent

In my judgment, the subject has voluntarily and knowingly given informed consent and possesses the legal capacity to give informed consent to participate in this research study.

____________________________________ _________ ________
Signature of Investigator **Date** **Time**

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APPENDIX C. THE HISTORY QUESTIONNAIRE

QUESTIONNAIRE

FILE CODE: ________

DOB: ________________________

AGE: ____________

Handedness: RIGHT LEFT

Education level (completed): ______________________________

Primary Language: ______________________

Secondary Language: ______________________

Medical history (please check all that apply):

☐ Stroke

Date of stroke(s):_______________

Site of stroke(s):________________

Side of stroke(s): LEFT RIGHT

☐ Speech/Language Disorder

If yes, please specify: ______________________________________

☐ Hearing Impairment

If yes, do you wear hearing aid(s)? __________

☐ Visual Impairment

If yes, do you wear glasses or contacts? ______________

☐ Brain Injury

☐ Cognitive Disorder

☐ Psychiatric Disorder

☐ Drug or Alcohol Abuse

Surgical Intervention YES NO Type: ______________

CT Scan/MRI Results: ______________________________________

____

____

Other injuries: ____

COMMENTS/Additional Information:

____

____

____

____

____

APPENDIX D. CLQT AND TOWRE SCORES

Table D-1. CLQT and TOWRE scores for individual domain evaluations for each participant in older group.

Participant	CLQT						TOWRE		
(n=14)	Att	Mem	ExF	Lang	Vis	CSR	SWE	PDE	TWE
1*	198	160	32	32	97	4.0	91	103	96
2*	163	149	16	26	73	3.6	76	71	68
3	207	167	38	39	103	4.0	99	109	105
4	188	176	26	32	85	4.0	74	80	72
5	201	185	32	37	94	4.0	84	97	89
6	137	144	26	31	78	3.6	86	56	65
7	199	160	31	32	93	4.0	75	71	68
8*	200	176	33	33	82	4.0	83	89	83
9	192	125	27	29	93	2.8	85	79	78
10	165	197	26	29	99	4.0	71	76	78
11	151	164	22	31	71	3.8	87	78	78
12	206	175	35	37	98	4.0	97	115	107
13	206	160	34	32	98	4.0	70	82	72
14	184	179	34	36	77	3.6	97	96	96
15	189	128	25	25	91	3.4	71	76	68
16	186	178	28	35	84	4.0	84	84	81
17	187	152	28	29	90	4.0	68	87	73
18*	132	110	12	27	27	2.6	63	64	56
**	196	153	29	30	83	4.0	76	84	76
Mean	**185.6**	**163.6**	**29.4**	**32.4**	**88.9**	**3.8**	**82**	**84.7**	**78.4**

Notes: CLQT – Cognitive Linguistic Quick Test, TOWRE – Test of Word Reading Efficiency, Att – Attention: WNL (within normal limit) score for 70-89 yrs = 160-215; 18-69 yrs = 180-215, Mem - Memory: WNL score for 70-89 yrs = 141-185; 18-69 yrs = 155-185, ExF - Executive functions: WNL score for 70-89 yrs = 19-40; 18-69 yrs = 24-40, Lang - Language: WNL score for 70-89 yrs = 28-37; 18-69 yrs = 29-37, Vis - Visuospatial skills: WNL score for 70-89 yrs = 62-105; 18-69 yrs = 82-105, CSR - Composite severity rating: WNL - 3.5-4.0; MILD– 2.5-3.4; MODEARTE- 1.5-2.4; SEVERE- 1.0-1.4, SWE – Sight Word Reading Efficiency, PDE – Phonemic Decoding Efficiency, TWE - Total word efficiency standard (std.) score: WNL- typical population = 70-130; normal population = 85-115, *- Participants that were excluded from statistical analysis, **- A participant who did not meet age and several other criteria.

Table D-2. CLQT and TOWRE scores for individual domain evaluations for each participant in younger group.

Participant	CLQT						TOWRE		
(n=22)	**Att**	**Mem**	**ExF**	**Lang**	**Vis**	**CSR**	**SWE**	**PDE**	**TWE**
1	213	185	38	37	103	4.0	103	120	114
2	213	185	38	37	103	4.0	>113	109	113
3	207	173	36	35	101	4.0	88	96	90
4	189	167	33	34	78	3.8	>113	>120	120
5	193	177	36	34	99	4.0	98	112	106
6	197	160	29	34	95	4.0	98	103	101
10	183	154	28	31	93	3.8	93	96	93
11	207	184	34	36	98	4.0	90	84	84
12	206	175	33	37	94	4.0	>113	120	120
13	204	166	30	33	94	4.0	85	96	89
14	210	179	37	36	102	4.0	81	95	86
15	202	163	27	30	96	4.0	79	78	74
16	203	145	40	32	101	3.8	87	84	83
17	210	174	36	36	98	4.0	98	100	99
18	187	166	25	33	81	3.8	>113	106	111
19	194	167	30	34	87	4.0	100	103	102
20	199	172	30	34	94	4.0	84	81	79
21	207	155	38	32	101	4.0	97	84	89
22	208	169	37	36	98	4.0	>113	115	117
Mean	**202.2**	**169.9**	**33.8**	**34.3**	**96.5**	**3.9**	**98.4**	**102.6**	**100.7**

Notes: CLQT – Cognitive Linguistic Quick Test, TOWRE – Test of Word Reading Efficiency, Att – Attention: WNL (within normal limit) score for 18-69 yrs = 180-215, Mem - Memory: WNL score for 18-69 yrs = 155-185, ExF - Executive functions: WNL score for 18-69 yrs = 24-40, Lang - Language: WNL score for 18-69 yrs = 29-37, Vis - Visuospatial skills: WNL score for 18-69 yrs = 82-105, CSR - Composite severity rating: WNL - 3.5-4.0; MILD– 2.5-3.4; MODEARTE- 1.5-2.4; SEVERE- 1.0-1.4, SWE – Sight Word Reading Efficiency, PDE – Phonemic Decoding Efficiency, TWE - Total word efficiency standard (std.) score: WNL- typical population = 70-130; normal population = 85-115, *- Participants that were excluded from statistical analysis, **- A participant who did not meet age and several other criteria.

APPENDIX E. STIMULI LISTS OF PRINTED WORDS AND CATEGORY NAMES

Table E-1. List of printed word stimuli along with category names presented in block 1.

			Category Name		
Word1	**Word2**	**Word3**	**A**	**B**	**C**
Wolf	Rat	fox	Food	Animals	Tools
monkey	rabbit	table	Tools	Animals	Toys
Horn	moth	ant	Insects	Food	Body Parts
Bee	Ant	fly	Clothing	Tools	Insects
Ankle	elbow	finger	Body Parts	Utensils	Clothing
Foot	Skirt	knee	Food	Clothing	Body Parts
Apple	wrench	ginger	Food	Animals	Insects
Kiwi	train	berry	Toys	Vehicles	Food
Desk	couch	chair	Furniture	Instruments	Tools
mattress	cupboard	bookcase	Utensils	Furniture	Insects
Stove	knife	dress	Utensils	Clothing	Body Parts
Kettle	oven	toaster	Vehicles	Tools	Utensils
Hand	dress	glove	Clothing	Toys	Food
Coat	blouse	dress	Tools	Body Parts	Clothing
Truck	flute	car	Instruments	Vehicles	Food
toaster	wagon	airplane	Toys	Furniture	Vehicles
Shears	screw	axe	Toys	Body Parts	Tools
Axe	shears	hair	Clothing	Instruments	Tools
Bat	Kite	doll	Toys	Furniture	Animals
Doll	Ring	bat	Tools	Clothing	Toys
Kite	Bell	horn	Furniture	Toys	Instruments
Bell	flute	drum	Food	Vehicles	Instruments
mango	lettuce	dresser	Animals	Food	Tools
Glove	Toe	thumb	Toys	Clothing	Body Parts
Pan	stool	lamp	Instruments	Furniture	Vehicles
Deer	Hat	owl	Furniture	Utensils	Animals

Table E-2. List of printed word stimuli along with category names presented in block 2.

Word1	Word2	Word3	Category Name A	Category Name B	Category Name C
leopard	shovel	Rooster	Body Parts	Animals	Food
Deer	Hat	Owl	Toys	Animals	Clothing
Ant	Fly	Corn	Utensils	Insects	Furniture
Bee	Ant	Fly	Insects	Animals	Vehicles
Leg	Eye	Thumb	Insects	Instruments	Body Parts
blouse	Arm	Lip	Body Parts	Clothing	Toys
Guava	weeder	Lettuce	Furniture	Food	Tools
pepper	orange	Mushroom	Animals	Utensils	Food
kickball	futon	Cupboard	Furniture	Instruments	Toys
Desk	couch	Chair	Vehicles	Furniture	Tools
Kettle	oven	Toaster	Utensils	Food	Insects
Fork	Pan	Dog	Clothing	Animals	Utensils
Waist	blouse	Tie	Body Parts	Tools	Clothing
Coat	blouse	Dress	Vehicles	Toys	Clothing
Train	Bus	Stove	Instruments	Food	Vehicles
aircraft	wagon	Airplane	Tools	Furniture	Vehicles
Chisel	hammer	Shovel	Tools	Clothing	Utensils
Screw	apple	Wrench	Tools	Animals	Food
Kite	Ball	Ant	Toys	Clothing	Body Parts
Bat	Kite	Doll	Instruments	Furniture	Toys
trumpet	guitar	Cheetah	Instruments	Toys	Tools
Drum	flute	Horn	Vehicles	Instruments	Furniture
Okra	toaster	Apple	Food	Utensils	Toys
Watch	Leg	Coat	Animals	Clothing	Body Parts
Bus	train	Glass	Vehicles	Instruments	Tools
leopard	raccoon	Walrus	Animals	Food	Body Parts

Table E-3. List of printed word stimuli along with category names presented in block 3.

			Category Name		
Word1	**Word2**	**Word3**	**A**	**B**	**C**
ostrich	squirrel	mattress	Animals	Toys	Food
donkey	baseball	walrus	Insects	Furniture	Animals
Wasp	moth	fly	Insects	Instruments	Tools
Bee	wasp	glass	Utensils	Vehicles	Insects
mouth	wrist	foot	Food	Insects	Body Parts
Hand	Arm	ear	Body Parts	Clothing	Toys
Carrot	kiwi	pliers	Insects	Food	Furniture
orange	trumpet	eggplant	Body Parts	Food	Tools
Futon	dresser	table	Utensils	Animals	Furniture
Rug	stool	lamp	Vehicles	Instruments	Furniture
Foot	Cup	spoon	Utensils	Tools	Clothing
Finger	oven	kettle	Instruments	Utensils	Food
Watch	Leg	coat	Clothing	Body parts	Animals
Skirt	Hat	glove	Clothing	Body parts	Insects
Bus	Car	truck	Vehicles	Furniture	Animals
Train	flute	car	Tools	Utensils	Vehicles
Axe	screw	wrench	Tools	Toys	Furniture
Chisel	hammer	shovel	Body Parts	Tools	Instruments
Bat	Kite	doll	Food	Toys	Insects
Kite	Ball	ant	Animals	Toys	Instruments
Flute	drum	glass	Instruments	Vehicles	Body Parts
Bell	Toe	harp	Tools	Utensils	Instruments
giraffe	turtle	monkey	Animals	Insects	Vehicles
Cup	Fork	pan	Clothing	Toys	Utensils
Waist	Face	leg	Body Parts	Clothing	Animals
orange	mango	guava	Furniture	Vehicles	Food

Table E-4. List of printed word stimuli along with category names presented in block 4.

Word1	Word2	Word3	Category Name A	Category Name B	Category Name C
Deer	mouse	wolf	Animals	Insects	Toys
cheetah	airplane	oyster	Animals	Vehicles	Body Parts
Bee	wasp	glass	Furniture	Toys	Insects
Horn	moth	ant	Insects	Body Parts	Tools
Ankle	trouser	elbow	Furniture	Body Parts	Clothing
Knee	Lip	toe	Animals	Body Parts	Clothing
mango	okra	dresser	Furniture	Food	Instruments
Pear	Kale	lip	Food	Body Parts	Toys
Frog	chair	rug	Animals	Utensils	Furniture
bookcase	turtle	mattress	Furniture	Insects	Food
Spoon	Pot	knife	Furniture	Toys	Utensils
Stove	glass	fork	Utensils	Instruments	Food
Toe	Ring	skirt	Body parts	Vehicles	Clothing
Skirt	Hat	glove	Clothing	Toys	Tools
toaster	wagon	airplane	Utensils	Vehicles	Instruments
Bus	Car	truck	Vehicles	Animals	Body Parts
Shears	screw	axe	Furniture	Food	Tools
Screw	okra	wrench	Tools	Insects	Clothing
Doll	watch	bat	Clothing	Instruments	Toys
Kite	Bat	tie	Body Parts	Toys	Vehicles
Drum	flute	horn	Food	Animals	Instruments
trumpet	guitar	penguin	Animals	Utensils	Instruments
shovel	ankle	hammer	Body Parts	Furniture	Tools
squirrel	rabbit	donkey	Animals	Insects	Vehicles
trouser	sweater	kettle	Utensils	Food	Clothing
Grape	Kale	peach	Toys	Instruments	Food

APPENDIX F. THE QUESTIONNAIRE

Subject #

Questionnaire

Based on a five-point scale, please respond to the following statements.

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
1	2	3	4	5

1. I paid exclusive attention to the background music.

1 2 3 4 5

2. Content of song:

a. The song was about relationships.

1 2 3 4 5

b. The song ended on a happy note.

1 2 3 4 5

c. The song was about pain.

1 2 3 4 5

3. I knew this song before participating in the study.

1 2 3 4 5

4. I remember the original singer.

1 2 3 4 5

5. Listening to just instrumental music was the most distracting while working on the computer.

1 2 3 4 5

6. Listening to a song with words was the most distracting while working on the computer.

1 2 3 4 5

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Strongly disagree	Disagree	Undecided	Agree	Strongly agree
1	2	3	4	5

7. I think I performed better in silence.

1 2 3 4 5

8. I sang along or subvocalized (sang silently to myself) during the task.

1 2 3 4 5

9. I like music.

1 2 3 4 5

a. I like instrumental music more.

1 2 3 4 5

b. I like music with singers more.

1 2 3 4 5

10. I listen to music every day.

1 2 3 4 5

11. I listen to loud music.

1 2 3 4 5

12. I listen to music over headphones.

1 2 3 4 5

13. I listen to music on speakers.

1 2 3 4 5

14. I sing along or subvocalize (sing silently to yourself) while I listen to music.

1 2 3 4 5

15. I listen to music while studying or working.

1 2 3 4 5

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IRB APPROVAL DATE: 06/20/2014

Subject #

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
1	2	3	4	5

16. Listening habits:

a. I listen to loud music while studying or working.

1 2 3 4 5

b. I listen to instrumental music while studying or working.

1 2 3 4 5

c. I listen to music with words while studying or working.

1 2 3 4 5

d. I listen to music over headphones while studying or working.

1 2 3 4 5

e. I listen to music on speakers while studying or working.

1 2 3 4 5

17. If you said no to all statements in # 16, then skip this question.

I listen to music while studying or working because -

a. It helps me study or work better.

1 2 3 4 5

b. It helps me focus.

1 2 3 4 5

c. It helps me remember the material.

1 2 3 4 5

18. I would like it if music was played during classes, at my work place, or in my home.

1 2 3 4 5

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Subject #

Strongly disagree	Disagree	Undecided	Agree	Strongly agree
1	2	3	4	5

19. Why?

a. It would help me focus.

1 2 3 4 5

b. It would distract me.

1 2 3 4 5

c. It would differ from past classroom, home, or work settings.

1 2 3 4 5

20. I am trained in music.

1 2 3 4 5

21. If trained in music, what type and how much of training did you have?

___

___

___

Thank you for your participation!

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APPENDIX G. WRITTEN INSTRUCTIONS

Part 1: You will be presented with a few sets of 3 words. Please press YES, if ALL 3 words belong to the same common category or NO if ANY word in the set does not belong to the common category.

Part 2: On the next screen after the set of words, you will be given 3 options to choose the category for the set of words. Please press the A or B or C key to identify the common category for 2 or 3 words in the set in the set that you had just seen.

Press any key to start the experiment.

APPENDIX H. INDIVIDUAL MEASUREMENTS OF REACTION TIME (MS) FOR PARTICIPANTS IN TWO AGE GROUPS

Group	Particip-ant	Song with Words	Piano Melody	Violin Melody	Quiet
Older Group	1*	3500.00	3386.85	3355.84	2738.00
	2*	3500.00	3486.85	3500.00	3500.00
	3	1576.92	1780.25	1653.12	1826.12
	4	2119.21	2118.00	2257.22	2179.88
	5	1787.60	1599.63	1986.96	2064.23
	6	1829.36	1766.91	1699.00	2057.60
	7	2570.36	2470.32	2347.24	2884.56
	8*	3500.00	2979.00	2820.48	2464.38
	9	1872.67	1603.28	2676.08	2118.57
	10	1968.88	2118.60	2094.80	2013.21
	11	3205.52	2956.36	2733.71	2605.33
	12	1732.96	2298.88	1995.09	1892.08
	13	2377.25	1551.04	2084.36	1536.71
	14	1317.33	1258.65	1276.29	2131.24
	15	3121.09	2542.17	2592.20	2510.77
	16	2381.28	2626.13	2727.36	2540.20
	17	2646.71	2765.76	2813.50	2787.88
	18*	3271.45	2045.05	2346.26	2640.33
Younger Group	1	2031.65	1754.91	1630.04	1478.67
	2	1197.27	1844.08	1323.00	1218.20
	3	1734.63	1900.96	1525.12	1677.09
	4	1974.54	1838.92	2094.48	1896.70
	5	2047.42	2140.12	2038.79	2144.19
	6	1999.96	2195.32	2111.60	2293.32
	7	1778.48	1474.80	1457.44	2001.38
	8	1998.31	1773.92	1466.46	1383.36
	9	1490.25	1431.13	1812.24	1526.75
	10	1751.54	1889.91	1817.04	2066.83
	11	2174.32	2091.46	2016.56	1632.68
	12	1318.72	1945.04	1799.54	1862.79
	13	1727.26	1628.33	1659.25	1744.75
	14	1626.13	1749.04	1732.80	1958.35
	15	2790.55	2468.52	2636.00	2640.21
	16	2100.12	2041.87	2142.00	2258.71
	17	1761.63	1662.32	1755.79	1890.16
	18	2355.96	1664.72	1699.84	2059.08

Appendix H. (Continued).

Group	Particip-ant	Song with Words	Piano Melody	Violin Melody	Quiet
Younger Group	19	1835.28	1611.00	1550.46	1535.91
	20	1784.35	2560.95	2144.52	2015.39
	21	1774.88	2033.36	1910.64	1994.65
	22	1640.08	1467.68	1547.96	1407.12

Notes: *- Participants that were excluded from statistical analysis.

APPENDIX I. INDIVIDUAL MEASUREMENTS OF ACCURACY OF RESPONSES (% AND RAD.) FOR PARTICIPANTS IN TWO AGE GROUPS

		Song with Words		Piano Melody		Violin Melody		Quiet	
Gr.	P	%	rad.	%	rad.	%	rad.	%	rad.
Older Gr.	3	96.15	2.75	92.31	2.58	96.15	2.75	96.15	2.75
	4	88.46	2.45	84.62	2.34	88.46	2.45	92.31	2.58
	5	92.31	2.58	92.31	2.58	88.46	2.45	96.15	2.75
	6	92.31	2.58	88.46	2.45	88.46	2.45	92.31	2.58
	7	96.15	2.75	96.15	2.75	96.15	2.75	76.92	2.14
	9	92.31	2.58	96.15	2.75	80.77	2.23	76.92	2.14
	10	96.15	2.75	92.31	2.58	92.31	2.58	92.31	2.58
	11	69.23	1.97	84.62	2.34	84.62	2.34	88.46	2.45
	12	96.15	2.75	96.15	2.75	88.46	2.45	92.31	2.58
	13	88.46	2.45	96.15	2.75	96.15	2.75	92.31	2.58
	14	69.23	1.97	88.46	2.45	92.31	2.58	92.31	2.58
	15	69.23	1.97	92.31	2.58	84.62	2.34	96.15	2.75
	16	96.15	2.75	88.46	2.45	92.31	2.58	92.31	2.58
	17	88.46	2.45	88.46	2.45	88.46	2.45	80.77	2.23
Younger Gr.	1	96.15	2.75	88.46	2.45	96.15	2.75	92.31	2.58
	2	100	3.14	96.15	2.75	96.15	2.75	96.15	2.75
	3	92.31	2.58	88.46	2.45	96.15	2.75	88.46	2.45
	4	96.15	2.75	100	3.14	84.61	2.34	88.46	2.45
	5	92.31	2.58	96.15	2.75	92.31	2.58	100	3.14
	6	92.31	2.58	96.15	2.75	96.15	2.75	96.15	2.75
	7	92.31	2.58	96.15	2.75	96.15	2.75	100	3.14
	8	100	3.14	92.31	2.58	92.31	2.58	96.15	2.75
	9	92.31	2.58	92.31	2.58	76.92	2.14	92.31	2.58
	10	92.31	2.58	84.62	2.34	88.46	2.45	88.46	2.45
	11	96.15	2.75	100	3.14	88.46	2.45	96.15	2.75
	12	96.15	2.75	92.31	2.58	100	3.14	88.46	2.45
	13	69.23	1.97	92.31	2.58	92.31	2.58	92.31	2.58
	14	88.46	2.45	88.46	2.45	96.15	2.75	80.77	2.23
	15	76.92	2.14	88.46	2.45	84.62	2.34	92.31	2.58
	16	96.15	2.75	84.62	2.34	100	3.14	88.46	2.45
	17	92.31	2.58	96.15	2.75	92.31	2.58	96.15	2.75
	18	88.46	2.45	96.15	2.75	96.15	2.75	96.15	2.75
	19	92.31	2.58	84.62	2.34	88.46	2.45	88.46	2.45

Appendix I. (Continued).

Gr.	P	Song with Words		Piano Melody		Violin Melody		Quiet	
		%	rad.	%	rad.	%	rad.	%	rad.
Younger Gr.	20	100	3.14	73.08	2.05	96.15	2.75	88.46	2.45
	21	100	3.14	96.15	2.75	96.15	2.75	100	3.14
	22	100	3.14	96.15	2.75	84.62	2.34	96.15	2.75

Notes: Gr. – group, P – participant.

APPENDIX J. STATISTICS FOR INTERQUARTILE RANGE (IQR) RULE FOR REACTION TIME (MS) FOR TWO AGE GROUPS

Group	Measure	Song with Words	Piano Melody	Violin Melody	Quiet
Older Group	Q1	1773.94	1602.37	1914.97	1982.93
	Q3	2589.45	2563.16	2688.90	2556.48
	IQR	815.51	960.79	773.93	573.56
	LIF	550.68	161.18	754.08	1122.59
	UIF	3812.71	4004.35	3849.79	3416.82
	LOF	-672.59	-1280.00	-406.82	262.25
	UOF	5035.98	5445.53	5010.69	4277.16
Younger Group	Q1	1705.47	1653.82	1549.84	1533.62
	Q3	2035.59	2054.27	2052.71	2061.02
	IQR	815.51	960.79	773.93	573.56
	LIF	482.20	212.64	388.94	673.28
	UIF	3258.86	3495.45	3213.61	2921.36
	LOF	-741.07	-1228.55	-771.96	-187.06
	UOF	4482.12	4936.64	4374.50	3781.69

Notes: Q-1st quartile, Q3-3rd quartile, IQR-Interquartile range (Q3-Q1), LIF-Lower inner fence (Q1-1.5*IQR), UIF-Upper inner fence (Q3+ 1.5*IQR), LOF-Lower outer fence (Q1-3*IQR), UOF-Upper outer fence (Q3+ 3*IQR).

APPENDIX K. STATISTICS FOR INTERQUARTILE RANGE (IQR) RULE FOR ACCURACY OF RESPONSES (RAD.) FOR TWO AGE GROUPS

Group	Measure	Song with Words	Piano Melody	Violin Melody	Quiet
Older Group	Q1	2.33	2.45	2.42	2.39
	Q3	2.75	2.75	2.62	2.62
	IQR	0.42	0.30	0.20	0.23
	LIF	1.70	2.00	2.12	2.04
	UIF	3.38	3.20	2.92	2.96
	LOF	1.07	1.55	1.82	1.70
	UOF	4.01	3.65	3.22	3.31
Younger Group	Q1	2.58	2.45	2.45	2.45
	Q3	2.84	2.75	2.75	2.75
	IQR	0.26	0.30	0.30	0.30
	LIF	2.19	2.00	2.00	2.00
	UIF	3.23	3.20	3.20	3.20
	LOF	1.80	1.55	1.55	1.55
	UOF	3.62	3.65	3.65	3.65

Notes: Q-1st quartile, Q3-3rd quartile, IQR-Interquartile range (Q3-Q1), LIF-Lower inner fence (Q1-1.5*IQR), UIF-Upper inner fence (Q3+ 1.5*IQR), LOF-Lower outer fence (Q1-3*IQR), UOF-Upper outer fence (Q3+ 3*IQR).

APPENDIX L. CORRELATIONS AMONG A SET OF QUESTIONS RELATED TO REACTION TIME (MS) AND ACCURACY OF RESPONSES (RAD.) ACROSS PARTIPANTS IN TWO AGE GROUPS

Condn.	Measure	r	Sig.	r	Sig.	r	Sig.
		QN 1		QN 5		QN 6	
Song with Words	RT	.023	.184	.082	.636	-.206	.228
	Accuracy	-.440**	.009	.287	.094	-.308	.072
Piano Melody	RT	-.095	.589	.020	.907	-.355*	.034
	Accuracy	-.011	.950	.208	.230	.067	.703
Violin Melody	RT	.071	.685	.054	.753	-.315	.062
	Accuracy	-.070	.694	-.241	.163	.121	.489
Quiet	RT	.069	.692	-.232	.173	-.128	.456
	Accuracy	-.216	.220	.154	.378	.355*	.036
		QN 7		QN 8		QN 15	
Song with Words	RT	.276	.103	-.030	.076	-.047	.786
	Accuracy	-.014	.935	.038	.829	-.050	.775
Piano Melody	RT	.113	.513	-.374*	.025	-.017	.920
	Accuracy	.051	.772	.205	.238	-.271	.116
Violin Melody	RT	.121	.483	-.541**	.001	-.147	.393
	Accuracy	-.277	.107	.239	.166	.212	.221
Quiet	RT	.014	.934	-.379*	.023	.105	.542
	Accuracy	.207	.233	.153	.379	-.013	.940

Notes: Condn. – condition, r – Pearson's correlation coefficient, QN – question number, RT – reaction time, ** Sig. – 2-tailed significance level at .01, * Sig. – 2-tailed significance level at .05.

VITA

Sukhada Vaidya Mairal was born in 1983 in Mumbai, India. She received her Master's degree in Physics from University of Pune, India in 2005. She was enrolled at the University of Tennessee into a doctoral program in Speech and Hearing Science in August 2007. She received her doctorate in August 2015.