Development and Validation of a Music-based Attention Assessment for Patients with Traumatic Brain Injury

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UNIVERSITY OF MIAMI

DEVELOPMENT AND VALIDATION OF A MUSIC-BASED ATTENTION ASSESSMENT FOR PATIENTS WITH TRAUMATIC BRAIN INJURY

By

Eunju Jeong

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DEVELOPMENT AND VALIDATION OF A MUSIC-BASED ATTENTION ASSESSMENT FOR PATIENTS WITH TRAUMATIC BRAIN INJURY

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Impairments in attention are commonly seen in individuals with traumatic brain injury (TBI). While attention assessment measurements have been developed rigorously and utilized frequently in cognitive neurorehabilitation, there is a paucity of auditory attention assessment instruments that are ecologically valid and that assess different subtypes of attention. Yet, deficits in auditory attention can severely limit everyday functioning, negatively impact work and personal relationships and compromise personal safety. The purpose of this study was to develop and to investigate the psychometric properties of a Music-based Attention Assessment (MAA) instrument. The MAA is a multiple choice, melodic contour identification test, designed to assess three different types of auditory attention, including sustained attention, selective attention, and divided attention. The MAA was piloted with patients with TBI (n = 15) and healthy adults (n = 30) separately to evaluate preliminary psychometric properties. Both pilot studies reported that the MAA possessed a very high reliability and appropriate item properties. However, the MAA was revised due to a ceiling effect on mean test scores in the healthy adult group.
The revised version of the MAA was administered to healthy adults \((n = 165)\) as well as TBI patients \((n = 22)\) to investigate construct validity, item properties, test reliability, and difference in MAA performance between groups. Here, psychometric validation of the revised version of the MAA is described, and the obtained results reported. Exploratory factor analysis identified five-factor constructs, supporting the different types of attention that underlie the test items of the revised version of the MAA. The factors identified were *Sustained-Short, Sustained-Med to Long, Selective-Noise, Selective & Divided, and Divided-Long*. After item elimination, the finalized 45-item MAA in relation to the identified five-factor constructs provided evidence of high internal consistencies as computed by split-half reliability coefficients \((r = .836)\) and Cronbach’s alpha \((\alpha = .940)\), indicating homogeneity of test items within each of the five subtest as well as for the total test. As predicted, significant differences were found between the healthy adult and TBI patient samples across the exploratively obtained five-factor constructs of the revised version of the MAA. The MAA performance was significantly better in the healthy adult group than in the TBI patient group, except on the Sustained Attention–Short Subtest, indicating pervasive attention impairments in patients with TBI. The finding also suggests that a basic level of sustained attention to deal with a small amount of auditory information during a limited time might be intact for the patients with TBI who have a moderate to severe level of brain injury. The aggregate findings suggest that the MAA is a valid and reliable measure that provides diagnostic information in regards to the three
types of auditory attention deficits frequently observed in patients with TBI. The use of melodic contours in attention assessment is discussed along with limitations of the study and suggestions for future research. The MAA, when used in conjunction with attention assessment instruments in different sensory modalities, would provide a greater level of precision in the attention assessment of patients with TBI, resulting in more symptom specific and individualized rehabilitation and treatment.
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Chapter 1

Introduction

An estimated 1.5 to 2 million people sustain a traumatic brain injury (TBI) each year in the United States (Faul, Xu, Wald, & Coronado, 2010; Langlois, Rutland-Brown, & Thomas, 2006; National Institute of Neurological Disorders and Stroke [NINDS], 2002; Stierwalt, & Murray, 2002). From this population, 80,000 to 90,000 experience significant disabilities following their injury (Langlois et al., 2006). One of the most common complications following TBI is problems with attention which in turn affect every domain of a patient’s functioning (e.g., work, relationships, health, and safety). Accurate diagnosis, immediate treatment, effective rehabilitation, and additional community supports are necessary to achieve maximum recovery.

For TBI-related attention impairments, precise assessment as part of the diagnostic process is particularly crucial for establishing appropriate treatment and effective therapeutic goals. Current attention assessment instruments for patients with TBI, however, are limited and tend to rely on visual discrimination. Of the few tools that apply auditory stimuli, these rely solely upon verbal directions. This study examines the effectiveness of using auditory stimuli in the form of music to discriminate between the various forms of attention deficits observed in patients with TBI. More specifically, this study investigated the psychometric properties of test items and latent factors of a researcher-developed music-based attention assessment (MAA) for patients with TBI.
Attention Impairments Following TBI

TBI is defined as damage to brain tissue caused by an external mechanical force and evidenced by loss of consciousness (LOC), presence of post-traumatic amnesia (PTA), or by objective neurological findings that are attributable to TBI upon a physical or mental status examination (Kashluba, Hanks, Casey, & Millis, 2008). Physical assaults to various brain locations lead to either permanent or temporary impairments in cognitive, socio-emotional and/or sensory-motor domains. These impairments depend on the area of the brain affected, the extent of the brain injury, and the patient’s general health prior to the injury (Arciniegas et al., 2000; Ponsford, Sloan, & Snow, 1995; Putnam, Millis, & Adams, 1996; Scheibel et al., 2007; Stuss, Shallice, Alexander & Picton, 1995). Due to the neural plasticity of the brain, rehabilitation is believed to offer some improvement in functioning even for patients with permanent impairments as a result of TBI.

Cognitive impairments associated with TBI include dysfunctions of attention, memory, and executive functioning, such as decision-making and problem solving skills. Impairments specific to attention are observed as notable decreases in alertness, slowed reaction time, difficulties in completing attention performance tasks (i.e., focused, sustained, selective, alternating, and divided attention), decreases in attention span, and malfunctions of supervisory attentional control (Arciniegas, Held, & Wagner, 2002; Mathias & Wheaton, 2007; Niemann, Ruff, & Kramer, 1996; Park, Moscovitch, & Roberston, 1999; Ponsford, 2008; Ponsford & Willmot, 2004; Stuss et al., 1989).

For these patients, even watching television is a frustrating and confusing experience. Because of the difficulties in gaining and sustaining focus, patients with
TBI understand very little from what they are hearing and seeing. This deficit is also observed when they are talking with someone in a noisy room or are in a room with many people. Because of the inability to attend selectively to what they need to hear, patients with TBI often miss verbal cues and other pertinent information vital to maintaining personal relationships and professional commitments.

Attention-related problems commonly found in patients with TBI are the result of their increased vulnerability to distraction. Patients with TBI perform poorly on attention tasks in the presence of auditory distraction (Kaipio et al., 1999; Kaipio, Cheour, Ceponiene, Ohman, & Näätänen, 2000). Moreover, task-irrelevant or placement of distracting non-target stimuli attract TBI patients’ attention leading to distraction and difficulty in completing target attention tasks (Escera, Alho, Schröger, & Winkler, 2000; Kewman, Yanus, & Kirsch, 1988; Solbakk, Reinvang, & Andersson, 2002).

Previous clinical studies confirm the need for attention rehabilitation following brain injury (Benedict, 1989; Mateer et al., 1990). Attention rehabilitation is possible because of the neural plasticity of the brain. In a study regarding plasticity of the attention networks, Kim et al. (2008) found that rehabilitation training was effective in remediating attention impairment among patients with TBI.

Researchers who have developed and evaluated attention training programs conceive of attention as a paradigm consisting of a number of distinct components (Gauggel & Niemann, 1996; Novack, Caldwell, Duke, Bergquist, & Gage, 1996; Park, Proulx, & Towers, 1999; Posner & Petersen, 1990; Sohlberg & Mateer, 1987; Sturm, Willmes, Orgass, & Hartje, 1997). In attention rehabilitation, treatment varies according
to the levels and types of attention deficits affected (Sturm & Willmes, 1991). The MAA aims to provide diagnostic information in regards to different attention components.

**Current Attention Assessment Measurements**

People with TBI must be able to purposefully focus their attention before they can successfully return to activities of daily life and obtain maximal benefits of therapeutic interventions. Attention assessment, therefore, is a primary step in rehabilitation following TBI (Benedict, 1989; Mateer et al., 1990). Precise diagnostic information in regards to attention abilities of patients helps identify the specific types of attention impairment as well as establish the primary goals and objectives of treatment.

Current attention assessment measurements in neurorehabilitation mostly consist of visual stimuli, including the Letter Cancellation Test (Talland, 1965), Trail Making Test A and B (Reitan & Wolfson, 1985), Stroop Color-Word Test (Stroop, 1935), and Delis-Kaplan Executive Function System Color-Word Interference Test (D-KEFS, Delis, Kaplan, & Kramer, 2001). Auditory stimuli are rarely used, and are mostly limited to numeric information (i.e., number recall, summation of numbers), such as in the Digit Span Test from Wechsler Adult Intelligence Scale Fourth Edition (WAIS-IV, Wechsler, 2008), and Paced Auditory Serial Addition Task (PASAT, Gronwall, 1977). These assessment tools, thus, do not assess adequately the different subtypes of auditory attention that are necessary for functioning in society.

Auditory attention has been defined as an ability to allocate one’s attention appropriately to relevant information from auditory environments (Giard, Fort, Mouchetant-Rostaing, & Pernier, 2000). In this sense, the currently available attention
assessment tools provide little knowledge regarding the breadth of auditory attentional ability. Moreover, current auditory attention assessments do not simulate real-world auditory environments in which there are auditory distractors. Such distractors are needed to challenge the patient’s ability to either attend to one stream of information or shift from one source of information to another. Thus, there is a need for an authentic and a more ecologically valid auditory assessment tool that incrementally challenges and measures patients’ attentional ability.

**Music as Attention Assessment Stimuli**

Music, defined as organized sounds and pauses over time (Radocy & Bolye, 2003), provides an appropriate medium for assessing auditory attention. A relatively moderate amount of information conveyed by music may lead to optimal arousal of the brain. The brain’s reward system evaluates the resulting arousal as a pleasurable experience and endows priority access to music (Berlyne, 1971). Consequently, music can direct and maintain attention based on the priority that is awarded by the brain.

Experimental research has indicated that listening to music activates different types of attention, supporting the potential of music as an effective stimulus to measure attention. First, voluntary as well as involuntary attention occurs during the course of auditory Gestalt formation and auditory scene analysis (Bregman & Campbell, 1971; Carlyon, Cusack, Foxton, & Roberston, 2001; Cusack, Deeks, Aikman, & Carlyon, 2004; Macken, Tremblay, Houghton, Nicolls, & Jones, 2003; Treisman, 1988; Treisman & Gelade, 1980; Van Noorden, 1975). Second, neuroanatomical and behavioral studies provide evidence of the different types of attention given to single and multi-voice music (Bengtsson et al., 2009; Janata, Tillmann, & Bharucha, 2002; Jones, 1984; Satoh, Takeda,
Hatazawa, & Kuzuhara, 2001; Stephan et al., 2002; Snyder et al., 2006). Third, neuroanatomical commonalities have been found between attention to non-auditory stimuli (i.e., visual, tactile) and attention to music (Bengtsson et al. 2009; Janata et al. 2002; Johnson & Zatorre, 2006; Johnson, Strafella, & Zatorre, 2007; Lawrence, Ross, Hoffman, Garavan, & Stein, 2003; Loose, Kaufmann, Auer, & Lange, 2000; Macaluso, Frith, & Drive, 2002; Ortuño et al., 2002; Sarter, Givens, & Bruno, 2001; Satoh et al., 2001; Serences & Yantis, 2007; Stephan et al. 2002; Talsma & Kok, 2001).

The current study addressed different melodic contour tasks that were assumed to reflect three types of attention, including sustained attention, selective attention, and divided attention. When a given task requires an individual to sustain one’s attention over time, one has to maintain that focus during task performance (Cohen et al., 1993; Mirsky et al., 1991; Ponsford, 2008; Sohlberg & Mateer, 1987). When a given task requires an individual to selectively attend to one target sound in the presence of distracting sounds, one has to select relevant information from the surrounding acoustic events while resisting distractors (Cohen et al., 1993; Ponsford, 2008; Sohlberg & Mateer, 1987). Listening to a friend speak while blocking out the traffic noises in the background is an example of selective attention. When a given task requires an individual to split one’s attention between two target sounds, one has to allocate one’s limited attentional resources equally to the simultaneously presented auditory stimuli (Cohen et al., 1993; Sohlberg & Mateer, 1987). These definitions are central to the researcher-developed music-based attention assessment (MAA) where different music listening tasks are associated with the different types of attention.
Statement of the Problem

A precise diagnosis as a part of symptom-specific treatment is considered critical to improving the attentional functioning and well-being of patients with TBI. Clinicians and other professionals use various attention assessment measurements to identify the extent and degree of attention deficits following TBI. However, considering the limitations of the current attention measurements, little relevant knowledge is available in regards to the auditory attention of patients with TBI in a simulated auditory environment where distracting or competing sounds are present. To date, a lack of quantitative measurement tools that assess the auditory attention of patients with TBI has been reported in the fields of music therapy and neuropsychology.

Despite the promise of music stimuli as a diagnostic tool for attention impairments, only a small number of studies have attempted to develop such assessment instruments (Hunter, 1989; Jones, 1986; Kim, 2005; Lipe, 1995; Lipe, York, & Jensen, 2007; Magee, 2007; Rider, 1981; Waldon & Wolfe, 2006; York, 1994, 2000). Presently, only one auditory attention assessment measure, named Music therapy assessment tool for low awareness states (Magee, 2007), has been reported suitable for administration to patients with TBI. Given that this measurement is designed for patients who are in low awareness or vegetative states, the need exists for assessment tools that are appropriate for measuring the attentional ability of patients with TBI who are functioning in the community but have ongoing attentional deficits that interfere with functions.

Therefore, assessment tools that measure the attentional ability of adults with TBI, specifically those who have a moderate to severe level of brain injury severity, are needed. There is also a need for assessment tools that fully measure auditory attention in
a simulated auditory environment where distracting or competing stimuli exist. Lastly, there is a great need for assessment tools that permit professionals who work with individuals with TBI to identify levels and types of auditory attention impairment, and provide appropriate rehabilitation and remediation.

**Purpose of the Study**

The purpose of this study was to evaluate the psychometric properties of a Music-based Attention Assessment (MAA) administered to healthy adults and adult patients with TBI. The MAA is a theoretically based, researcher-developed multidimensional measure designed to assess the following three key components of attention: sustained attention, selective attention, and divided attention.

**Research Questions and Hypotheses**

The following research questions were addressed:

1. What are the latent factor constructs that underlie test items of the MAA?
   
   1-1. Are the factor constructs of sustained attention, selective attention, and divided attention adequately represented by the test items presented in the MAA?
   
   1-2. Which test items are good indicators of each factor construct? Does each factor construct include at least four test items that are unique to the factor construct?

2. What are the item properties and the reliabilities of the MAA, in relation to the exploratively obtained factor constructs?

3. What differences in MAA performance are found between healthy adults and patients with TBI, in relation to the exploratively obtained factor constructs?
The hypotheses for these research questions included the following:

H1: It was predicted that the 54 test items of the MAA would be factored into at least three different factor constructs. It was further predicted that each factor construct would be indicated by at least four test items that are unique to that factor construct.

H2: It was predicted that test items would possess a wide range of item difficulty and fall above the conventional minimum threshold of item discrimination. It was further predicted that the MAA would adequately provide evidence of reliability as computed by split half coefficients and Cronbach’s alpha coefficients.

H3: It was predicted that the scores on each of the exploratively obtained factor constructs would be significantly better in healthy adults than patients with TBI.

**Theoretical Significance of the Study**

The human brain is exposed to a vast amount of information when it is faced with sensory and non-sensory (e.g., feelings, cognitions) stimuli. However, the capacity to process these stimuli is constrained due to limited brain resources. As such, attention allows the brain to select which incoming stimuli are task-relevant and therefore desirable for processing.

A theory that explains attention to music, however, has not yet been fully established in the music psychology and music therapy research literature. While there are several studies addressing the relationship between music and error detection in a performance context, no theory or model describes the relationship between music and attention.

This study examined how the different sub-types of attention are utilized and measured by various music listening tasks. These tasks were created based on previous
studies that reported the effect of the structured use of melodic contours on error/change detection tasks (Byo, 1997; Carlyon et al., 2001; Cusack et al., 2004; Crawley, Acker-Mills, Pastore, & Weil, 2002; Davison & Banks, 2003; Dowling, 1973; Fritz, Elhilali, David, & Shamma, 2007; Fujioka, Trainor, Ross, Kakigi, & Pantev, 2005). Conceptual and experimental evidence in the present study, therefore, contributes to the establishment of a theoretical model that elucidates the relationship between music and attention and supports the use of music as an attention assessment stimulus.

**Practical Significance of the Study**

The development and evaluation process of the MAA will contribute to obtaining initial assessment knowledge regarding auditory attention in an ecological context (i.e., a target sound in the presence of distracting sounds, which more closely approximates the actual environments). The fundamental idea of the current study is to use response to melodic contours as an indicator of different types of attention. More specifically, the study hypothesized that responses to one or more melodic contours would reflect each of the three attention sub-types (i.e., sustained attention, selective attention, divided attention).

Music therapists as well as professionals who work with patients with TBI, such as speech-language pathologists, audiologists, and neuropsychologists, can use the MAA to identify levels of attention impairment and recommend appropriate types of tasks that would assist in attention rehabilitation. In addition, the MAA can contribute to the collection of objective evidence that professionals use to document progress toward therapeutic goals in cognitive rehabilitation.
The MAA is a listening test that utilizes musical stimuli with a minimum level of verbal instruction. The MAA can be administered to measure attention impairments of patients with TBI who have either temporary or permanent difficulty understanding complex verbal instructions as a result of damage to cortical areas responsible for language comprehension. Since current attention assessment measurements involve relatively complex verbal instructions, the attentional ability of patients is often underestimated. Misdiagnosis based on such underestimation is detrimental since it disguises these patients’ underlying disorders resulting in misguided treatments. The MAA, however, requires minimal prerequisite abilities (i.e., intact sensory and perceptual ability to musical stimuli, postural stability) and is therefore useful for a broad range of patients.

The current study also investigates the reliability and validity of a researcher-developed MAA. While it was not the intent of this study to engage in actual music therapy interventions for attention rehabilitation of patients with TBI, the study’s findings can extend the understanding of attention rehabilitation through music for patients with TBI. Earlier findings that attention sub-types to musical and non-musical stimuli are housed by overlapping brain structures provide the rationale for using music listening in order to improve various forms of attention deficits. Different music listening tasks of the MAA can be applied to a broad range of fields, including neuroscience, neurorehabilitation, speech-audiology, and music therapy that aim to aid attention rehabilitation for clinical populations.
Operational Definition of Terms

Assessment. Assessment is a process that relates to diagnosis and subsumes information gathering, awareness of need, observation of behavior, and program planning (Cohen & Gericke, p. 162).

Sustained attention. Sustained attention is an ability to continuously maintain an individual’s focus on external stimuli relevant to a given task.

Selective attention. Selective attention is an ability to focus on target stimuli when presented with other distracting stimuli.

Divided attention. Divided attention is an ability to track two different stimuli simultaneously to obtain relevant information that is coming from both sources.

Attention to music. In this study, attention to music is considered the same as attention to auditory stimuli. Auditory attention has been defined as an ability to allocate one’s focus appropriately to relevant information from auditory environments (Giard et al., 2000). When a given task requires an individual to selectively attend to one target sound in the presence of distracting sound, one has to select relevant information from the surrounding acoustic events while resisting distractors. When a given task requires an individual to split one’s focus over two or more target sounds, one must allocate limited attentional resources equally to the simultaneously presented auditory stimuli.

Melodic contours. Melodic contours refer to the shape of melody, or course changes in pitch positions (Levitin, 1999). In the current study, melodic contours include three different directions, including ascending (i.e., up), stationary (i.e., same), and descending (i.e., down).
**Organization of the Dissertation**

The role of musical stimuli in diagnosing the three types of attention deficits observed in patients with TBI is examined from both a conceptual as well as an experimental perspective. The literature review in chapter 2 is divided into four sections. The first section explores how attention has been defined in the literature and describes the various types of attention as well as the role of attention in human information processing. The neuroanatomy of the three types of attention is also presented. The second section presents several perspectives that address the complex nature of attention response to musical stimuli. The empirical research on the neuroanatomy of the three types of attention to music is summarized, followed by studies measuring behavioral responses to single/multi-voice music. This section also includes a description of neuroanatomical commonalities between attention sub-types to nonmusical stimuli and attention sub-types to musical stimuli. The third section presents specific information regarding attention impairments following TBI, including definition, neuropathology, and specific symptoms of attention deficits. Current attention assessment tools are reviewed, followed by a discussion concerning their limitations. Finally, the fourth section reviews music-based assessment tools used in the field of neuropsychology and music therapy along with the need to develop and validate a music-based attention assessment that is appropriate and specific to the needs of patients with TBI.

Chapter 3 describes the development, evaluation, and validation process of the researcher-developed MAA. The procedures followed during measurement development are presented and issues surrounding test development are discussed. Recruitment strategies, measures, equipment used and testing procedures are also explained.
Chapter 4 provides descriptive statistics in regards to demographic information, scale and item characteristics, and resultant factors of exploratory factor analysis.

The final chapter, Chapter 5, is a discussion of the findings of this study. The dissertation closes with suggestions for future research and implications for music therapists and other professionals are given.
Chapter 2

Review of the Literature

This chapter will review the literature that is relevant to attention impairments following Traumatic Brain Injury (TBI) and, as well, how musical stimuli can be used to provide diagnostic knowledge in assessing attention deficits. The role of musical stimuli in diagnosing the three types of attention deficits common in patients with TBI will be examined from both a conceptual as well as experimental perspective. The literature presented here is organized according to the following topics: (a) attention, (b) attention to music, (c) attention impairments following TBI, and (d) music-based attention assessment.

Attention

Definition

The term *attention* is used to describe a broad range of cognitive functions necessary for information processing. Due to its breadth, attention has been given different definitions in different fields of study (Luck & Vecera, 2002). One of the first psychological definitions of attention was established by William James (1890). He described attention as a focalization or concentration of mind used to deal effectively with one stimulus over another (James, 1890).

From the perspective of cognitive psychology, attention is a vital mental function that enhances perception and cognitive processing due to the limited capacity of the brain (Luck & Vecera, 2002). The human brain is exposed to a vast amount of sensory and
non-sensory stimuli. However, the amount of information one can attend to and the duration during which information can be maintained varies depending on an individual’s attention capacity (Schneider & Shiffrin, 1977). According to Miller (1956), the amount of information that an individual can attend to in one exposure is between five and nine items and these items can be held for only 3 to 5 seconds.

More recently, neuropsychologists have posited that attention is necessary due to the finite capacity of the brain to direct neural processing resources toward exogenous and endogenous information. Attention is used to allocate neural resources appropriately toward incoming information in accordance with one’s goals (Cohen, Sparling-Cohen, & O’Donnell, 1993; Driver & Mattingley, 1995; Purves et al., 2008). For the current study, attention is defined as an ability to sustain focus over time, to focus selectively on a target against a distractor, and to allocate brain resources equally to simultaneously presented stimuli in a goal-oriented manner.

Mechanisms of Attention

This section offers descriptions of attention involved in two modes of information processing: bottom-up and top-down (Buschman & Miller, 2007; Fritz, Elhilali, David, & Shamma, 2007; Jonides & Yantis, 1988; Müller & Rabbitt, 1989; Neisser, 1976; Robinson & Kertzman, 1995; Theeuwes, 2008). The bottom-up mode appears at the beginning stage of sensory perception. Here, the hard-wired sensory system in the brain prioritizes stimulus properties, such as saliency and novelty (Fritz et al., 2007; Van Zoest, Donk, & Theeuwes, 2004). The incoming stimulus automatically captures one’s attention in a pre-attentive manner; hence, this type of attention is interchangeably referred to as involuntary, or exogenously-driven attention (Jonides & Yantis, 1988; Müller & Rabbitt,
1989; Robinson & Kertzman, 1995). This strategy is in contrast to the top-down mode of information processing.

The top-down mode occurs at the higher level of information processing. When sensory information is projected to higher cognitive processes, an individual’s knowledge, goals, intentions, and/or expectations filter out task-irrelevant sensory information. This type of voluntary or endogenously-driven attention helps an individual maintain goal-directed behaviors (Neisser, 1976).

Exogenously- and endogenously-driven attention interact in a reciprocal and complementary manner (Cohen et al., 1993; Hopefinger & West, 2006; Legrain et al., 2009; Peelen, Heslenfeld, & Theeuwes, 2004). Recent event-related potentials (ERP) studies demonstrate how involuntary and voluntary attention enhance one another and work synergistically during information processing (Hopefinger & West, 2006; Peelen et al., 2004). In a line of studies that supported cooperation between these two modes of attention, Legrain et al. (2009) demonstrated how the two types of attention complement each other (see Figure 2.1). According to Legrain et al.’s model, bottom-up attention is driven by saliency and novelty of stimuli to which the brain gives priority access for a higher level of information processing (i.e., short term memory, long term memory).

In contrast, top-down attention is directed by the goal of a given task. The brain first determines the relevance of the stimuli and then decides whether to select or inhibit the stimuli. The brain activates a selection mechanism for the relevant stimuli, while it simultaneously activates an inhibition mechanism for the irrelevant stimuli. Top-down attention also contributes to computing the amount of neural resources to be invested. As
the relevance of stimuli to a given task increases, the brain decides to allocate more attention resources to those stimuli (Legrain et al., 2009).

Musical stimuli used to create different types of music listening tasks in the current study were considered to utilize two mechanisms of attention (i.e., top-down, bottom-up). Musical stimuli used were external sensory stimuli and were perceived through bottom-up information processing. Individuals, further, process the perceived stimuli in accordance with goals of given music listening tasks, utilizing top-down information processing.
Types of Attention

This section reviews the different types of attention from a multifaceted approach. In his theoretical framework describing attention, Cohen et al. (1993) categorized attention into four types depending on task demands and stimulus characteristics. The types included focused attention, sustained attention, selective attention, and divided attention. Focused attention refers to the ability to direct one’s consciousness to stimuli for a relatively short period of time. When the task requires persistent attention over a relatively long period of time, sustained attention is necessary in order to maintain one’s focus on a given task. Selective attention is the ability to put priority on one stimulus over others. As the number of information sources increases, the ability to deal with multiple sources by splitting the focus of attention over multi-stimuli is required. Cohen et al. (1993) called this ability divided attention.

Mirsky, Anthony, Duncan, Aheam, and Kellam (1991) provided statistical support for their own subgrouping of the attention types. The four components of attention that functioned independently were focus_execute, sustain, shift, and encode. The focus_execute component referred to the ability to select target information from sensory environments and respond appropriately. The sustain component denoted the ability to maintain focus over time; while the shift component required additional effort to change the focus in a flexible manner. Finally, the encode component included the necessary ability to register and manipulate information sequentially during mental processes.

Additionally, Mirsky et al. (1991) investigated latent factors that corresponded to each of the four components of attention previously defined. Results of the study revealed
that the attention batteries concerning perceptual-motor speed identified the focus-execute component. The batteries aiming to measure vigilance identified the sustain component, while those measuring mental flexibility identified the shift component. Finally, the batteries using a numerical-mnemonic method were found to be related to the encode component.

Further, Mirsky et al. (1991, p. 126) suggested a visualized map of specific neural structures associated with each of the four components of attention (Figure 2.2). According to the authors’ neural model of attention, the multiple brain regions communicated in a reciprocal manner to modulate the focus-execute component, including the inferior parietal, superior temporal, and striatal regions. The lower part of the brain mediated the sustain component, including brain stem (i.e., the tectum, mesopontine, and reticular formation) and the thalamus. Relatively higher parts of the brain mediated the shift component, including the prefrontal cortex, medial frontal cortex and anterior cingulate gyrus. Finally, the hippocampus and amygdala, which were known to be responsible for the initial process of information storage, controlled the encode component (Mirsky et al., 1991).
Figure 2.2. Neuroanatomical model of attention adapted from Mirsky et al. (1991)

The neurorehabilitation literature described similar concepts concerning the different types of attention, but used different terminology. Ponsford (2008) demonstrated a neural model of attention consisting of an arousal-sustained system, sensory-selective system, and intentional control system. According to her research-based definition, the arousal-sustained subsystem controls the level of arousal and vigilance while detecting stimulus saliency. The sensory-selective subsystem orients, engages/disengages, and recognizes objects. The intentional control subsystem establishes strategies and manipulates information.

Ponsford (2008) also proposed neurological networks specific to each of the three systems of attention. The lower to mid-brain regions involved the modulating arousal-sustained system, including the reticular formation and limbic structures. The parieto-temporo-occipital areas mediated the sensory-selective system. Broader regions of the
brain were responsible for the intentional control system, including the frontal lobe, anterior cingulate cortex, and the basal ganglia in conjunction with the thalamus. These three systems of attention provided a neurologic basis for attention rehabilitation in TBI.

In the field of cognitive neurorehabilitation, researchers have established a hierarchy of attention (Baron, 2004; Sohlberg & Mateer, 1987). They view attention as a multidimensional capacity, by way of a hierarchy that includes five subtypes: focused, sustained, selective, alternating, and divided attention. Focused attention is an ability to respond discretely to sensory stimuli in specific modalities. Sustained attention is required to maintain a consistent behavioral response during continuous or repetitive activity (Sohlberg & Mateer, 1987). The remaining three types of attention are necessary when two or more stimuli are present. Selective attention is an ability to maintain a cognitive set which requires activation or inhibition of response depending on the types of stimuli, either task-relevant or task-irrelevant. When two or more tasks are given, mental flexibility, called alternating attention, is required to shift one’s sustained attention from one task to another. Finally, divided attention refers to an ability to respond simultaneously to multiple tasks (Sohlberg & Mateer, 1987).

**Summary.** The types of attention varied from one another, but also possessed particular commonalities (Cohen et al., 1993; Mirsky et al., 1991; Ponsford, 2008; Sohlberg & Mateer, 1987). By definition, sustained attention and selective attention were common to each model of attention. Sustained attention (Cohen et al., 1993; Sohlberg & Mateer, 1987), sustain component (Mirsky et al., 1991), and arousal-sustained subsystem (Ponsford, 2008) shared the same conceptual foundation. Likewise, selective attention (Cohen et al., 1993; Sohlberg & Mateer, 1987), focus-execute component (Mirsky et al.,
1991), and sensory-selective subsystem (Ponsford, 2008) were similar to each other. However, focused attention (Cohen et al., 1991, Sohlberg & Mateer, 1987), shift component/alternating attention (Mirsky et al., 1991; Sohlberg & Mateer, 1987), intentional control (Ponsford, 2008), and encode (Mirsky et al., 1991) were unique to their respective models.

In addition to commonalities in terminology, neuroanatomical commonalities were found. The lower- to mid-brain areas were responsible for controlling the sustain component (Mirsky et al., 1991; Ponsford, 2008). The intercommunication and the polysensory association areas of each sensory cortex were involved in modulating the focus-execute component (Mirsky et al., 1991) and the sensory-selective system (Ponsford, 2008). The anterior cingulate cortex and prefrontal cortex mediated the ability to manipulate information that came from two or more resources in accordance with one’s intention, including alternating attention (Sohlberg & Mateer, 1987), shift and encode components (Mirsky et al., 1991), and intentional control (Ponsford, 2008). These combined findings supported the multidimensional nature of attention and confirmed the existence of at least three to five types of attention.

The current study emphasized neuroanatomical commonalities among different components and types of attention by focusing on three types of attention: sustained attention, selective attention, divided attention. The selection of the first two components/types of attention was supported by earlier research demonstrating their neuroanatomical commonalities (Mirsky et al., 1991; Ponsford, 2008). Additionally, divided attention was selected for inclusion in this study because it is representative of the intentional control component of attention (Ponsford, 2008). Divided attention refers
to the ability to allocate brain resources equally to multiple-layered stimuli and is mediated by the prefrontal and anterior cingulate cortices. In addition, divided attention is more frequently used than alternating attention in order to describe a mental effort assigned to more than two stimuli/tasks (Adcock, Constable, Gore, & Goldman-Rakic, 2000).

The three components of attention excluded from the present study included focused, shift/alternating, and encode. First, focused attention was excluded because focused attention is related to involuntary responses to external stimuli (i.e., sensory orientation) (Sohlberg & Mateer, 1987), and the present study measured voluntary responses only. Also, considering that the MAA was designed for patients who have a moderate to severe level of brain injury, focused attention does not match with their level of attentional function. Second, the encode component was more related to mnemonic capacity, such as manipulation, registration, and recall of information. Since the purpose of this study was to measure the different types of attention, the encode component was excluded because it does not address the topic of the study.

Third, the shift/alternating type was eliminated because it related to the ability to shift one’s attention from one stimulus or task to another to perform a given task. Thus, an individual was required to attend consecutively to two stimuli/tasks by taking turns. For example, when two tasks are given and an individual is asked to alternate between the tasks, the individual determines the priority and selects task A, and sustains this focus over time. At some point, the individual needs to switch that focus from task A to task B and sustain the focus for a while until both tasks are complete. This attention sub-type was considered an ability of mental flexibility to control both sustained attention and
selective attention. Moreover, Lipscomb (1996) stated that divided attention and alternating attention in music listening are identical. Due to the complex nature of this attention type, this attention type was not included in this study.

The following language is used to identify the attention sub-types explored in this study: (a) the term sustained attention, housed by the lower to mid-brain regions, is used in place of the term arousal-sustained, (b) the term selective attention, housed by the poly-sensory association areas, includes sensory-selective and focuse-execute, and (c) the term divided attention, housed by the anterior cingulate and prefrontal cortices, subsumes shift component, alternating attention, and intentional control. The following section provides definitions regarding the three types of attention explored in this study and summarizes the neural regions activated during each type of attention using non-auditory stimuli.

**Neuroanatomical Evidence of Attention**

This section reviews the specific neural regions activated in response to each of the three types of attention explored in this study. Studies cited in this section used non-auditory stimuli; however, auditory stimuli were used in bimodal conditions (e.g., where two types of sensory stimuli were presented simultaneously, in other words bisensory stimulation) of some parts of the following studies.

**Sustained attention.** Sustained attention is defined as an ability to detect sensory stimuli that occur over time and to maintain behavioral response during continuous activity (Cohen et al., 1993; Koelega, 1996; Mirsky et al., 1991; Ponsford, 2008). This type of attention represents a fundamental function that influences the efficacy of higher
levels of attention (e.g., selective attention, divided attention) and of cognitive capacity in general (e.g., learning and memory).

A broad range of brain regions are known to modulate sustained attention. In support of this general idea, Sarter, Givens, and Bruno (2001) proposed a schematic model of sustained attention. Central to their model are three neural circuits that modulate sustained attention performance in the brain. The first system is a sensory perception system. The second and third systems are the anterior- and posterior-attention systems. The posterior attention system includes neural structures around parietal areas (i.e., the fronto-parietal) while the anterior attention system includes neural structures around frontal areas (i.e., the medial frontal- and dorsolateral prefrontal-cortices) (Sarter et al., 2001).

From both bottom-up and top-down aspects, this model indicates that a variety of neural structures intervene during sustained attention performance. First, sensory stimulation and its projection to the thalamus and basal forebrain via noradrenergic pathways mediate arousal states. Arousal was distinguished from the more global term of sustained attention. However, the aroused states in the thalamus and forebrain are sufficient to sustain attention performance, which requires the ability to maintain focus on given stimuli while performing a task. Second, activation of the thalamus and basal forebrain leads to activation of the fronto-parietal regions via corticopetal cholinergic pathways. Activations of the two neural structures, such as the thalamus and basal forebrain, modulate the bottom-up aspect of sustained attention. Third, the cholinergic corticopetal projection, in turn, activate the medial frontal and dorsolateral prefrontal cortices. The prefrontal activations involve top-down aspect of sustained attention and
regulated the conscious effort to hold and monitor the perceived stimuli (Sarter et al., 2001).

Using functional magnetic resonance imaging (fMRI), Lawrence, Ross, Hoffman, Garavan, & Stein (2003) examined the neural structures that mediate sustained attention performance. Twenty-five participants performed a rapid visual information processing (RVIP) task where target sequences of numbers (e.g., 2–4–6, 3–5–7, or 4–6–8) were embedded into a randomly selected series of numbers and participants were asked to press a keyboard at detection of a target sequence (Lawrence et al., 2003).

Results revealed that two independent neural circuits were involved during task performance. One group of brain structures was positively activated, including the frontal, parietal, occipital, thalamic, and cerebellar regions. The other group, which showed deactivation, included the anterior and posterior cingulate, insula, and the left temporal and para-hippocampal gyrus (Lawrence et al., 2003).

The activations found in the first group indicated that sustained attention and working memory were involved in the task performance. The decreased activities observed in the second group revealed a process to inhibit task irrelevant stimuli. The authors concluded that the two independent neural circuits might point to the involvement of sustained attention and selective attention (Lawrence et al., 2003).

In summary, sustained attention is the most fundamental type of attention and necessary for attention performance requiring higher and more complex attention capacity. As suggested by Sarter et al. (2001) various subcortical as well as cortical structures mediated sustained attention performance. Activations in broad brain regions indicate that sustained attention is essential no matter what the given attention task might
be. Additionally, research findings (Lawrence et al., 2003) support the idea that sustained attention was the earliest and the most fundamental type of attention process. This view was consistent with theoretical studies of attention sub-types where the authors claimed that sustained attention was subjacent to higher levels of attention (Cohen et al., 1993; Mirsky et al., 1991; Ponsford, 2008; Sohlberg & Mateer, 1987).

**Selective attention.** Selective attention is defined as an ability to selectively attend to task-relevant stimuli while ignoring task-irrelevant or distracting stimuli (Cohen et al., 1993; Ponsford, 2008; Sohlberg & Matter, 1987; Van Zomeren & Brouwer, 1994). Two assumptions have been proposed in regards to the neuroanatomical structures that mediate selective attention performance. In general, it is assumed that two independent groups of brain regions modulate selective attention performance: selection of relevant stimuli and inhibition of irrelevant stimuli. In addition, it is assumed that brain activation would be modality-specific. However, modality-independent attention, which controls sensory information transmitted from each modality-specific sensory cortex, would exist regardless of stimulus type. These assumptions were investigated using uni- and bi-sensory stimulations.

Talsma and Kok (2001) investigated selective attention performance under different sensory stimulations. Healthy participants were presented with: (a) one stimulus type, either visual or auditory stimuli (i.e., unisensory stimulation), and (b) both stimulus types in a simultaneous manner (i.e., bisensory stimulation). Visual stimuli consisted of square-wave gratings where sets of a white horizontal bar and an adjacent black bar were presented with varied cycles. Auditory stimuli consisted of sine waves ranging from 900 Hz to 2000 Hz. Target stimuli included visual and auditory stimuli of varying width (i.e.,
narrower or wider bar length) and of varying time duration (i.e., shorter or longer tones). The participants were instructed to press a button when target stimuli were detected from a pre-determined side (i.e., left or right). ERPs were recorded while participants were presented with random trials of visual or/and auditory stimuli.

The ERP findings of unisensory stimulation revealed that negativity at the occipital areas was activated by visual stimuli. The negativity was strongest at detection of target stimuli from the attended channel as compared with detection of target stimuli from the unattended channel and non-target stimuli from the attended channel. Specific to auditory stimuli, early enhanced negativity as shown in amplitude was observed at the lateral part of the auditory cortex. This temporal negativity was more delayed and involved broader brain regions than visual stimuli, including the inferior medial frontal areas, the anterior cingulate, and the right prefrontal cortex (Talsma & Kok, 2001).

Comparison of responses to bisensory stimulation revealed that the negativity, that is, a negative-going wave after the onset of stimulus, was more significantly delayed in bisensory stimulation than unisensory stimulation. The mean amplitude at the medial inferior occipital areas was significantly stronger in the bisensory than the unisensory stimulation and in the attended than the unattended channel (Talsma & Kok, 2001).

Given that ERP negativity is typically interpreted as detection of distracting sounds or violation of a learned scheme, the findings indicated the following. First, specific brain regions were associated with different sensory modalities. That is, the occipital areas were activated by visual stimuli while the temporal areas were stimulated by auditory stimuli. Second, broader brain regions were involved in auditory stimulus processing and, thus, more processing time was needed for auditory stimuli. Lastly, when
visual and auditory stimuli were presented simultaneously (i.e., bisensory stimulation), the medial inferior occipital areas, known as the poly-sensory areas, were activated. The authors concluded that there existed sensory integration areas, such as poly-sensory association cortices, that control sensory information transmitted from modality-specific sensory cortices brain areas, suggesting a modality-independent selective attention control (Talsma & Kok, 2001).

Macaluso, Frith, and Drive (2002) investigated the underlying neural substrates of selective attention that were directed to different spatial locations and stimulus modalities. Two types of sensory stimuli were presented either separately (i.e., unisensory stimulation) or simultaneously (i.e., multisensory stimulation). Visual stimuli consisted of red flashing lights presented to eye fields, and tactile stimuli consisted of 30 Hz vibrations delivered to the thumb. Target stimuli were longer in terms of duration than non-target stimuli. Participants responded verbally when they detected target stimuli from a pre-determined side. Positron emission tomography (PET) and regional cerebral blood flows (rCBF) were recorded throughout trials (Macaluso et al., 2002).

Results showed that unisensory stimulation led to neural activations specific to sensory modality. The superior occipital gyrus was activated during visual stimulation, while the superior post-central gyrus was activated during tactile stimulation. Bisensory stimulation, on the other hand, activated the intra-parietal sulcus, known as the poly-sensory areas. These findings indicated that neural structures involved in selective attention were modality-specific. However, there existed common neural structures that mediated spatial attention regardless of stimulus modality (i.e., inter-modal spatial selective attention) (Macaluso et al., 2002).
Continuing the line of study that supported multiple neural mechanisms of selective attention, Serences and Yantis (2007) conducted an fMRI study to investigate how three sub-types of attention (i.e., sustained attention, selective attention, and attention shift) were housed by different neural structures. Participants pressed a button when they detected target stimuli while maintaining and shifting visual focus from the left and then to the right, or vice versa. Visual stimuli consisted of a series of letters in various colors presented simultaneously to each eye field, while target stimuli consisted of the letters colored in red or green.

Results revealed that multiple brain areas were activated during the task performance. The occipital areas were activated during sustained attention to target and non-target stimuli as well as selective attention to target stimuli. The parietal and prefrontal areas were activated during selective attention and voluntary attention shifts. The findings indicated that the occipital areas were involved in both sustained and selective attention performance using visual stimuli. Parietal and prefrontal areas mediated selective attention performance and attention shift (Serences & Yantis, 2007).

In summary, the findings confirmed the two assumptions in regards to selective attention performance. First, Lawrence et al. (2003) supported the theoretical definition established by Van Zomeren and Brouwer (1994). Two groups of neural structures were found to mediate selective attention performance, indicating selection of task-relevant stimuli and inhibition of task-irrelevant stimuli. Second, the three experimental studies (Macaluso et al., 2002; Serences & Yantis, 2007; Talsma & Kok, 2001) supported the idea of sensory-specific brain regions. Their findings point to the existence of common
brain regions among stimulus types that are responsible for selective attention performance.

**Divided attention.** Divided attention is defined as an ability to deal with two or more sources of stimuli presented simultaneously, which is necessary to perform multiple tasks (Cohen et al., 1993; Sohlberg & Mateer, 1987; Williamson, Scott, & Adams, 1996). Posner and DiGirolamo (1998) stated that divided attention is related to one’s ability to allocate attentional resources optimally to different sets of stimuli or tasks by splitting the locus of attention. The attentional locus can be divided according to spatial locations, stimulus features, and sensory modalities (Braun, 1998).

Researchers have investigated whether neural mechanisms exist that are specific to divided attention. In an fMRI study, Loose, Kaufmann, Auer, and Lange (2000) investigated the brain areas activated during selective attention and divided attention. Participants were exposed to three conditions in which visual and auditory stimuli were presented simultaneously: (a) auditory selective attention, (b) bimodal divided attention, and (c) visual selective attention. Visual stimuli consisted of a series of dots and crosses with a randomly embedded target (i.e., a four cross pattern). Auditory stimuli consisted of two tones that alternated between high and low frequency with a randomly embedded target (i.e., two same-pitched tones).

Results revealed the existence of neural structures specific to divided attention. Consistent with previous findings (Macaluso et al., 2002; Serences & Yantis, 2007; Talsma & Kok, 2001), the brain regions were modality-specific in the selective attention condition. Auditory stimuli led to bilateral brain activation in the primary auditory cortex, while visual stimuli activated the visual, inferior parietal, and dorsolateral prefrontal
cortices. In the divided attention condition, the brain regions activated were similar to the regions activated in the selective attention condition. However, the divided attention performance evidenced greater activation in the prefrontal areas and deactivation in the sensory areas. The deactivations in the sensory areas were thought to be due to the limited capacity of the brain to deal with more challenging tasks that use simultaneously presented stimuli. The authors concluded that the prefrontal cortex played an important role in mediating divided attention performance (Loose et al., 2000).

Johnson and Zatorre (2006) examined neural bases of bimodal selective and divided attention performance. Participants were subjected to four conditions where in novel melodies and geometric shapes were presented simultaneously: (a) selective attention to the melodies, (b) selective attention to the shapes, (c) divided attention to both stimuli, and (d) baseline with no stimulus presentation. Functional magnetic resonance imaging (fMRI) was recorded in each of the four conditions and memory tests followed to validate the behavioral responses after sensory stimulations.

Results showed that brain activations were modality-specific in selective attention performance. Selective attention performance to auditory stimuli activated the primary auditory cortex, while those to visual stimuli activated the primary visual cortex. Divided attention performance to both types of stimuli activated the left dorsolateral prefrontal cortex (Johnson & Zatorre, 2006). Johnson et al. (2007) confirmed the findings of Johnson and Zatorre (2006) in a follow-up study that examined the role of dorsolateral prefrontal areas in bimodal divided attention.

In summary, the aggregate findings in regards to the neural basis of divided attention performance (Johnson et al., 2007; Johnson & Zatorre, 2006; Loose et al., 2000)
concluded that brain activations were specific to the sensory modality. The regions of activation varied by the goals and demands of the given tasks; however, the commonly activated areas in divided attention performance were the dorsolateral part of the prefrontal cortex.

**Attention to Music**

This section explains how musical elements activate attention. Literature relevant to musically induced attention is reviewed from a theoretical and experimental perspective. Beginning with the definition of auditory attention, this section integrates the conceptual frameworks of music and attention. Neuroanatomical evidence of the three types of attention to music is presented along with a description of behavioral responses to single/multi-voice music. Lastly, commonalities in terms of neuroanatomical functions between attention to nonmusical and musical stimuli are summarized.

**Auditory Attention**

Auditory stimuli activate attention in a similar manner to the processing of visual and tactile information. The definition of auditory attention focuses on selectivity. Because of the distracting and competing nature of auditory stimuli, Giard, Fort, Mouchetant-Rostaing, and Pernier (2000) defined this sensory-specific attention as an ability to select task-relevant information from surrounding acoustic events while resisting distractor stimuli. In a more recent study, Fritz, Elhilali, David, and Shamma (2007) defined auditory attention as an ability to attend selectively or to alternate one’s focus on acoustic events from the auditory environment. For the current study, the definition of auditory attention, which is the ability to select relevant information from a
complex auditory environment, could be used to explain attention to music, since musical stimuli can be thought of as well-organized auditory stimuli.

**Music and Attention**

In the book *Aesthetics and Psychobiology*, Berlyne (1971) emphasized the role of art in attention activation. He stated that the properties of art stimuli, such as psychophysical, collative, and ecological, are perceived by the hard-wired brain system (Berlyne, 1971). These properties arouse the reticular formation in the brain stem, which is the part of the brain attention system that screens task-irrelevant information from auditory environments. The current study used musical stimuli that are temporally organized tones over time and convey psychophysical properties of music that have arousal potential. Berlyne’s (1971) statements concerning art experiences from the psychobiological perspective, thus, provided support for the use of musical stimuli to trigger the attention system in the brain and, as well, to measure the brain function associated attention ability.

Huron (1992) has also described continuously changing features in music that contribute to directing and maintaining a focus of attention. Analysis of numerous piano compositions revealed that changes in dynamics of musical passages (i.e., gradual increases followed by a sudden decrease) and textural density in musical texture (i.e., addition of lyrics to the texture) were effective for drawing passive attention and eliciting orienting responses in listeners (Huron, 1992). His study, further, illustrated a “ramp archetype” of musical elements that use a sufficient strategy to direct and maintain a relatively constant stream of auditory attention.
According to Huron’s illustration, some patterns in terms of changes in musical texture are structured into a sequence of stimulus “ramps.” This ramp archetype leads to the optimal rate of changes that contribute to maintaining interest and attention of the audience. The changing features in music elements, such as intensity and musical texture, play an important role in activating attention (Huron, 1992). Huron’s (1992) model of the ramp archetype could be extended to other musical elements, such as rhythm and melody.

**Auditory Gestalts and Auditory Scene Analysis**

Auditory Gestalts and auditory scene analysis are the main concepts used to explain how attention is triggered by musical stimuli. According to Bregman and his colleagues (Bregman, 1999; Bregman & Campbell, 1971; Bregman & Dannenbring, 1973), individuals are programmed to organize sounds into perceptually meaningful units called auditory Gestalts. As the formation of auditory Gestalts is continuously maintained over time, individuals tend to establish separate sound streams. This phenomenon is called auditory scene analysis or sound stream segregation. The purpose of forming auditory Gestalts and separate sound streams is to process musical sounds that come from different locations and consist of various psychoacoustic properties (Bregman, 1999).

The formation of auditory Gestalts from complex auditory environments follows the laws of Prägnanz, such as proximity, similarity, common direction, closure. More specifically, frequency, sound location, and timbre are the main factors that contribute to this phenomenon (Deutsch, 1982). In addition, sound stream segregation is primarily caused by primitive grouping, which is determined by stimulus properties. For example, according to Deutsch (1982), a series of tones that are close in proximity of time, spatial location, and intensity are likely to form a single stream.
Without the formation of auditory Gestalts and auditory scene analysis, people would fail to process musical and nonmusical stimuli, such as speech, when exposed to situations in which multiple sources produce similar sounds. The “cocktail party effect” introduced by Cherry (1953) illustrates the selective nature of auditory attention. The effect describes how people at a party are able to separate relevant information from multiple sound sources and maintain their conversations (Cherry, 1953).

According to Cherry, certain aspects of the physical properties of sounds, such as speech tempo, voice quality, and accents, can direct auditory attention. More recently, Snyder and Alain (2007) described auditory scene analysis as a phenomenon where two or more competing sounds that differ by at least one acoustic attribute are perceived as separate sound streams. Psychoacoustic properties in music play a critical role in establishing separate sound streams in a similar way as in speech processing.

**Auditory Scene Analysis in Polyphonic Music**

Auditory scene analysis involved in music listening is more complex than that used for speech comprehension. The “cocktail party” situation requires mostly selective auditory attention. However, listening to music necessitates the use of various attention types. For example, individuals might perceive musical sounds as a single stream, multiple streams, or as an integrated flow of all components in order to understand the meaning of polyphonic music. Bigand, McAdams, and Forêt (2000) proposed five strategies for analyzing the acoustic scene of polyphonic music. The strategies included: (1) obligatory integration, (2) divided attention, (3) figure-ground, (4) attentional switching, and (5) voluntary integration.
In the “obligatory integration” strategy, an individual combines multi-streams of polyphonic music into one stream. In the “divided attention approach,” individuals split their attention between multi-voices of polyphonic music. The “figure-ground” approach describes individuals who are not able to attend to the individual voices in a multi-voice environment. Instead, these individuals listen to polyphonic music based on the overall figure-ground relationship, which is the core of Gestalt principles of perceptions. So, any changes or errors from an unattended voice can be detected based on the relationship (Bigand et al., 2000). The “attentional switching” strategy is where individuals analyze polyphonic music by alternating their focus among multi-voices. “Voluntary integration” is a perceptual strategy in which individuals form a coherent overall pattern in order to compensate for the limited processing capacity resulting from splitting attentional focus (Bigand et al., 2000).

The different strategies of listening to polyphonic music can be matched with different attention sub-types. For example, the divided attention approach explains divided auditory attention involved in listening to multi-voice music. The figure-ground, and voluntary integration approaches demonstrate divided as well as selective auditory attention involved in polyphonic listening. Lastly, the attentional switching approach is an example of alternating auditory attention. Therefore, listening to multi-voice music can be used to trigger different types of attention.

**Attention and Auditory Scene Analysis**

Attention is intricately involved in auditory scene analysis. Until recently, it was thought that auditory scene analysis occurred without focal attention or conscious control (Bregman & Campbell, 1971; Macken, Tremblay, Houghton, Nicolls, & Jones, 2003;
Van Noorden, 1975). However, a group of researchers who argued that focal attention was necessary for auditory scene analysis (Carlyon, Cusack, Foxton, & Roberston, 2001; Cusack, Deeks, Aikman, & Carlyon, 2004; Fritz et al., 2007; Treisman, 1988; Treisman & Gelade, 1980). The role of attention in auditory scene analysis is key to understanding how individuals perceive and recognize the meaning of music (Bregman, 1999; Deutsch, 1982).

Three recent studies examined the role of attention in auditory scene analysis (Carlyon et al., 2001; Cusack et al., 2004; Macken et al., 2003). These studies used a repeating ABA pattern where the frequency separation and the presenting rate between two notes (i.e., low tones A, high tones B) were varied. The three studies showed conflicting results.

Macken et al. (2003) reported that auditory scene analysis could occur preattentively. In contrast, Carlyon et al. (2001) and Cusack et al. (2004) postulated that focal attention or conscious control was necessary to detect differences in frequency separation and in presentation rate, while establishing separate auditory streams. Such behavioral findings support the critical role of both involuntary and voluntary auditory attention in establishing separate sound streams (Carlyon et al., 2001; Cusack et al., 2004; Macken et al., 2003).

A recent neurophysiological model provided a solution for the conflict. In an ERP study, Snyder, Alain, and Picton (2006) investigated the effects of attention on auditory scene analysis. Participants listened to ABA patterns consisting of two alternating tones that differed by frequency (i.e., attended condition) and watched a muted movie on a screen while attempting to ignore the ABA patterns presented simultaneously (i.e., ignore
condition). The participants pressed a key when they detected sound segregation of the two tones while the researchers recorded ERP amplitude and latency in each condition (Snyder et al., 2006).

Results showed that ERP amplitude increased as the ABA patterns proceeded during the experimental course. This trend was more prominent in the attended than in the ignored condition. ERP amplitude also increased as the frequency separation increased, and was accompanied by increased activity in the primary auditory cortex, including Heschl’s gyrus. The findings indicated that auditory scene analysis occurred automatically based on frequency differences. Additionally, voluntary attention became involved in order to maintain sound segregation over time (Snyder et al., 2006).

In a follow-up study, Snyder and Alain (2007) confirmed that frequency-based segregation occurred preattentively. The initial sound segregation was followed by time-based segregation that occurred with conscious effort. The findings also suggested that auditory scene analysis required both automatic as well as voluntary attention.

Continuing in the line of studies that supported the involvement of automatic and voluntary attention, Trainor, McDonald, and Alain (2002) examined the relationship between attention and melody. Non-musically trained individuals were presented with melodic contours and pitch intervals in two conditions: (a) passive listening where the participants read a book of their choice while ignoring the melodies and (b) active listening where the participants pressed a button when they detected target stimuli. Melodic contours consisted of a set of five tones moving in an ascending direction. Pitch intervals consisted of a set of the first five tones of a major scale. Target stimuli consisted
of a set of five tones in which the last notes deviated from the standard contour and intervals. ERPs were recorded throughout trials (Trainor et al., 2002).

In the passive listening condition, mismatch negativity (MMN) components were later and more negative with the target stimuli than with the non-target stimuli. MMN was interpreted as appearing when the brain detected changes in pitch information automatically. The findings, therefore, indicated that attention was driven automatically even when actively ignoring the presented melodies (Trainor et al., 2002).

In the active listening condition, frontal negativity (i.e., N1) was larger with melodic contours than pitch intervals and with the altered stimuli rather than the standard stimuli. Frontal positivity (i.e., P3a and P3b) was earlier for melodic contour stimuli than pitch intervals and larger for the altered than for the standard stimuli. P3a component was interpreted as pre-attentive focus on novel and salient non-target stimuli, and P3b component as attentive focus on target stimuli. The findings indicated that both involuntary and conscious attention were activated in detecting changes in melodic contours and pitch intervals (Trainor et al., 2002).

In addition, the results implied that both automatic and voluntary attention involve processing melodic contours and pitch intervals, even without musical experience and absolute pitch presentation. This means both forms of attention are involved in the two-tone sequence paradigm (i.e., ABA pattern) (Bregman & Campbell, 1971; Carlyon et al., 2001; Cusack et al., 2004; Fritz et al., 2007; Macken et al., 2003; Treisman, 1988; Treisman & Gelade, 1980; Van Noorden, 1975).

Neurological evidence further supports the influence of the structured use of a melodic element on attention performance. Magnetoencephalogram (MEG) and
behavioral responses were recorded while musicians and non-musicians listened to two melodic contours presented simultaneously (Fujioka, Trainor, Ross, Kakigi, & Pantev, 2005). Melodic contours consisted of five tones that were taken from a major scale and of which the order was rearranged. Half of the contours were altered in that the last notes remained either within the key or outside the key. The altered last note alteration was embedded randomly in one of the two contours, either higher or lower.

Results of MMN and magnetic counterpoint (MMNm) differed depending upon the presence of the altered note and the musical expertise of participants. MMN at the point of altered note detection was larger in musicians than non-musicians. MMNm at detection of the altered note was larger for both groups. The larger MMNm became more prominent when the altered last notes were placed in the higher voice than in the lower voice (Fujioka et al., 2005).

In general, MMN and MMNm are interpreted as appearing when a perceptual violation was detected and when involuntary attention was involved. The findings further indicated that learned tonality enabled the participants to detect the altered note (i.e., perceptual violation) involuntarily. Involuntary attention was more strongly activated when the altered note became salient (i.e., when placed in the higher voice than the lower voice) (Fujioka et al., 2005). The findings of the study were consistent with Palmer and Holleran’s (1994) study, in which musicians recognized errors placed in the lower voice better than non-musicians.

**Summary.** The research on attention to music is summarized as follows: (a) various properties of music, such as psychophysics, collative, and ecological, activate the attention system in the brain (Berlyne, 1971), (b) continuously changing features of
music direct and maintain attention (Huron, 1992), (c) listening to simultaneously presented melodies necessitates the use of different attention types (Bigand et al., 2000), and (d) formation of auditory Gestalt and sound segregation over time can activate automatic as well as voluntary attention (Bregman & colleagues; Fujioka et al., 2005; Trainor et al., 2002). Both involuntary as well as voluntary attention, therefore, can be induced by listening to musical stimuli (Fujioka et al., 2005; Snyder et al., 2006; Trainor et al., 2002).

Neuroanatomical Evidence of Attention to Music

Researchers have provided neuroanatomical evidence that listening to music activates specific neural regions which house each of the three attention sub-types. Generally, rhythmic elements activate sustained attention, while there is a greater association between melodic elements and selective attention and divided attention (Bengtsson et al., 2009; Janata, Tillmann, & Bharucha, 2002; Ortuño et al., 2002; Satoh, Takeda, Hatazawa, & Kuzuhara, 2001; Stephan et al., 2002).

Sustained attention. Rhythm, the most fundamental element of music, helps individuals to organize complex sounds into perceptually comprehensible patterns (Radocy & Boyle, 2003). Dynamic attending theory, proposed by Jones (1984), explains how recurrent patterns of rhythm capture and maintain our attention. According to Jones, the periodicity of an internal oscillator is specific and subjective for each individual when in a neutral state where a time reference for movement is unavailable. When individuals are exposed to external auditory rhythm, the internal oscillator becomes attuned to the cycles of the patterns of the rhythm. The synchronization of the hard-wired pattern
generator to the external auditory rhythm suggests that rhythm plays an important role in
directing and sustaining attention.

Stephan et al. (2002) examined how motor movements were synchronized and
adjusted to auditory rhythms. Regional cerebral blood flow (rCBF) was recorded while
nine healthy adults tapped with their right index finger to rhythm sequences. The rhythm
sequences were metronome beats of which inter-stimulus intervals (ISI) were (a) equal,
(b) varied with a predictable ratio, or (c) varied according to a random ratio (Stephan et
al., 2002).

Results showed that the brain activation varied depending on the predictability of
the rhythm sequences. First, common brain regions were activated across the three types
of rhythm sequences. The common regions were (a) the subcortical regions, such as the
insula, the putamen, the thalamus, and the cerebellum and (b) the cortical regions, such as
the primary sensorimotor and anterior cingulate areas, the bilateral premotor areas, and
the ventral prefrontal cortex. Second, the brain activations varied depending on the types
of rhythm sequences. The ventral mediofrontal cortex modulated processing of rhythm
sequences with equal ISI, while the prefrontal areas played a critical role for processing
rhythm sequences with randomly varied ISI (Stephan et al., 2002).

Additionally, the brain regions differed by the degree to which ISI was changed.
As the ratio of ISI increased above the perceptual threshold, the prefrontal cortex and its
surrounding areas (i.e., the ventral prefrontal, premotor, anterior cingulate, and
dorsolateral prefrontal) became more involved. These findings suggest the
synchronization and adjustment of movements to auditory rhythm occurred at both
subcortical and cortical levels, directing and maintaining attention subconsciously as well as consciously (Stephan et al., 2002).

Whereas Stephan et al. (2002) examined the brain regions activated during motor synchronization, Bengtsson et al. (2009) focused on the brain areas activated during listening to auditory rhythm. An fMRI was recorded while seventeen healthy participants listened to three types of rhythm sequences that were varied in a similar way as in the Stephan et al.’s (2002) study.

Results were similar to Stephan et al.’s findings (2002). While listening to the rhythm sequences with equal ISI, the brain activations were found in the dorsal premotor cortex, the pre-supplementary motor areas (pre-SMA), the supplementary motor area (SMA), and the lateral cerebellum. While listening to the rhythm sequences with ISI varied by a predictable ratio and a random ratio, the superior prefrontal cortex was activated. The brain activations in the prefrontal cortex became prominent as unpredictability of the rhythm sequences increased. The findings indicated that predictable rhythmic patterns activated the brain regions responsible for executing the planned motor movement, while unpredictable rhythmic patterns activated the prefrontal cortex, which was responsible for generating plans for motor movements (Bengtsson et al., 2009).

Ortuño et al. (2002) examined brain activation during sustained attention performance to auditory stimulation. Relative cerebral blood flow (relCBF) was recorded while participants experienced three conditions: (a) auditory stimulation, (b) counting with auditory stimulation, and (c) counting without auditory stimulation. In the third condition, the same counting task was given in the absence of an auditory click, and the
participants were asked to recall the rate of the auditory clicks presented in the previous condition.

The relCBF data revealed that the brain activations varied depending on tasks given in each condition. First, common brain regions were activated across the three conditions. The common regions were the motor cortex, the putamen, the cerebellum, and the anterior cingulate cortex. Unique to the mental counting task in the absence of auditory clicks, the inferiorparietal and dorsolateral prefrontal cortices were additionally activated (Ortuño et al., 2002).

The findings indicated that auditory rhythms, either heard from the external environments or generated from the internal imagination, activated the brain regions responsible for executing the planned motor movement. The regions also overlapped with those involved in sustained attention performance. Imagining auditory rhythms activated the brain regions responsible for working memory and time estimation. The findings suggest that recurrent patterns of auditory rhythm are synchronized with an individual’s internal oscillator, while automatically capturing attention and allowing the focus to be sustained (Ortuño et al., 2002).

In summary, the neural activations observed in Bengtsson et al. (2009), Ortuño et al. (2002), and Stephan et al. (2002) support a schematic model within which a broad range of brain regions regulate sustained attention performance (Sarter et al., 2001). These studies (Bengtsson et al., 2009; Ortuño et al., 2002; Stephan et al., 2002) also suggest that regularly recurring rhythmic patterns contribute to capturing and maintaining one’s attentional focus. However, previous studies revealed that rhythmic elements were inappropriate for use as assessment stimuli to measure different types of attention.
(Gfeller & Cradock, 1989; Reitan & Wolfson, 1989). In the present study, the researcher decided to focus more on melodic elements. This issue is further discussed in Chapter 3.

**Selective attention versus divided attention.** Melody is a rhythmically organized sequence of single tones of varying pitch (Radocy & Boyle, 2003). The different tasks necessary for melody perception activate the brain regions responsible for auditory selective attention and auditory divided attention (Janata, Tillmann, & Bharucha, 2002; Satoh, Takeda, Hatazawa, & Kuzuhara, 2001).

In an fMRI study, Janata et al. (2002) investigated how the different types of attention necessary to appreciate music in a holistic, selective, or divided manner were activated in different brain regions. Two experiments were conducted. In the first experiment, participants heard two movements taken from a Baroque suite in which two themes were played by strings and vibraphones. In the holistic listening condition, the participants listened to two themes simultaneously in a non-focused, relaxed manner (e.g., background music). In the selective listening condition, the participants alternated attention from a particular instrument to another following verbal instructions to do so (Janata et al., 2002).

In the second experiment, participants heard a movement taken from a Romantic piano trio. The participants split their focus equally over three different instruments (i.e., piano, violin, and cello) and then selectively attended to a particular instrument as directed by verbal instructions. Blood oxygen level dependent (BOLD), a specialized type of MRI that detects changes in blood deoxyhemoglobin, was measured in both experiments (Janata et al., 2002).
Results revealed that the neural activation patterns differed by listening condition. The findings of the first experiment showed that common brain regions were activated in the holistic and selective listening conditions; however, additional activations were found in selective listening. The common brain regions activated were the superior temporal gyrus, the precentral sulcus (PcS), and the supplementary motor area (SMA) and pre-SMA. Additional brain regions activated were the inferior frontal gyrus (IFG), the inferior PcS, frontal and parietal areas, and the larger superior temporal areas (Janata et al., 2002).

The findings of the second experiment showed that the neural activations in divided listening were dissociated from the activations in selective listening. Divided music listening led to more laterally extended activations in the IFG, and larger activations around the superior PcS, the superior frontal sulci and the posterior part of the middle frontal gyrus (MFG) than selective listening. Unique brain regions activated during divided listening were the left intra-parietal sulcus (IPS), the parietal cortex, the superior frontal cortex, the ventro-rostral part of the middle frontal gyrus (MFG), and the anterior cingulate cortex (Janata et al., 2002).

Continuing the line of study that supports neural activations specific to different music listening tasks, Satoh et al. (2001) examined brain activations to multi-voice music. Musicians listened to a four-voice harmonic progression consisting of eight chords. In the single-voice listening condition, the participants listened to the alto part only and responded by using their right index finger at detection of a dominant or tonic note. In the multi-voice listening condition, the musicians listened to four voices and responded in the
same way at detection of minor chords. Regional cerebral blood flow (rCBF) with PET was recorded.

The rCBF data showed that brain activations differed, depending on the given tasks associated with the multi-voice music. In the single-voice listening condition, brain activations were found in the superior parietal lobules, the precunei, the premotor areas, and the orbital frontal cortex. The regions were interpreted as being responsible for selective attention, attentional effort, and spatial localization of a tone. In the multi-voice listening condition, brain activations were observed in the temporal poles, the anterior portion of the cingulate gyrus, the occipital cortex and the medial surface of the cerebellum. The regions were interpreted as mediating short-term memories, discrimination of meter, detection of familiarity, and anticipation of a newly learned task (Satoh et al., 2001).

In summary, neural activation patterns were discernable dependent upon the types of music stimuli presented. The various music listening tasks led to the use of different listening strategies and, thus, activated different attention sub-types. Consistency in the findings suggests the potential of using melodic elements as an indicator of the three attention sub-types reviewed in the previous section (i.e., sustained attention, selective attention, divided attention) (Bengtsson et al., 2009; Janata et al., 2002; Ortuño et al., 2002; Satoh et al., 2001; Stephan et al., 2002).

**Behavioral Evidence of Attention to Single/Multi-voice Music**

Psychological aspects of listening to single/multi-voice music have been measured by reaction time, error detection rates, and accuracy in error/change detection tasks. The following five studies show how the structured use of various musical
elements could possibly lead to differentiated behavioral responses that reflect the activation of three types of attention (Bigand et al., 2000; Byo, 1997; Crawley, Acker-Mills, Pastore, & Weil, 2002; Davison & Banks, 2003; Dowling, 1973).

Byo (1997) examined whether different music textures influenced error detection performance. Musically trained students listened to music composed in homophonic or polyphonic texture and detected rhythm and pitch errors that were embedded in one of three voices. The voice to be attended was not specified prior to music listening. That is, all three voices included errors and the participants were told to record the errors for one of the three voices after listening to all. A notated score was given, upon which participants circled the errors (Byo, 1997).

Results revealed that error detection performance differed by the type of musical texture and the number of voices presented simultaneously. Task performance was most accurate for one-voice texture as compared to performance on the two- and three-voice textures. Task performance was better with the homophonic than the polyphonic texture, and performance was better for detection of rhythm errors than pitch errors (Byo, 1997).

Crawley et al. (2002) investigated whether the manner of listening to three-voice homophonic or polyphonic texture impacted performance on a note-change detection task. Musicians as well as non-musicians listened to chord-related or chord–unrelated note changes that were placed in one of the three voices of each texture. In the integrative listening condition, the participants attended to all of the three voices, and in the selective listening condition, they attended selectively to only the pre-assigned target melody (Crawley et al., 2002).
Results indicated that change detection performance differed by the type of musical texture, the manner of listening, the chord-relatedness and the placement of the note changes. Overall, task performance was better in the homophonic texture than the polyphonic texture, and when the single note changes were chord-unrelated rather than chord-related. In addition, task performance differed by the manner of listening and the placement of the note changes. When the participants listened to the polyphonic texture in an integrative manner (i.e., listening to music in a non-focused, relaxed manner), task performance was poorest for the note changes placed in the highest voice. However, in the selective listening task, performance was best for note changes placed in the highest voice. When the participants listened to homophonic texture, task performance did not differ significantly by the manner of listening and the placement of note changes (Crawley et al., 2002).

According to the authors, when participants attended simultaneously to all three voices of the polyphonic texture, integration of all voices occurred to form a single stream (Crawley et al. 2002). Consequently, the placement of the voices did not influence the task performance. In contrast, when participants attended selectively to one voice, note changes placed in the highest voice obtained saliency, leading to better task performance. These findings overlapped with Bigand et al. (2000), who reported different strategies used by musicians and non-musicians. According to their findings, non-musicians detected errors by attending selectively to the saliency of the tune, while musicians detected the errors based on the harmonic context learned from musical experience (Bigand et al., 2000).
Davison and Banks (2003) examined whether the structured use of two melodic contours influenced selective attention performance. Participants listened to two-tone melodic contours presented simultaneously and identified the direction of one contour played by a pre-assigned instrument timbre. The contours varied by instrument timbre (i.e., piano, bassoon), direction (i.e., move up, move down), interval (i.e., major second, perfect fifth), and pitch register (Davison & Banks, 2003).

Results revealed that reaction time and accuracy differed significantly by congruency, intervallic relationship, and pitch register between the two simultaneous melodic contours. The participants performed better: (a) when the directions of the melodic contours moved in the same direction rather than in the opposite direction, (b) when two tones in a row were separated by perfect fifth rather than a major second, and (c) when the melodic contours were presented in separate pitch registers. The findings indicated that contour identification performance was influenced by (a) congruency between the contour directions, (b) the intervallic relationship between each separate contour, and (c) the interference between the melodic contours (Davison & Banks, 2003).

Davison and Bank’s (2003) findings partially overlapped with the results of Dowling’s (1973) study. The author examined whether melody identification performance differed by pitch register between two melodies. Participants identified the title of two melodies presented simultaneously. Two melodies were more easily identified when they were separated in terms of the pitch register, so that they did not interfere with each other (Dowling, 1973). For example, “Twinkle, Twinkle Little Star” and “Frere Jacques” were separated by a major sixth.
Behavioral Evidence of Attention to Single/multi-layered Speech

Speech differs from music in a significant way since spoken passages convey semantic meanings. However, both speech and music share common acoustic properties, such as pitch, duration, and timbre. At the phonetic level, overlapping neural processing in response to both types of auditory stimuli has been reported (Brown, Martinez, & Parsons, 2006). Previous studies that examined attention triggered during the processing of single/multi-voice spoken passages have provided a valuable framework for understanding attention sub-types to single/multi-voice music.

Two studies investigated how attention performance differed by task associated with single/multi-voice speech sentences (Gallun, Mason, & Kidd, 2007; Shinn-Cunningham & Ihlefeld, 2004). Shinn-Cunningham and Ihlefeld (2004) examined the effect of sound location on attention performance. Two three-word speech sentences (including a name, color, and number in a particular order) were presented simultaneously at various sound locations (i.e., fixed and random). Participants experienced two conditions. In the selective listening condition, they reported the content of a target sentence while ignoring the content of a masker sentence. In the divided listening condition, they reported the contents of both target and masker sentences. Results of the study revealed that task performance was better when speech sentences were heard from different sound locations rather than the same location; and from fixed locations rather than random locations. The effect of sound location on speech processing was greater in divided listening than selective listening (Shinn-Cunningham & Ihlefeld, 2004).
In a related study, Gallun et al. (2007) expanded upon Shinn-Cunningham and Ihlefeld’s (2004) idea of using two speech sentences in a dichotic listening framework. The authors examined whether attention performance differed by the task demands imposed on the three relevant types of attention. Participants were tested under three conditions: (a) single task/single ear condition (ST/SE), (b) single task/dual ear condition (ST/DE), (c) dual task/dual ear condition (DT/DE) (Gallun et al., 2007).

In the ST/SE condition, one speech sentence was presented to one ear and the participants identified key words in the sentences. In the ST/DE condition, two speech sentences were presented, one to each ear, and the participants identified key words in the target sentence while ignoring the masker sentence. In the DT/DE condition, two types of tasks, detection/identification (DET/ID) and identification/identification (ID/ID), were given to the participants. In the DET/ID condition, the participants detected the presence of one sentence (DET) and identified key words in the target sentence (ID). In the ID/ID condition, the participants identified key words from both sentences. The participants verbally identified key words in the target sentence (i.e., color and number), and indicated their detection by answering yes or no. The purpose of using two types of tasks was to vary task demands by varying the level of competition between the given tasks. For example, the authors assumed that DET/ID would be easier than ID/ID (Gallun et al., 2007).

Results revealed that attention performance differed by the number of speech sentences presented simultaneously, the type of tasks given in each condition, and the attended ear. Task performance was best in the ST/SE condition followed by the ST/DE, and the worst in the DT/DE conditions. Differences between the ST/SE and ST/DE
conditions indicated that additional effort between sustained and selective attention performance is required. Differences between the ST/DE and DT/DE conditions indicated that additional effort was required between selective and divided attention performance. Differences between the DET/ID and ID/ID conditions demonstrated that task demands increased by increasing the level of competition between the given tasks. The authors concluded that task performance differed by the number of speech sentences presented simultaneously and the level of competition given by different types of tasks (Gallun et al., 2007). The findings suggest that the manner of presenting stimuli and the distraction/competition between the stimuli given in different tasks determine the three types of attention, including sustained, selective, and divided attention.

**Summary.** Music psychologists used a framework of error/change detection tasks as main means of investigating attention to single/multi-voice music. Depending on the given stimuli and tasks, performance was associated with each of the three different attention sub-types (Bigand et al., 2000; Byo, 1997; Crawley et al., 2002; Davison & Banks, 2003; Dowling, 1973). Studies of the attention sub-types involved in layered speech processing reported similar findings (Gallun et al., 2007; Shinn-Cunningham & Ihlefeld, 2004).

Earlier findings indicated that listening to single/multi-voice music activated the three types of attention. Task performance differed by the number of stimuli presented simultaneously, the manner of listening (i.e., holistic, sustained, selective, divided), music texture (i.e., homophonic, polyphonic), placement of target music (i.e., higher, lower), key-relatedness (i.e., related, unrelated), direction (i.e., congruent, incongruent), instrument timbres, intervals, and pitch register between two musical stimuli (i.e.,
melodic elements). These findings justify the use of melodic contour as a diagnostic tool to measure the three types of attention. Involuntary attention to stimulus saliency and pitch perception provides a rationale for using a music-based tool in diagnosing attention disorders in both musicians and non-musicians (Bigand et al., 2000; Byo, 1997; Crawley et al., 2002; Davison & Banks, 2003; Dowling, 1973; Gallun et al., 2007).

**Neuroanatomical Commonalities between Attention to Non-musical and Musical Stimuli**

The following is a summary of the common brain regions activated in different attention tasks with non-musical and musical stimuli. The neuroanatomical commonalities provide a foundation for the development of the music-based attention assessment.

**Sustained attention.** The neural structures activated during sustained attention performance on non-auditory stimuli were (a) the subcortical regions, such as the reticular formation, cerebellum, and thalamus, and (b) the cortical regions, such as the primary sensory, the prefrontal, parietal, and occipital cortices (Lawrence et al., 2003; Sarter et al., 2001). The neural structures activated during listening to rhythms were (a) the subcortical regions, such as the reticular formation, the insula, the putamen, the thalamus, and cerebellum, and (b) the cortical regions, such as the primary sensory, premotor, supplementary motor, parietal, anterior cingulate, and prefrontal cortices (Bengtsson et al., 2009; Ortuño et al., 2002; Stephan et al., 2002).

A large number of neural structures employed in sustained attention are activated similarly by non-auditory stimuli and musical stimuli. The brain regions activated by both stimulus indicated (a) arousal responses to sensory stimuli, and (b) conscious effort
to maintain the arousal and to project it to other brain structures responsible for higher cognitive processes.

**Selective attention.** The neural structures activated during selective attention to non-auditory stimuli were (a) the primary sensory cortices (i.e., occipital, parietal cortices), and (b) the occipito-temporal junction and intra parietal sulcus (i.e., the polysensory association areas) (Lawrence et al., 2003; Macaluso et al., 2002; Serences & Yantis, 2007; Talsma & Kok, 2001). The neural structures activated during listening to a target melody over a distracting melody included (a) the temporal areas, and (b) the superior temporal sulcus (i.e., poly-sensory association area), areas between the inferior frontal gyrus (IFG) and intra-parietal sulcus (IPS), and the frontal and parietal regions (Janata et al., 2002). Many of the same neural structures activated in selective attention are triggered by both non-auditory and musical stimuli.

**Divided attention.** The neural structures activated during divided attention to non-auditory stimuli were the inferior and posterior parietal areas, and the dorsolateral prefrontal cortex (Loose et al., 2000; Johnson & Zatorre, 2006; Johnson et al., 2007). The neural structures activated specific to musical stimuli were the occipital areas, the intraparietal sulcus, the anterior cingulate, and frontal cortices (Janata et al., 2002; Satoh et al., 2001). Neural activations in divided attention performance were modality-specific and varied by the goals and demands of the given task. However, a higher degree of activation was found commonly in the prefrontal cortices (i.e., dorsolateral prefrontal), suggesting the existence of common neural structures that mediate divided attention performance for both non-auditory stimuli and music.
Attention Impairments following TBI

In an attempt to clarify key issues in TBI, this section begins by defining TBI and describes its prevalence and leading causes. Neuropathology of attention impairments is explained, followed by the types of distractibility that are known to contribute to these impairments. A summary of types of attention impairments is presented and, lastly, neuropsychological attention assessment measures and their limitations are discussed.

Introduction to TBI

TBI has been defined as “a functionally significant disruption of brain function produced by blunt or penetrating trauma or rapid acceleration/deceleration forces that results in immediately apparent cognitive or physical impairments” (Arciniega, 2010, p. 127). The occurrence of a TBI is confirmed by a loss of consciousness (LOC), post-traumatic amnesia (PTA), and/or evidence from noninvasive brain imaging tests. The existence of bone fractures or damaged brain tissues attributable to TBI are shown in the images (Kashluba, Hanks, Casey, & Millis, 2008). Due to damage to a broad range of brain regions, survivors of TBI typically experience significant cognitive, behavioral, and emotional disabilities (Faul, Xu, Wald, & Coronado, 2010; Thurman, Alverson, Dunn, Guerrero, & Sniezek, 1999). Precise assessment, prompt treatment, and effective rehabilitation are necessary to achieve maximum recovery. Neural plasticity of the brain plays an important role in improving the functioning of patients with temporary as well as permanent impairments as a result of TBI (Kim et al., 2008).

TBI-associated death and disability varies with age, gender, and cause (Bruns & Hauser, 2003). In a review of epidemiology in TBI, males are at higher risk of TBI, particularly during adolescence and young adulthood (Faul et al., 2010; NINDS, 2002;
Thurman et al., 1999). The principal causes include motor vehicle accidents, falls, acts of violence, and sports accidents (Corrigan, Wolfe, Mysiw, Jackson, & Bogner, 2003). For example, males ages 15 to 24, especially those at lower educational and socioeconomic levels, are most likely to become involved in high-speed or other risky driving, as well as physical fights and criminal activity. Such behaviors increase the likelihood of TBI associated with automobile and motorcycle accidents or with violent crimes.

Demographic factors such as age, gender, education, and socioeconomic status have been investigated in regards to attention deficits in TBI. Previous studies conducted up to 3 years post TBI have found that cognitive functioning was effected by injury severity, and, as well, by demographic factors (Brown et al., 2005; Cattelani, Tanzi, Lombardi, & Mazzucchi, 2002; Pastorek, Hannay, & Constant, 2004).

Working with patients 10 years post-TBI, Ponsford, Draper, and Schönberger (2008) examined the influence of injury severity, demographic factors, and cognitive functioning on functional outcomes, such as capacity for independent living, relationship, and employment. Demographic information, including age at time of injury, gender, education, pre-injury employment status, and pre-injury relationship status were obtained. Data on current information processing speed, attention, memory, and executive functioning were assessed and functional outcomes were measured using the Extended Glasgow Coma Outcome Scale (GOSE, Pastorek et al., 2004).

The results revealed significant associations among demographic variables, cognitive functioning and functional outcomes. Patients with lower functional outcomes had significantly longer posttraumatic amnesia (PTA) duration and lower levels of education. In addition, patients with low functional outcomes performed more poorly on
information processing speed, attention, memory, and executive functioning assessments. Even though associations between demographic variables and cognitive abilities were not directly investigated, the authors suggested that close correlations may still exist since functional outcomes were mediated by the demographic variables.

**Neuropathology of Attention Impairments in TBI**

Impairment following TBI is categorized as either primary or secondary. A primary brain injury occurs at the moment of trauma, and includes contusions, axonal shearing (diffuse axonal injury, DAI), and damage to blood vessels (Scalea, 2005). A secondary brain injury occurs as a complication of the primary insults, leading to a detrimental consequence, including ischemia, edema, cerebral hypoxia, and hypotension (Blank-Reid, McClelland, & Santora, 2008).

Contusion has been defined as a focal bleeding lesion inside of the brain. That is caused by contact between the surface of the brain and a bony protuberance within the skull (Scheid, Preol, Gruber, Wiggins, & Von Cramon, 2003). Contusions are frequently found at the surfaces of the frontal lobes, the lateral and inferior parts of the temporal lobes, the parietal lobes, the occipital lobes, the corpus callosum, the basal ganglia, the hippocampus and the hypothalamus, the brain stem, and the inferior surfaces of the cerebellum (Ponsford et al., 1995; Scheid et al., 2003).

Particularly in the frontal lobes, contusions are known to cause sudden clinical deterioration, such as attention deficits. The frontal lobes communicate reciprocally with the posterior parietal lobes, modulating the attention control system in the brain (Stuss et al., 1995). Via norepinephrine projection, the frontal lobes regulate the reticular
formation in the brainstem that is responsible for consciousness and arousal (Bourne, Dominowski, Loftus, & Hearn, 1986).

Diffuse axonal injury (DAI), another type of primary brain injury, is caused by axonal shearing from stretching and breaking when surrounding brain tissue moves due to a rotational force (Wolf, Stys, Lusardi, Meaney, & Smith, 2001). The shearing lesions associated with DAI are located in the broad regions including the frontal and temporal lobes, the basal ganglia, the ventricular zone, the corpus callosum, the brain stem, and the cerebellum (Parizel et al., 1998).

DAI disrupts networks that mediate cognitive controls, such as attention and memory (Scheibel et al., 2007). Widespread axonal disruption decreases information processing speed, leading to attention impairments (Ponsford & Kinsella, 1988; Putnam et al. 1996). DAI is also a causal factor that leads to malfunctioning of the cholinergic system, disturbing the formation of short-term memory (Arciniegas et al., 2000).

Primary and secondary head injuries cause sensory disturbances and distractibility following TBI. Sensory disturbances are caused by cranial nerve lesions, damage in subcortical areas, or injuries in the sensory cortices (Botvinick, Braver, Barch, Carter, & Cohen, 2001). These disturbances result in a slowed reaction time and a decreased perceptual threshold, leading to impairments in attention, memory, and executive function (Botvinick et al., 2001; Lew, Lee, Pan, & Date, 2004; Ponsford et al., 1995; Sarno, Eramus, Frey, Lippert, & Lipp, 2006; Sarno, Erasmus, Lipp, & Schlaegel, 2003).

**Attention Impairments in TBI**

Insults to any brain location lead to a variety of either temporary or permanent impairments in cognitive, socio-emotional and sensory-motor domains. Cognitive
impairments associated with TBI result in the inability to attend selectively to external or internal stimuli, to organize and store information, and to make decisions to solve problems in everyday life (Arciniega et al., 2000; Kashluba et al., 2008; Ponsford et al., 1995; Putnam et al., 1996; Scheibel et al., 2007; Stuss et al., 1995).

Attention impairments are among the most commonly observed deficits following TBI (Gronwall, 1987; Posner & Rafal, 1986; Sandson, Crosson, Posner, Barco, Velozo, & Brobeck, 1988). Impairments specific to attention ability are found in information processing speed, alertness, focused/selective attention, divided attention, attention span, and supervisory attentional control (Arciniega et al., 2002; Corrigan, Whiteneck, & Mellick, 2004; Mathias & Wheaton, 2007; Niemann et al., 1996; Park et al., 1999b; Ponsford & Willmot, 2004; Stuss et al., 1989).

Several factors are believed to be strongly associated with the degree of attention impairments in TBI. Willmott, Ponsford, Hocking, and Schönberger (2009) examined the influence of brain injury severity on attention performance. The severity of the brain injury was measured by the Glasgow Coma Scale (GCS), and ranged from severe to mild. In the study, patients with a moderate to severe level of brain injury and healthy adults completed six tasks of information processing speed, selective attention, sustained attention, and working memory. The results showed that task performance on information processing speed and selective attention was poorer in the patient group than the control group. Within the patient group, poor performance on the selective attention task was accounted for by slowed information processing speed. The findings indicated that the brain injury caused slowed information processing speed, and, in turn, contributed to deterioration in selective attention (Willmott et al., 2009).
Draper and Ponsford (2008) investigated the effect of brain injury severity on cognitive impairments. Patients with TBI and demographically matched healthy adults were administered several psychological and cognitive measures. The findings revealed that the severity of brain injury, as measured by the GCS, PTA, and computed tomography (CT) scan, was significantly correlated with attention performance as measured by the WAIS-III Digit Span test and Trail Making Test (Reitan & Wolfson, 1985). The authors concluded that the level of brain injury severity significantly influenced cognitive functioning, such as information processing speed, attention, memory, and executive function (Draper & Ponsford, 2008).

**Auditory Attention Impairments in TBI**

Attention impairments specific to the processing of auditory stimuli have been frequently reported following TBI (Hattiangadi, Pillion, Slomine, Christensen, Trovato, & Speediea, 2005). Overall, attention performance has been reported as worse in the presence of competing or distracting auditory stimuli than in the absence of such distractors (Godefroy, Lhullier, & Rousseaux, 1996; Godefroy & Rousseaux, 1996). The auditory attention impairments are possibly due to distractibility, which is defined as a rapid shifting of robust selective attention between competing stimuli for brief periods of time (Arciniegas et al., 2000). Dysfunction in the ability to allocate brain resources to task-relevant and task-irrelevant stimuli is believed to cause this distractibility in patients with TBI (Solbakk et al., 2002).

Two event related potentials (ERPs) studies investigated the effects of auditory distraction on visual attention performance in patients with TBI (Kaipio et al., 1999; Kaipio et al., 2000). Patients watched recorded visual stimuli on a screen while ignoring
auditory distraction. In Kaipio et al. (1999), auditory stimuli consisted of standard sounds (i.e., repeated single tones), occasionally replaced with deviants (i.e., frequency-modified tones and natural novel sounds). In Kaipio et al. (2000), auditory stimuli consisted of standard sounds (i.e., a vowel sound [o]), occasionally replaced with deviants (i.e., a vowel sound [e]).

Results of the two studies revealed that patients were more distracted in the presence of auditory distraction than were healthy adults. P3a components to deviated sounds were significantly delayed and significantly larger in the patient group than in the healthy adult group. The P3a components were typically interpreted as being related to the engagement of attention. Thus, the finding indicated that the patients with TBI were more susceptible to auditory distraction (Kaipio et al., 1999; Kaipio et al., 2000). Specific to Kaipio et al.’s (1999) finding, the P3a component was larger to natural novel sounds than frequency-modified tones in the patient group. This finding indicated an increased distractibility in the patient group when presented sounds deviated from standard sounds (i.e., novel) (Kaipio et al., 1999).

A related study focused on the effects of auditory distraction on an auditory target detection task (Solbakk et al., 2002). The authors examined whether target detection performance differed by the degree of auditory distraction. Auditory stimuli consisted of standard sounds (i.e., 25 millisecond repetitive tones), occasionally replaced by deviant sounds, including extended target sounds (i.e., 75 millisecond repetitive tones) and white noise. Patients with TBI and healthy adults heard the auditory stimuli and detected a deviant sound by pressing a button. Electroencephalographic (EEG) output was
simultaneously recorded along with behavioral responses as measured by the button press (Solbakk et al., 2002).

Behavioral findings showed varied performance between the TBI patient and the healthy adult groups. Accuracy in detecting the deviated sounds did not significantly differ by group; however, latency was significantly more delayed in the TBI patient group than in the healthy adult group. The delayed behavioral responses were accompanied by a prolongation of P3b components (Solbakk et al., 2002).

ERP results showed that P3a and P3b were more delayed at detection of the target sounds in the patients with TBI than the healthy adults. P3a was significantly delayed with the extended sounds as compared to the white noise in the patient group, indicating decreased processing speed and inattention in this group. The finding further indicated that the patients were more distracted by the deviated sounds that shared the same psychoacoustic features as the standard sounds. The authors concluded that the acoustic similarity between standard and deviated sounds increased distractibility and, in turn, led to worse performance on detection tasks in the patient group (Solbakk et al., 2002).

Kewman et al. (1988) examined the influence of auditory distraction on speech comprehension in patients with TBI. In a simulated speech task, patients with TBI and fourteen healthy adults listened to ten speech passages. Half of the passages were presented in the presence of a second voice. The participants took a multiple-choice test to validate the contents of the given passages and answered by marking on the given answer sheet (Kewman et al., 1988).

Results indicated that patients performed significantly worse than healthy adults with and without the second voice distraction. Both groups performed significantly worse
in the presence of the second voice. The ratio of decrement in the patient group was significantly higher than in the healthy adult group. These findings indicated that patients with TBI were more easily distracted in the presence of a distractor than healthy adults. The authors concluded that decreases in attention, memory, and language comprehension of patients with TBI were due to their susceptibility to distractibility (Kewman et al., 1988).

**Summary.** Patients with TBI suffer from attention deficits since they are susceptible to sensory distractions in their environment. The degree of distractibility differs according to the type of stimulus present in the distractor(s). Among the various sensory modalities, auditory stimuli are most challenging. Previous studies have shown that the type of researcher-selected auditory stimuli could influence attention performance (Kaipio et al., 1999, 2000; Kewman et al., 1988; Solbakk et al., 2002). Escera, Alho, Schröger, and Winkler (2000) confirmed that auditory distraction could provide an objective way of assessing distractibility in several clinical patient groups, such as patients suffering from TBI.

**Attention Assessment Measurements for TBI**

Attention rehabilitation is considered the primary step in a rehabilitation agenda following TBI, since attentional ability is a prerequisite for any type of information processing, such as registration of information and encoding for recall (Benedict, 1989; Filley, 1995; Mateer et al., 1990). This ability is necessary to return to activities of daily life as well as to obtain maximum benefit from therapeutic interventions. Since attention impairments following TBI vary depending on the location and severity of the brain
injury, it is important for professionals working with patients with TBI to obtain accurate assessment knowledge regarding their patients’ levels of attention impairments.

Several standardized assessment tools have been used to assess the attentional ability of patients with TBI. Franzen (2000) suggested that the Digit Span test of the Wechsler Adult Intelligence Scale-Revised (WAIS-R, Wechsler, 1981), Benton Serial Digit Learning Test (Crawford, Dickson, & Banos, 2000), Trail Making Test (TMT, Reitan & Wolfson, 1985), and Stroop Color-Word Test (Stroop, 1935) were appropriate to assess attentional ability in an acute phase of TBI.

Gronwall (1987) also supported the use of the aforementioned tests as attention assessment tools and recommended additionally that Reaction Time (RT), Stroop Color-Word Test (Stroop, 1935), Paced Auditory Serial Addition Task (PASAT, Gronwall, 1977), and WAIS-R Digit Span Test (Wechsler, 1981), administered in conjunction with PASAT, were appropriate to evaluate attentional ability of patients with TBI. Léon-Carrión, Taaffe, Barroso, and Martin (2006) also were of the view that the Letter Cancellation Test (Talland, 1965), Continuous Performance Test (CPT, Rosvold, Mirsky, Sarason, Bransome, & Beck, 1956), Test of Everyday Attention (TEA, Robertson, Ward, Ridgeway, & Nimmo-Smith, 1996), WAIS-III Arithmetic and Digit Span Tests (Wechsler, 1997), and Wisconsin Card Sorting Test (WCST, Grant & Berg, 1948; Heaton, Chelune, Talley, Kay, & Curtiss, 1993) were capable of measuring attentional function of patients with TBI.

The aforementioned attention batteries have been categorized according to the different attention sub-types (Cohen et al., 1993; Mirsky et al., 1991; Ponsford, 2008). In two factor-analysis studies (Park & Ingles, 2001; Duncan & Mirsky, 2004), the authors
performed principal components analysis and confirmed that the current attention batteries were grouped into the four independent components of attention (Mirsky et al., 1991). According to their findings, the focus-execute component, an ability to scan external stimuli to detect targets and to respond to them, is associated with WAIS-R Digit Symbol Test (Wechsler, 1981), Stroop Color-Word Test (Stroop, 1935), Letter Cancellation Test (Talland, 1965), and TMT (Reitan & Wolfson, 1985). The sustain component, an ability to maintain one’s focus over time, is associated with the CCPT (Rosvold et al., 1956). The shift component, an ability to shift one’s focus from one aspect to another aspect of the stimuli, is measured by the WCST (Grant & Berg, 1948; Heaton et al., 1993). Lastly, the encode component, equivalent to working memory, is measured by the WAIS-R Digit Span Test and Arithmetic Test (Wechsler, 1981). The aforementioned attention batteries provide little knowledge of attention impairments in a hierarchy. Therefore, if TBI-related clinicians and researchers want to identify the specific level of attention impairment, they have to use multiple batteries, leading to inefficiency in diagnosing attention impairments.

**Limitations in current attention assessment measures.** As demonstrated in previous studies regarding auditory distractibility following TBI (Escera et al., 2000; Kaipio et al., 1999; Kaipio et al., 2000; Kewman et al., 1988; Solbakk et al., 2002), it is evident that attention impairments following TBI are the result of distractibility, specifically in the presence of interfering and competing sounds. The degree of distractibility in patients with brain injury varies depending on the type of researcher-selected auditory stimuli (i.e., novel sounds, different types of vowel sounds, white noise).
However, current auditory attention assessment measurements used in neurorehabilitation settings are limited to numeric information (i.e., recall, summation of numbers) delivered by verbal directions, such as the Digit Span subtest from WAIS (Wechsler, 1981, 1997, 2008), and PASAT (Gronwall, 1977). These assessment instruments typically do not well assess complexity of auditory attention in the nature environment.

Several limitations are found in current attention assessment tools. First, the scope of the attention measures does not provide diagnostic knowledge in regard to auditory attention. Second, given that patients with TBI are more susceptible to distraction, which leads to poor attention performance, the current measures do not measure the attention ability of patients with TBI in the presence of sensory distraction in an ecological context. Third, the current measures do not assess the specific level of attention impairment within the hierarchy of attention. Professionals working with patients with TBI need diagnostic tools that can identify the level of attention impairment in order to recommend appropriate tasks and complementary practices to address the attention impairments.

An auditory tool that incrementally challenges and measures patients’ attention ability in the presence of auditory distraction and competition, therefore, is needed. Ample evidence supports the use of musical stimuli as an effective means for assessing auditory attention (Bengtsson et al., 2009; Berlyne, 1971; Bigand et al., 2000; Bregman & Campbell, 1971; Byo, 1997; Carlyon et al., 2001; Crawley et al., 2002; Cusack et al., 2004; Davison & Banks, 2003; Deutsch, 1982; Dowling, 1973; Fritz et al., 2007; Fujioka et al., 2005; Huron, 1992; Janata et al., 2002; Jones, 1984; Macken et al., 2003; Satoh et
al., 2001; Stephan et al., Trainor et al., 2002; Treisman, 1988; Treisman & Gelade, 1980; Van Noorden, 1975).

**Music-based Attention Assessment Measurement**

As reviewed in the previous section, existing auditory attention assessment instruments frequently used in cognitive neurorehabilitation do not adequately assess different subtypes of auditory attention. This section demonstrates the present need for music-based assessment measurements for TBI-related professionals and explores the possibility of using existing music therapy assessment tools for diagnosing different types of auditory attention deficits for patients with TBI. This section first reviews currently available music-based assessment measurements and discusses the limitations of these instruments for use with the TBI population.

Music therapy treatment typically includes five steps: referral, assessment, treatment plan, documentation, and evaluation and termination of treatment (Gfeller & Davis, 2008). Gfeller and Davis (2008) recommended that music therapists administer assessment tools to determine the nature and scope of treatment. Also, Bruscia, Hesser, and Boxil (1981) stipulated that the qualified music therapist must have the ability to identify the client’s functional needs through music assessment that is culturally and preferentially appropriate. Accurate assessment in music therapy, therefore, is considered critical in determining diagnosis, establishing baseline, providing stage-appropriate treatment, and evaluating the efficacy of intervention (Wilson, 2000).

Music therapy assessment should be specific to populations, work settings, and therapeutic approaches (Kim, 2005). Given the need in the field, many researchers have attempted to develop music therapy assessment measurements. In an early study,
Isenberg-Grzedą (1988) summarized a total of eleven music therapy assessments according to five major domains. The domains were client population (Boxill, 1985; Boxill & Chase, 2007; Braswell, Brooks, & Decuir, 1983, 1986; Crocker, 1955; Michel & Rohrbacher, 1982; Wasserman, Plutchik, Deutsch, & Takemoto, 1973); area of functioning (Boxill & Chase, 2007; Michel & Rohrbacher, 1982; Rider, 1981; Wasserman et al., 1973); theory/model (Braswell et al., 1983, 1986; Rider, 1981); technique (Bitcon, 1976; Bruscia, 1987; Crocker, 1955; Nordoff & Robbins, 1977); and response to the institution (Braswell et al., 1983; 1986; Sutton, 1984).

Later, Davis, Gfeller, and Thaut (2008) sub-categorized music therapy measurements according to client population. Six groups of music therapy measurements were organized by client groups: children and adolescents with mental retardation (Boxill, 1985; Boxil & Chase, 2007; Cohen & Katz, 1978; Cohen & Gericke, 1972; Wasserman et al., 1973); adults with psychiatric disorders (Braswell et al., 1983, 1986); children with hearing impairments (Gfeller & Baumann, 1988); children and adolescents with cognitive impairments (Rider, 1981); children with emotional disturbance (Crocker, 1955); and children with autism (Nordoff & Robbins, 1977).

Relatively recent music therapy assessment measurements have been reported. The measurements were developed, targeting patients with Alzheimer’s disease (York, 1994), patients with dementia (Lipe, 1995), gerontologic and geriatric patients (Adler, 2001; Hintz, 2000), psychiatric children and adults (Cassity & Cassity, 2006), terminally ill patients in hospice care (Groen, 2007), children with special needs (Coleman & Brunk, 1999; Douglass, 2006; Kim, 2005; Layman, Hussey, & Laing, 2002; Wigram, 2000), and unspecified populations (Bruscia, 1987; Loewy, 2000).
Among the existing music therapy assessment measurements, only a handful was designed to measure attention ability. They were the clinical use of Orff-Shulwerk (Bitcon, 1976), Music Therapy Assessment for Children with Developmental Disabilities (Boxil, 1985; Boxil & Chase, 2007), Musical-Perception Assessment of Cognitive Development (Rider, 1981; Jones, 1986), Computer-assisted Assessment of Melodic and Rhythmic Skills (Hunter, 1989), Residual Music Skills Test (York, 1994, 2000; Lipe, York, & Jensen, 2007), Music-Based Evaluation of Cognitive Functioning (Lipe, 1995; Lipe et al., 2007), and Music Therapy Assessment Tool for Low Awareness States (Magee, 2007).

The existing music therapy assessment measurements were carefully reviewed in order to investigate whether they were suitable to measure the different stages of attention ability. Two earliest measures (Bitcon, 1976; Boxil, 1985; Boxil & Chase, 2007) aimed to measure a broad range of behavioral functioning for children with special needs. These two measures utilized both music and non-music behaviors as indicators of functional behaviors. Concerning attention ability, both measures observed non-musical behaviors only (e.g., eye contact to the therapist or peer).

Rider (1981) developed Musical-Perception Assessment of Cognitive Development (M-PACD) to assess level of cognitive functioning through music perception. The M-PACD, modeled after Jean Piaget’s stages of cognitive development, included fifteen musical tasks. The study reported that the M-PACD was useful for assessing cognitive development of school-aged children (Rider, 1981) as well as children with mental retardation (Jones, 1986). However, of the fifteen tasks, only
discrimination tasks (i.e., discrimination of loudness, tempo, and duration) were thought appropriate to measure sustained attention (Rider, 1981).

Two measures, Residual Music Skills Test (RMST, York, 1994, 2000; Lipe et al., 2007) and Music-Based Evaluation of Cognitive Functioning (MBECF, Lipe, 1995; Lipe et al., 2007), were designed to measure cognitive function of older adults with Alzheimer’s disease and dementia by using various musical tasks. The RMST contains eleven items that assess singing, rhythmic, aural discrimination and recall abilities. The MBECF contains eighteen items that consist of verbal, singing, melodic (i.e., performing on the xylophone), rhythmic response tasks, and listening tasks.

Through follow-up studies, the authors addressed Davis and colleagues’ (Davis et al., 2008) concern in regards to test reliability and validity that was missing from the existing music therapy assessment tools. The reliability of the RMST has been established by inter-rater reliability ($r = .98$) (York, 1994) and test-retest reliability ($r = .92$) (York, 2000). Criterion validity has been investigated for both measures. The RMST was correlated with the Mini Mental State Examination (MMSE, Folstein, Folstein, & McHugh, 1975) ($r = .61$) (York, 1994). The MBECF was correlated with the MMSE ($r = .92$), Brief Cognitive Rating Scale (BCRS, Reisberg, Schneck, Ferris, Schwartz & DeLeon, 1983) ($r = -.78$), and Severe Impairment Battery (SIB, Saxton, McGonigle, Swihart, & Boller, 1993) ($r = .94$) (Lipe, 1995). The reliability of the MBECF measure has not yet been reported. However, strong correlation between the RMST and MBECF ($r = .83$) suggested that both measures assessed comparable ability (Lip et al., 2007).

Combined results indicated that the RMST and MBECF were relatively reliable and valid for use in the assessment of cognitive function of older adults. Also, the two
tools were useful to measure residual skills in behavioral domains, such as sensorimotor, attention, and memory, of older adults using music performance. However, the items in the RMST and MBECF utilized expressive music behaviors, such as, singing, playing instruments and listening discrimination. These music behaviors were deemed inappropriate to assess the subtypes of auditory attention.

Presently, only one auditory attention assessment measure is suitable for administration to patients with TBI in lower awareness states. The Music Therapy Assessment Tool for Low Awareness States (MATLAS, Magee, 2007) contains fourteen items that are systematically categorized to cover five behavioral domains, including motor responses, communication, arousal, auditory responsiveness, and visual responsiveness). The level of functional behaviors in each domain varies, for example, localizing and tracking response to external auditory stimuli, following verbal instruction and making a decision in accordance with the given instruction). Various musical stimuli are used to measure a broad range of functional behaviors (Magee, 2007).

The stimuli include a single auditory stimulus, complex musical sounds and musical activities, such as singing of familiar songs. Patients’ responses are marked using a numerical grading scale. Strong concurrent validity has been found between the MATLAS and the Sensory Modality Assessment and Rehabilitation Technique (SMART, Gill-Thwaites & Munday, 1999) and the Wessex Head Injury Matrix (WHIM, Shiel, Horn, Wilson, Campbell, & McLellan, 2000) scales. Investigations of reliability (i.e., intra- and inter-rater reliability) and psychometric properties (i.e., item analyses) of the measure are in progress (Magee, 2007).
Summary. Despite the promise of music stimuli in the assessment of auditory attention, the existing music-based assessment tools are not sufficient to provide information regarding different sub-types of auditory attention observed in receptive music behavior (i.e., music listening) for patients with TBI. The aforementioned measures rely almost exclusively on expressive music behaviors through music activities, and use the activities as an indicator of general cognitive ability (Bitcon, 1976; Boxil, 1985; Boxil & Chase, 2007; Lipe, 1995; Lipe et al., 2007; York, 1994, 2000). A few listening test-based measures (Hunter, 1989; Rider, 1981; Jones, 1986) are thought useful to assess focused attention and sustained attention to music. The MATLAS (Magee, 2007) is seen as a suitable measure for patients with TBI who are in low awareness states, specifically in vegetative states.

Given that the measures do not consider the competing nature of auditory stimuli, first, they are deemed insufficient for measuring auditory attention in an ecological context where distracting sounds are present. Second, the measures do not allow the practitioner to obtain diagnostic information regarding the higher levels of attention, such as selective attention and divided attention. The measures also provide little assessment knowledge that indicates the specific levels of attention deficits, so it is not sufficient for designing appropriate tasks that help attention rehabilitation. Third, the present auditory attention assessment for patients with TBI is considered inappropriate to administer to those who have a moderate to severe level of brain injury. Lastly, reliability and validity of these measures have not yet been established for most of the existing measures.
Summary of the Literature

Due to the limited information processing capacity of the brain, attention is necessary to deal with excessive amounts of incoming stimuli. Attention has been defined as an ability to maintain one’s focus over time, focus selectively on task-relevant stimuli, and split that focus equally to simultaneously presented stimuli in accordance with a goal given to a task.

Among various attention sub-types, common sub-types were found in the literature as follows: sustained, selective, and divided attention. Neuroanatomical evidence supports the existence of specific brain regions that individually house each of the three sub-types of attention. Lastly, the sub-categorization of attention deficits following TBI overlaps with the attention sub-types.

The sub-types of attention to music listening were reviewed. Music is an organization of auditory stimuli that contains an immense amount of information over time. From a theoretical perspective, attention is thought to involve processing musical stimuli that come from different locations and that consist of various psychoacoustic properties. Music psychologists offer a view that individuals are likely to organize sounds into perceptually meaningful units (i.e., auditory Gestalts) and to form the units into sound streams over time. Several experimental studies showed that automatic as well as voluntary attention are necessary during the process of forming recognizable auditory streams.

Neuroanatomical evidence support that the aforementioned three types of attention are utilized while listening to music. Sustained attention is involved in listening to rhythm, while selective and divided attention are activated in listening to melody.
Additionally, behavioral responses to single/multi-voice music revealed that attention performance is associated with the way that musical stimuli are organized and, as well, the characteristics of the given tasks. Also, the behavioral responses supported that the structured use of melodic contours effectively activates each of the three types of attention. Lastly, neuroanatomical commonalities revealed that the neural structures specific to the attention sub-types of music listening are similar to the attention sub-types utilized in non-auditory tasks. The literature supports the potential of music (i.e., melodic element) as effective attention assessment stimuli.

In application to TBI, attention sub-types that music can address overlap with attention deficits frequently observed following TBI. As compared with healthy, non-brain injured adults, patients with TBI showed reduced information processing speed, difficulties in focused and selective attention, inability to maintain attentional focus and supervisory attention control, and dysfunction of divided attention. In relation to the processing of auditory stimuli, the inability to discern separate sound streams has contributed to these attention deficits. Therefore, the ability of patients with TBI to identify separate sound streams against distractors and to track two separate sound streams indicate levels of attention ability.

The initial step in the cognitive rehabilitation of patients with TBI is assessment of their attention deficits. Current auditory attention assessment measurements are limited to numeric information (i.e., recall, summation of numbers) delivered by verbal direction. Moreover, current auditory attention assessment tools do not make use of a simulated real-world distraction in which multiple foci are required. Such distractors are needed to challenge the patient’s ability to either attend to one stream of information or divide one’s
focus equally between two or more streams of information relevant to the given task. Thus, there is a need for an authentic auditory tool that incrementally challenges and assesses patients’ attention ability, and music stimuli are an appropriate resource for such an auditory environment.

Despite the promise of music stimuli for auditory assessment of attention, only a small number of studies have attempted to develop such assessment measurements (Hunter, 1989; Jones, 1986; Lipe, 1995; Lipe et al., 2007; Magee, 2007; Rider, 1981; York, 1994, 2000). None of these instruments are considered appropriate to measure multi-faceted attention ability. Specifically, the previously listed measures provide little knowledge in regards to the competing nature of auditory attention when distracting sounds are present. In addition, reliability and validity of the measures have not been satisfactorily established. To date, a single auditory attention assessment measure (MATLAS, Magee, 2007) has been reported appropriate to administer to patients with TBI. The MATLAS measurement is intended for patients in low awareness or vegetative states, a more severe degree of impairment than the moderate to severe level of brain injury. Therefore, it is inappropriate for measuring the attention ability of patients with TBI who have a moderate to severe level of brain injury severity.

The present study, therefore, aimed to develop and validate a music-based attention assessment that was designed to measure the three sub-types of auditory attention deficits commonly found among patients with TBI, specifically those who are diagnosed as having moderate to severe levels of brain injury severity. The study attempted to address the need for an auditory attention assessment tool given a simulated real-world distraction. Lastly, the study sought to develop a music-based attention
assessment tool that professionals working with patients with TBI could use to identify levels of attention impairments and recommend appropriate tasks to aid in attention rehabilitation.
Chapter 3

Method

The following is a description of the development and validation procedures for the researcher-developed music-based attention assessment (MAA). Issues surrounding the selection of attention sub-types and their operational definitions are presented, followed by a description of item pool construction. In addition, psychometric validation processes are presented in regards to the participants in the study, the measures, the data collection procedure, and the statistical analyses.

The purpose of the study was to investigate the psychometric properties of a researcher-developed MAA, administered to both healthy adults and patients with TBI. The term “psychometrics” encompasses a broad range of theories and methods concerning psychological and educational instruments that intend to measure an individual’s mental function, such as intelligence, attitudes, and personality traits (Furr & Bacharach, 2008). In classical test theory, test items and scales are investigated to establish reliability and validity (Osterlind, 2006). In general, a preliminary psychometric investigation of a researcher-developed measure begins with item property analyses (i.e., item difficulty, item discrimination) and a reliability examination (Osterlind, 2006). For the current study, the psychometric properties of the MAA were investigated by conducting analyses to determine the MAA’s internal consistency, item properties, and latent factors.

The MAA aimed to measure the three key components of attention, consisting of sustained attention, selective attention, and divided attention. Support for the constructs that underlie the MAA was found in previous research studies concerning
psychology, cognitive neuropsychology, neurorehabilitation, music psychology, and music therapy. The researcher selected the three types of attention from a common list of attention subcomponents and common attention deficits following TBI. Test items were melodic contours of varying directions that were presented with various instrument timbres. Behavioral responses to the test items were assumed to reflect the selected three types of attention ability. In the present study, the 54 test items were factor-analyzed in an exploratory manner to identify the latent constructs of the MAA. Additional psychometric properties (i.e., item properties and reliabilities) were investigated.

The MAA was developed in six phases as suggested by Osterlind (2006). Each phase is described as a separate stage, as follows: (1) selecting types of attention to be measured, (2) development of a tentative model, (3) item pool construction, (4) initial evaluation of the measure, (5) test revision, and (6) evaluation and validation of the final model. Detailed procedures for the study are shown in Table 3.1.

**Phase 1: Selecting Types of Attention**

The first phase describes how the three types of attention were selected. With a multicomponent approach to attention, researchers have described diverse types of attention and have yielded terms to define each type. Terminologies varied depending on the given tasks and characteristics of task-relevant sensory stimuli. However, a list of common types of attention was found, including information processing speed, focused attention, sustained attention/vigilance, selective attention, alternating/shift attention, divided attention, and working memory (Cohen et al., 1993; Luck & Vecera, 2002; Mirsky et al., 1991).
Table 3.1

Development and Validation Procedures of the MAA

<table>
<thead>
<tr>
<th>Phase</th>
<th>Contents</th>
</tr>
</thead>
</table>
| 1     | Selecting Types of Attention  
      | • Identified the purpose of the measure  
      | • Selected three types of attention based on literature review  
      | • Established operational definitions for each of the three types of attention |
| 2     | Development of Tentative Model  
      | • Reviewed three types of attention to music  
      | • Reviewed how music can be used to assess attention impairments in TBI  
      | • Established the use of melodic contours as assessment stimuli |
| 3     | Item Pool Construction  
      | • Created a total of 48 test items  
      | • Conducted a content review with a panel of five experts  
      | • Modified the test items and rearranged the order of subtests  
      | • Conducted an additional interview with a small group of music therapists and adult students |
| 4     | Pilot Study  
      | • Piloted with patients with TBI ($N = 15$) to analyze the internal consistency and item properties of the initial measure (Jeong & Lesiuk, 2011) |
| 5     | Test Revision  
      | • Revised the measure due to ceiling effect of the mean scores obtained from healthy adults ($N = 30$)  
      | • Recreated a total of 54 test items by varying time duration of test items  
      | • Conducted a content review with representative individuals  
      | • Eliminated the problematic test items based on feedback |
| 6     | Validation and Evaluation  
      | • Piloted with healthy adults ($N = 165$) and patients with TBI ($N = 22$)  
      | • Investigated the latent constructs of the revised measure  
      | • Eliminated problematic test items and finalized 45-item MAA with the five construct model  
      | • Confirmed the stability of the identified factor structure  
      | • Item properties and reliability of the 45-item MAA were investigated |
TBI-relevant professionals and researchers have identified the types of attention impairments most commonly found in their patients. Attention deficits were observed in alertness, information processing speed, focused attention, sustained attention, selective attention, alternating/shifting attention, divided attention, and supervisory attentional control (Arciniegas et al., 2002; Mathias & Wheaton, 2007; Niemann et al., 1996; Park et al., 1999b; Ponsford, 2007; Ponsford & Willmot, 2004; Stuss et al., 1989). A five-layer hierarchy of attention (Sohlberg & Mateer, 1987) is the most prevalent framework in clinical use. These layers include focused attention, sustained attention, selective attention, alternating attention, and divided attention.

For the current study, the researcher decided to retain sustained attention, selective attention, and divided attention. The reasons for excluding the remaining types follow. First, focused attention was considered more relevant concerning sensory orientation to external stimuli (Sohlberg & Mateer, 1987). Second, Lipscomb (1996) stated that divided attention and alternating attention in music listening are identical. Third, divided attention is a more frequently used term than alternating/shift attention. Because of the terms selected, the prospective findings of the current study would be more likely to complement findings from other research.

For the present study, the three types of attention were operationally defined as follows: (a) **sustained attention** is the ability to continuously maintain one’s focus to external stimuli relevant to a given task, (b) **selective attention** is the ability to focus on target stimuli when presented with other distracting stimuli, and (c) **divided attention** is the ability to track two different stimuli simultaneously to obtain relevant information that is coming from both sources.
Phase 2: Development of a Tentative Model of the MAA

The second phase of the study involved determining whether the selected types of attention were applicable to music listening. Brain-imaging and behavioral studies addressed this concern. Neuroanatomical findings provided evidence of the existence of the three types of attention to music. Also, behavioral responses to single/multi-voice music demonstrated the involvement of the three types of attention to the stimuli.

Of the various components of music, the researcher selected melodic contours as the assessment stimuli for the following reasons. First, rhythm task performance was associated only with the activation of sustained attention (Bengtsson et al., 2009; Ortuño et al., 2002; Stephan et al., 2002). The other types of attention were only activated when rhythm was combined with melody (Knox, Yokota-Adachi, Kershner, & Jutai, 2003; Wit, Knox, Jutai, & Loveszy, 1994).

Second, previous studies attempted to use rhythm discrimination tasks to assess attention ability for patients with TBI. However, the findings were controversial (Charter & Webster, 1997; Gfeller & Cradock, 1989; Reitan & Wolfson, 1989). Researchers also utilized the Seashore Rhythm Test (SRT), a subtest of the Seashore’s Measure of Musical Talents (Seashore, 1919), which requires an individual to discriminate between the same and different pairs of rhythm patterns. Gfeller and Cradock (1989) and Reitan and Wolfson (1989) reported that patients with TBI performed significantly worse than healthy adults, and performance failure correlated positively with their brain injury severity. However, Charter and Webster (1997) found that many of test items did not discriminate well due to low item means and test-retest reliability fluctuated between .34 and .76.
Third, melody is defined as a rhythmically organized sequence of pitches (Radocy & Boyle, 2003). Based on this definition, the space-time integration inherent in melody would be appropriate to provide a perceptual cue to attend selectively to one stimulus against another (i.e., selective attention) or to split one's attentional focus over two or more stimuli (i.e., divided attention). For the current study, melodic contours, a series of tones moving in specified directions, were presented with steady rhythm patterns consisting of quarter notes. Melodic contours with standardized rhythms were, therefore, considered appropriate to measure sustained, selective, and divided attention.

Previous studies that utilized melody perception were reviewed. Table 3.2 summarizes the melodic contours and tasks that have been previously used to measure each of the three types of attention.
<table>
<thead>
<tr>
<th>Author(s)</th>
<th>Melodic Contour(s)</th>
<th>Attention Sub-type(s)</th>
<th>Task(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Janata et al. (2002)</td>
<td>Two movements of a Baroque suite played by two instrument timbres A movement of a Schubert trio</td>
<td>Selective attention</td>
<td>Listening to one instrument timbre at a time following instructions</td>
</tr>
<tr>
<td>Satoh et al. (2001)</td>
<td>Four-voice harmonic progression</td>
<td>Divided attention</td>
<td>Listening to two or more instrument timbres by splitting the focus equally</td>
</tr>
<tr>
<td>Trainor et al. (2002)</td>
<td>Melodic contours and pitch intervals consisting of five tones</td>
<td>Selective attention</td>
<td>Listening to one voice only to detect a note embedded to the voice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Divided attention</td>
<td>Listening to four voices to detect a chord embedded to one of the four voices</td>
</tr>
<tr>
<td>Bigand et al. (2000)</td>
<td>Nursery tunes</td>
<td>Automatic attention</td>
<td>Reading a book of choice while ignoring a presented melody</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Voluntary attention</td>
<td>Listening to a melody to detect a last note altered</td>
</tr>
<tr>
<td>Byo (1997)</td>
<td>One to three-voice homophonic and polyphonic music</td>
<td>Sustained attention</td>
<td>Listening to one nursery tune to detect an error</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Selective attention</td>
<td>Listening to two nursery tunes presented simultaneously to detect errors embedded in the lower voice</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Divided attention</td>
<td>Listening to two nursery tunes presented simultaneously to detect errors embedded in the higher and lower voices</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Listening to music to detect errors embedded in one of the three voices of each of the two textures</td>
</tr>
<tr>
<td>Author(s)</td>
<td>Melodic Contour(s)</td>
<td>Attention Sub-type(s)</td>
<td>Task(s)</td>
</tr>
<tr>
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<tr>
<td>Crawley et al. (2002)</td>
<td>Three-voice homophonic and polyphonic music</td>
<td>Selective attention</td>
<td>Listening to three voices to detect note changes embedded in a predetermined voice</td>
</tr>
<tr>
<td>Davison &amp; Banks (2003)</td>
<td>Two-tone melodic contours</td>
<td>Selective attention</td>
<td>Listening to two two-tone contours presented simultaneously to identify a contour direction played by a predetermined instrument timbre</td>
</tr>
<tr>
<td>Dowling (1973)</td>
<td>Melodies</td>
<td>Selective attention</td>
<td>Listening to two melodies presented simultaneously to detect a note deviation embedded in one of the melodies</td>
</tr>
<tr>
<td>Fujioka et al. (2005)</td>
<td>Melodic contours consisting of five tones</td>
<td>Divided attention</td>
<td>Listening to two melodies presented simultaneously to detect last-note alteration embedded either higher or lower voice</td>
</tr>
<tr>
<td>Shinn-Cunningham &amp; Ihlefeld (2004)</td>
<td>Two speech sentences</td>
<td>Selective attention</td>
<td>Identifying the content of a target sentence only while ignoring the content of a masker sentence</td>
</tr>
<tr>
<td>Gallun et al. (2007)</td>
<td>Two speech sentences</td>
<td>Sustained attention</td>
<td>Identifying the content of a target sentence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Selective attention</td>
<td>Identifying the content of a target sentence only while ignoring the content of a masker sentence</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Divided attention</td>
<td>Identifying the contents of both target and masker sentences</td>
</tr>
</tbody>
</table>
Commonalities in the structured use of melodic contours were found in previous studies. Across studies, melodic contours were controlled to activate different attention sub-types as follows: (1) the number of melodic contours, (2) the type of music listening tasks, and (3) instrument timbres and pitch distances. First, different attention sub-types were activated depending on the number of melodic contours presented. For example, one melodic contour was used to measure sustained attention (Bigand et al., 2000; Gallun et al., 2007; Shinn-Cunningham & Ihlefeld, 2004). Two melodic contours presented simultaneously were used to gauge selective attention or divided attention (Bigand et al., 2000; Byo, 1997; Crawley et al., 2002; Davison & Banks, 2003; Fujioka et al., 2005; Gallun et al., 2007; Janata et al., 2002; Shinn-Cunningham & Ihlefeld, 2004; Sato et al., 2001).

Second, different attention sub-types were activated depending on the type of music listening tasks. For example, listening to and identifying one melodic contour presented simultaneously with another melodic contour reflected the ability to use selective attention. Listening to and identifying two melodic contours while splitting focus equally was associated with the ability to use divided attention.

Third, attention sub-types were shaped by the use of different instrument timbres and pitch registers. Both musical elements provided perceptual cues that guided how individuals attended to two melodic contours. For example, a particular instrument timbre directed individuals to attend selectively to a pre-determined target voice (selective attention). Both instrument timbres and pitch registers helped individuals segregate complex, multi-layered music into individual melodic contours (divided attention).
Thus, the researcher decided to use melodic contours as attention assessment stimuli and to build an attention assessment measurement with the intention of measuring three attention sub-types. The number of melodic contours presented either individually or simultaneously and the manner of listening to them shaped the tasks given in each of the three attention subtests. Instrument timbres and/or pitch registers were used to categorize each subtest into two sections. In adapting Gallun et al.’s (2004) ideas, the instrument timbres and pitch registers were used to vary the degree of distraction/competition between two melodic contours given in different tasks.

The MAA, therefore, is a melodic contour identification task consisting of three attention subtests, labeled as MAA-Sustained (Sustained Attention Subtest), MAA-Selective (Selective Attention Subtest), and MAA-Divided (Divided Attention Subtest). Each of the three attention subtests is divided into two sections in which the instrument timbres and pitch registers are controlled. Table 3.3 presents overall construction of the MAA.

Table 3.3

*Tentative Model of the MAA*

<table>
<thead>
<tr>
<th>Subtests</th>
<th>Sections</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA</td>
<td>Test I. Instrument</td>
</tr>
<tr>
<td></td>
<td>Test II. Instruments</td>
</tr>
<tr>
<td>MAA-Sustained</td>
<td>Test III. Instruments and Noise</td>
</tr>
<tr>
<td>MAA-Selective</td>
<td>Test IV. Two Instruments</td>
</tr>
<tr>
<td>MAA-Divided</td>
<td>Test V. Two Instruments with Different Directions</td>
</tr>
<tr>
<td></td>
<td>Test VI. Same Instruments with Different Directions</td>
</tr>
</tbody>
</table>
Phase 3: Item Pool Construction of the MAA

The third phase describes how test items were created and assigned to each of the three attention subtests of the MAA. A series of five tones were adopted from Fyk’s (1995) study in which the author examined melodic contour recognition as it differed by direction, pitch range, and length of melodic contours. The stimuli used in the Fyk study were manipulated to create each of the three contours for this study, including “ascending” (Figure 3.1) and “descending” (Figure 3.2). The researcher created a “stationary” contour (Figure 3.3) by repeating a tone in the same pitch. Each contour was presented in each of the twelve major keys.

The quarter notes were presented in 4/4 meter at 96 beats per minute. The time duration of the test items was identical in the initial version of the MAA, and set at seven seconds for each test item based on the average attention span for healthy adults (Cornish, 2009; Finset et al., 1999; Lindahl, 2003; Mathias & Wheaton, 2007). The two melodic contours that were presented simultaneously in the Selective Attention Subtest (Section IV) and Divided Attention Subtest (Section V and VI) were in the perfect fifth key relationship. For example, if one melodic contour was presented in C major, the other melodic contour was presented in G major.

![Figure 3.1. Example of the ascending contour.](image-url)
In the MAA-Sustained, test items consisted of melodic contours that were played by the piano (Test I) and one of three different instrument timbres consisting of the piano, guitar, or flute (Test II). In the MAA-Selective, test items consisted of melodic contours presented simultaneously with distracting sounds. The distracting sounds consisted of environmental noises (e.g., rain, bird singing, clapping, laughing) (Test III), and another melodic contour sounded by different instrument timbre (Test IV). In the MAA-Divided, test items consisted of two melodic contours that were played by two different instrument timbres (Test V) and the same instrument timbres, for example two pianos, two flutes or two guitars (Test VI). Overall, the test items gradually increased in difficulty between and within each subtest.

Once the item pool construction was completed, the design and test items of the MAA were reviewed by consulting university faculty, including three persons with expertise in the fields of music therapy and musicology from a school of music and two persons with expertise in neuropsychology from a school of medicine, prior to field-testing. Figures 3.4, 3.5, and 3.6 are examples of test items given in each of the three attention subtests.
Phase 4: Pilot Study of the MAA

The fourth phase includes a description of the participants, the measures, the procedures, the statistical analyses, and the results of an initial evaluation of the MAA. The purpose of this phase was to field test the 48-test items of the initial version of the MAA with patients with TBI. This phase also aimed to examine comprehensibility and readability and to evaluate the preliminary item properties and internal consistency of the proposed measure.
Participants. Fifteen participants with a diagnosis of TBI were recruited from the inpatient and outpatient neurorehabilitation unit of Ryder Trauma Center at University of Miami Jackson Memorial Medical Center. The participants were eligible for the study if they had a score of less than 13 on the Glasgow Coma Scale (GCS) at the time of admission to the hospital or alternatively a Rancho Los Amigos Scale (RLAS) score of greater than V at time of brain injury assessment. Participants were required to have at least elementary English skills. Individuals with sensory perceptual impairments, such as visual or hearing impairments, were not eligible for the study.

Level of injury severity. The participant’s level of injury severity was identified using the Glasgow Coma Scale (Teasdale & Jennett, 1974). The Glasgow Coma Scale (GCS) is a brief assessment technique frequently used to evaluate severity of posttraumatic injury in patients whose consciousness is altered (i.e., Traumatic Brain Injury). The GCS has been widely accepted as the standard measure of awareness since the GCS scores represent depth of lesions. A lower GCS score is likely to be associated with lesions in the deep central gray matter of the brain stem rather than cortical or subcortical white matter lesions (Levin, Williams, Crofford, et al., 1988). In rehabilitation, the GCS score is used when a patient is admitted to the facility, since the GCS can indicate the patient’s level of consciousness and severity of injury, predict the course of development during the initial posttrauma period, and be a good predictor of outcome from other medical conditions (Bhagwanjee, Paruk, Moodley, & Muckart, 2000; Gotoh, Tamura, Yasui, et al., 1996; Mullie, Verstringe, Buylaert, et al., 1988; Plum & Carona, 1975).
The GCS score is obtained by summing the scores of different response
dimensions (i.e., eye opening, verbal response, motor response). The GCS ranges from 3
to 8, 9 to 12, and 13 to 15 are considered severe, moderate, and mild, respectively, in
evaluation of injury severity (Rimel, Giordani, Barth, & Jane, 1982). Participants in this
study must have had a GCS score less than 13, indicating moderate or severe level of
consciousness, and those who were classified as moderate and severe were considered to
be at a medium to low functioning level. The range of functioning level of participants
may help in the development of an investigator-made assessment with different types of
attention.

**Level of cognitive functioning.** The participants’ level of cognitive functioning
was identified using the Rancho Los Amigos Scale (Hagen, 1984; Hagen, Malkmus,
Durham, & Bowman, 1979). The Ranch Los Amigos Scale (RLAS) is a scale that is used
to assess the course of improvement in terms of the level of cognitive functioning in
patients with TBI. The cognitive functioning assessed by using the RLAS may include
responsiveness, orientation, information processing, attention, understating of verbal
commands, and performance of goal-directed behavior. Since the RLAS covers a broad
range of cognitive psychosocial relevant behaviors following TBI, clinicians may use the
RLAS for planning of therapeutic goals and placement (Mysiw, Corrigan, Hunt, et al.,
1989) as well as evaluation of treatment effects (Lal, Merbitz, & Grip, 1988; Razack,

The RLAS differentiates eight stages of recovery in cognitive functioning
typically seen after a brain injury. The Stages of the RLAS include no response,
generalized response, localized response, confused-agitated, confused-inappropriate,
confused-appropriate, automatic-appropriate, and purposeful and appropriate. In this study, participants who had an RLAS greater than level V are capable to respond to simple instructions consistently. However, they are agitated by external stimuli and respond to more complex commands in a non-purposeful manner.

**Procedures.** The pilot study was approved by two University of Miami ethics committees: the Human Subjects Research Office, a committee which reviews all studies involving human subjects; and the Clinical Research Review Committee (CRRC), a committee which reviews all studies involving patients registered in the Jackson Health System (JHS). In addition, the neurorehabilitation program director at JHS worked with the researcher to determine participant eligibility. After a careful review of patients’ medical records, the program director met with the patients and/or caregivers who were eligible to participate in the study. The researcher had a follow-up meeting with the patients and/or caregivers who indicated interest in the study. If the patients and/or caregivers decided to volunteer for the study, they signed an informed consent form (see Appendices A and B).

Once the informed consent letters were collected, a neurorehabilitation staff member arranged for the researcher to use a room at JHS. The researcher met each patient individually to administer the MAA. At time of administration, the patient was provided a short demographic questionnaire (Appendix C) and then took the MAA. The researcher provided guidance and was available to answer any participant questions. Approximate time to complete a total of 48 test items in the initial version of the MAA was 30 minutes.
Measures. The following measures were used in the fourth phase.

Demographic questionnaire. Patients completed a demographic questionnaire (as seen in Appendix C) prior to administration of the test. The 8-item questionnaire was researcher-designed and requested information concerning age, gender, ethnicity, date of the TBI, level of general education, and years of music education. The purpose of the questionnaire was to gather demographic information to describe the patient characteristics.

Music-based Attention Assessment. Patients completed the initial version of the MAA, a 48-item multiple-choice melodic-contour identification test, consisting of three attention subtests (i.e., MAA-Sustained, MAA-Selective, and MAA-Divided) with sixteen test items assigned to each subtest. The different tasks given in each of the three attention subtests required the patient to identify the direction(s) of: (a) a melodic contour (MAA-Sustained), (b) a target melodic contour heard against a distracting or competing sound (MAA-Selective), and (c) two simultaneously presented melodic contours that were played by different or the same instrument timbres (MAA-Divided). Detailed instructions were provided as a recorded prompt for test performance (see Appendix D).

Practice session items \( (n = 8) \) and practice exercise items \( (n = 8) \) were provided prior to actual test items. Practice session items were used to introduce the three directions of melodic contours and the three instrument timbres. Practice exercise items were used to familiarize participants with the actual test items in regards to how to circle the relevant choice. Practice items consisted of (a) six session items and six exercise items prior to the MAA-Sustained, and (b) two session items and two exercise items prior to the MAA-Divided. There was a five-second silent interval between the presentation of
each musical stimulus. Five-second silence was given between test items and the initial version of the MAA required approximately 30 minutes for completion.

Participants identified the directions of the targeted melodic contours by circling one of the choices that indicated each of the melodic contours on the given answer sheet (see Appendix E). Participants’ responses were marked as correct or incorrect/unanswered. Each item on a completed answer sheet was coded as 1 (i.e., correct) or 0 (i.e., incorrect or unanswered). When participants circled a “Not sure” option instead of options for a specific contour direction (e.g., up, same, down), the test item was awarded zero points same as incorrect answers. Sixteen points were allotted to each of the three subtests, for a total possible test score of 48.

**Materials.** Patients were provided sound items via a laptop computer amplified with speakers (Insignia 2.0 Pedal Speaker System, NS-2024). Sound items of the MAA were produced and recorded by using a music synthesizer (Korg N5EX) and Logic MIDI software (version 8.0) The MAA was then programmed into iTunes (version 10.0), a digital media player application developed for the purpose of playing and organizing digital music.

**Data analysis.** The statistical analyses utilized in this study were adapted from measurement theories of music (Boyle & Radocy, 1987; Gordon, 1998) and previous research studies concerning the development and validation of music therapy assessment tools (Magee, 2007; York, 1994; Lipe, 1995). Data were collected and analyzed to obtain (a) demographics, (b) item characteristics (i.e., item difficulty and item discrimination), and (c) scale characteristics (i.e., descriptive statistics, and internal consistency as computed by Cronbach’s alpha). Item properties were analyzed by using the indices of
item difficulty \((IF)\) and item discrimination \((ID)\). Descriptive analyses of the test scores included the number of patients \((n)\), number of test items \((N)\), mean \((M)\), and standard deviation \((SD)\). Internal consistency was estimated by using Cronbach’s \(\alpha\) coefficients \((\alpha)\).

**Results and discussion.** The evaluation of the initial version of the MAA described preliminary psychometric properties of the scale and test items. Results of the study are reported along with the discussion (see Appendix F). This pilot study has been accepted for publication at the Journal of Music Therapy (Jeong & Lesiuk, 2011).

**Phase 5: Revision of the MAA**

The fifth phase justified the decision to revise the 48 test items of the initial version of the MAA. A second pilot study, approved by the University of Miami Institutional Review Board (IRB), involved healthy adults \((N = 30)\). The purpose of the study was to investigate the construct validity of the MAA. The result of the second pilot revealed a ceiling effect on the test, as shown in the total test scores, which are a summed-up score of three attention subtest scores \((M = 46.4, SD = 3.11)\). A Cronbach’s \(\alpha\) estimated at .917 indicated that internal consistency of the MAA remained high with healthy adults. The high \(\alpha\) coefficient suggested that the initial MAA was a potentially reliable measurement for assessing auditory attention of patients with TBI as well as healthy adults. However, given that the perfect score of the initial MAA was 48 points, the total mean scores indicated that the MAA was too easy for healthy populations. The decision to revise the initial MAA was based upon the descriptive findings of the second pilot study.
For the test revision, test items were recreated with the purpose of varying the level of difficulty of the test items, which contributed to producing more varied test items. The melodic contours (Fyk, 1995), a series of five tones, were used in a consecutive manner to vary the time duration of each test item, including short, medium, and long. Test items with a short length were a set of five tones with a 3-second presentation time. Test items with a medium length were two sets of five tones with a 5-second presentation time. Test items with a long length were three sets of five tones with a 10-second presentation time. The quarter notes were presented in 4/4 meter at 112 beats per minute. Figures 3.7, 3.8, and 3.9 are examples of melodic contours that were varied by time duration and the number of tones.

Figure 3.7. Example of a test item with one set of five tones: Short.

Figure 3.8. Example of a test item with two sets of five tones: Medium.

Figure 3.9. Example of a test item with three sets of five tones: Long.
The varied melodic contours were used to construct the item pool of the revised version of the MAA. The figures below present test items given in each subtest. Since one melodic contour was presented in MAA-Sustained, examples of test items given in MAA-Sustained are identical to Figures 3.7, 3.8, and 3.9. Figures 3.10, 3.11, and 3.12 represent test items that were given in MAA-Selective. Figures 3.13, 3.14, and 3.15 represent test items that were given in MAA-Divided.

*Figure 3.10.* Example of a test item in the MAA-Selective subtest: Short. The top line is an environmental noise.

*Figure 3.11.* Example of a test item in the MAA-Selective subtest: Medium. The top line is an environmental noise.
Figure 3.12. Example of a test item in the MAA-Selective subtest: Long. The top line is an environmental noise.

Figure 3.13. Example of a test item in the MAA-Divided subtest: Short.

Figure 3.14. Example of a test item in the MAA-Divided subtest: Medium.

Figure 3.15. Example of a test item in the MAA-Divided subtest: Long.
Once the item pool construction for the revised version of the MAA was completed, test items were reviewed with representative field-expert individuals (i.e., adults with non-music experience, non-music major undergraduate students, music-major doctoral students, etc). Revisions and eliminations of relevant test items were conducted based on this feedback.

**Phase 6: Evaluation and Validation of the MAA**

The sixth phase included investigations of the construct validity and reliability of the revised version of the MAA. A principal axis factoring method with direct oblimin rotation was completed to identify the latent factors that underlie test items of the revised measure. Additionally, item analysis and reliability investigations were conducted.

**Participants.** The 54-item, revised version of the MAA was administered to 187 adults, including both healthy adults \((n = 165)\) and patients with TBI \((n = 22)\). Healthy adults were students who attended an Intensive English Program \((n = 56)\), and college students who were taking an Introduction to Psychology course \((n = 109)\) at the University of Miami. Clinical patients had a diagnosis of TBI \((n = 22)\) recruited from the inpatient and outpatient neurorehabilitation unit of a South Florida hospital. The inclusion criteria for the patients for this phase remained the same as in the fourth phase.

The sample size was determined based on guidelines from previous studies, concerning a sufficient sample size for factor analysis (Asmus, 1981; Klein, 2005). The purpose of including different populations was to increase the variability of the responses and to increase the sample size for factor analysis. The inclusion of clinical as well as non-clinical populations was justified based on previous measurement development.
studies (Advokat, Martino, & Gouvier, 2007; Hufford & Fastenau, 2005; Meyers & Rohling, 2004).

**Procedures.** This study was approved by two University of Miami ethics committees: the Human Subjects Research Office, a committee which reviews all studies involving human subjects; and the CRRC, a committee which reviews all studies involving patients registered in JHS.

The healthy adults were identified via the director of the Intensive English Program and the chairman of the Psychology Department at the University of Miami, who both granted permission for this study. The researcher posted available dates, times, and sites for the experiment on a website, and students signed up electronically. At the time of administration, the researcher explained the purpose of the study. If the participants decided to volunteer for the study, they showed their intention to participate by signing an informed consent form (see Appendix G). The participants filled out a demographic questionnaire and then were administered the MAA. The researcher provided guidance and was available to answer any questions. For patients with TBI, the recruitment procedures and documents used were identical to those in the fourth phase (as seen in Appendices A and B). The time to complete the revised version of the test was shortened from 30 to 20 minutes.

**Measures.** The following measured were used in the sixth phase.

**Demographic questionnaire.** Healthy adults completed a demographic questionnaire (see Appendix H) prior to administration of the test. The 7-item questionnaire was researcher-designed and requested information concerning the participant’s age, gender, ethnicity, level of general education, and years of music
education. The purpose of the questionnaire was to gather demographic information to describe participant characteristics. Patients with TBI completed a demographic questionnaire that was identical to the one used in the fourth phase of the study (as seen in Appendix C).

**Revised Music-based Attention Assessment.** Healthy adults and patients with TBI completed the revised version of the MAA, a 54-item multiple-choice melodic-contour identification test, consisting of three attention subtests (i.e., MAA-Sustained, MAA-Selective, and MAA-Divided) with eighteen test items assigned to each. The theoretically based model of attention remained the same for the revised version of the MAA. The tasks given in each of the three attention subtests were identical with those given in the initial version of the MAA. Detailed instructions were provided via a recorded vocal prompt before each section (see Appendix I).

For the revised version of the MAA, the time duration of test items varied depending on the number of tones presented (see phase 5 for more information). The item length was identical between all test items for the initial version of the MAA; however, the item length ranged from short to long for the revised version of the MAA. For each section, three short test items were presented, followed by three medium and three long test items. Overall, the test items gradually increased in difficulty between and within each subtest. So, the researcher assumed that the score would be highest in the MAA-Sustained and the lowest in the MAA-Divided. Note score of actual test items is included in Appendix J.

Practice session items \((n=6)\) and practice exercise items \((n=3)\) were provided prior to actual test items being presented. Different contour directions and instrument timbres
were introduced during the practice sessions. Examples of test items with varied time
duration were also presented during the practice exercises. Participants were instructed to
circle the relevant choice from the options given on the answer sheet during the 5-second
silence given between test items (i.e., after the beep was heard). There was a five-second
silent interval between the presentation of each musical stimulus. The MAA required
approximately 20 minutes for completion.

Participants identified the directions of the given melodic contours by circling
their choice from options given on an answer sheet (see Appendix K). Participants’
responses were marked as correct or incorrect/unanswered. Each item on a completed
answer sheet was coded as 1 (i.e., correct) or 0 (i.e., incorrect or unanswered). In case the
participants did not answer two consecutive test items, the researcher skipped the subtest
and then went to the next subtest. The unanswered test items were considered incorrect.
When participants circled a “Not sure” option instead of options for a specific contour
direction (e.g., up, same, down), the test item was regarded as incorrect. Eighteen points
were allotted to each of the three subtests, for a total possible test score of 54.

Materials. All equipment used was the same as in Phase 4.

Data analysis. Once the answer sheets were collected, the researcher deleted the
names of the participants and any other identifying information and then assigned
numbers for correlation purposes. Participants’ responses were marked as correct or
incorrect/unanswered. The marked test items were coded as 1 (i.e., correct) or 0 (i.e.,
incorrect or unanswered). The scores were analyzed by conducting exploratory factor
analysis, item analysis, reliability analysis, and Multivariate Analysis of Variance
(MANOVA) in the Statistical Package for Social Science (SPSS) version 17.0. The
statistical analyses performed in this study were adopted from measurement theories of
music (Boyle & Radocy, 1987; Gordon, 1998), quantitative research methods in music
education (Asmus, 1980, 1981, 1989, 1999; Asmus & Radocy, 2006; Russell, 2007), and
previous research studies concerning development of music therapy assessment tools

A total of 54 test item scores were factor analyzed by using the principal axis
factoring method with direct oblimin rotation. Results of exploratory factor analyses
included Kaiser-Meyer-Oklin Measure of Sampling Adequacy (MSA), Bartlett’s Test of
Sphericity, scree plot of eigenvalues, variance analysis (%), and rotated factor loadings.
Item properties were analyzed by using indices of item difficulty (item mean, $M$) and
item discrimination (corrected item-total correlation, $r$). Reliability was investigated by
computing split-half coefficients with Spear-Brown correction ($r$) and Cronbach’s $\alpha$
coefficients ($\alpha$). For the MANOVA, the independent variable was group (i.e., healthy
adults and patients with TBI) and the dependent variables were the factor scores on each
of the exploratively obtained factor constructs. The factor scores ($r$) were computed using
the factor score coefficient matrix from the overall factor analysis solution and
multiplying by the corresponding variable $z$ scores for the corresponding variances.
Results of the analysis included the number of patients ($n$), sum of squares ($SS$), degree of
freedom ($df$), F-ratio ($F$), and significance ($p$). Each statistical method used in the present
study is described in Appendix L.
CHAPTER 4

Results

This chapter reports the results obtained from the analysis of the data. The chapter begins with participants’ demographic characteristics. The chapter then discusses the factor constructs, reliabilities, and the inferential results from the statistical analyses in order to address the three research questions.

Demographics

**Descriptive analysis.** To investigate demographic characteristics, a descriptive analysis was completed by using the Statistical Package for the Social Sciences (SPSS) version 17.0. The descriptive results of the sample’s demographic characteristics, presented in Table 4.1, include number of participants \( (n) \), mean \( (M) \), standard deviation \( (SD) \), and percentage \( (%) \).
Table 4.1
Demographic Characteristics

<table>
<thead>
<tr>
<th>Variables</th>
<th>Healthy Adults ((n = 165))</th>
<th>Patients with TBI ((n = 22))</th>
<th>Total ((n = 187))</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Continuous</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>20.42 (±5.90)</td>
<td>35.45 (±15.08)</td>
<td>22.19 (±8.94)</td>
</tr>
<tr>
<td>Education</td>
<td>13.82 (±1.98)</td>
<td>14.09 (±3.00)</td>
<td>13.85 (±2.11)</td>
</tr>
<tr>
<td>Music Education</td>
<td>4.51 (±4.02)</td>
<td>1.14 (±1.47)</td>
<td>4.12 (±3.96)</td>
</tr>
<tr>
<td><strong>Categorical</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>67 (40.60)</td>
<td>15 (68.20)</td>
<td>82 (43.90)</td>
</tr>
<tr>
<td>Female</td>
<td>98 (59.40)</td>
<td>7 (31.80)</td>
<td>105 (56.10)</td>
</tr>
<tr>
<td>Total</td>
<td>156 (100)</td>
<td>22 (100)</td>
<td>187 (100)</td>
</tr>
<tr>
<td>Ethnicity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Caucasian</td>
<td>63 (38.20)</td>
<td>4 (18.20)</td>
<td>67 (35.80)</td>
</tr>
<tr>
<td>African American</td>
<td>4 (2.40)</td>
<td>1 (4.50)</td>
<td>5 (2.70)</td>
</tr>
<tr>
<td>Hispanic</td>
<td>36 (21.80)</td>
<td>17 (77.30)</td>
<td>53 (28.30)</td>
</tr>
<tr>
<td>Asian/Pacific Islanders</td>
<td>45 (27.30)</td>
<td>0 (0.00)</td>
<td>45 (24.10)</td>
</tr>
<tr>
<td>Others</td>
<td>17 (10.30)</td>
<td>0 (0.00)</td>
<td>17 (9.10)</td>
</tr>
<tr>
<td>Total</td>
<td>165 (100)</td>
<td>22 (100)</td>
<td>187 (100)</td>
</tr>
</tbody>
</table>
The results of group comparison, shown in Table 4.2, include degree of freedom (df), t score (continuous variables), chi-square score (categorical variables), p value (continuous variable), and Φ value (categorical variable). Table 4.2 shows that the two groups did not differ by ethnicity or education. However, the groups did differ significantly by age, gender, and music education (See Table 4.2). Differences between groups could have been due to the sampling strategy (i.e., school-based and clinically-convenient sampling strategies) used for the current study, as discussed in Chapter 5.

Table 4.2

Demographic Differences between Groups

<table>
<thead>
<tr>
<th>Variables</th>
<th>df</th>
<th>statistic</th>
<th>sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Continuous</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>185</td>
<td>-8.798</td>
<td>.000***</td>
</tr>
<tr>
<td>Education</td>
<td>185</td>
<td>-.573</td>
<td>.567</td>
</tr>
<tr>
<td>Music Education</td>
<td>185</td>
<td>3.897</td>
<td>.000***</td>
</tr>
<tr>
<td>Categorical</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender</td>
<td>1</td>
<td>2.829</td>
<td>.093</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>4</td>
<td>70.674</td>
<td>.000***</td>
</tr>
</tbody>
</table>

Notes: Independent sample t-test was used for categorical variables of Age, Education and Music Education (N=187). * p < .05, ** p < .01, *** p < .001. Chi-square Test was used for categorical variables of Gender and Ethnicity. * Φ < .05, ** Φ < .01, *** Φ < .001.
For patients with TBI, an average of 223 days had passed since date of the injury ($SD = 160.18$). The severity of brain injury and level of cognitive functioning were obtained from the participants’ medical records as measured by the GCS and the RLAS. The average GCS score of 7.30 ($SD = 4.04$) indicated that most patients had a severe level of brain injury. The RLAS score was averaged at 7.43 ($SD = 0.51$) at the time of neuropsychological assessment and indicated that the persons were in either the automatic-appropriate (VII) or purposeful-appropriate (VIII) stage at the time of brain injury assessment.

**Research Question #1:** What are the latent factor constructs that underlie test items of the MAA? This first research question is broken down into two sub-research questions as follows.

**Research Question #1-1:** Are the factor constructs of sustained attention, selective attention, and divided attention adequately represented by the test items presented in the MAA?

**Research Question #1-2:** Which test items are good indicators of each factor construct? Does each factor construct include at least four test items that are unique to the factor construct?

**Exploratory Factor Analysis**

The first half of the first research question (i.e., Research Question #1-1) is an examination of the emergent factor solutions from the obtained data. To address this research question, the principal axis factoring with direct oblimin rotation was performed using SPSS version 17.0. A sample of 187 cases was used to analyze the original 54 test items of the MAA. Factors were identified following the criteria outlined in previous
research (Asmus, 1989): (a) factors with an eigenvalue greater than 1.0, (b) factors above
the critical point as identified by the scree plot, and (c) distribution of factor loadings.

The Kaiser-Meyer-Oklin Measure of Sampling Adequacy (MSA) was .856 and
indicated a matrix suitable for factoring. The Bartlett’s Test of Sphericity was significant
(see Table 4.3). The factor analysis produced a 14-factor solution with eigenvalues
greater than one, which accounted for 66.79% of the variance in the total scores of the
revised MAA (see Table 4.4).

Table 4.3

*Measure of Sampling Adequacy for Item Pool*

<table>
<thead>
<tr>
<th></th>
<th>Chi-square</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiser-Meyer-Oklin Measure of Sampling Adequacy</td>
<td>.856</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bartlett’s Test of Sphericity</td>
<td>5638.273</td>
<td>1431</td>
<td>.000</td>
</tr>
</tbody>
</table>
Table 4.4

*Initial Eigenvalues and Variance Analysis of Item Pool*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Eigenvalue</th>
<th>% of Variance</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>15.899</td>
<td>29.443</td>
<td>29.443</td>
</tr>
<tr>
<td>2</td>
<td>3.224</td>
<td>5.970</td>
<td>35.413</td>
</tr>
<tr>
<td>3</td>
<td>2.185</td>
<td>4.047</td>
<td>39.460</td>
</tr>
<tr>
<td>4</td>
<td>2.042</td>
<td>3.782</td>
<td>43.242</td>
</tr>
<tr>
<td>5</td>
<td>1.594</td>
<td>2.952</td>
<td>46.194</td>
</tr>
<tr>
<td>6</td>
<td>1.569</td>
<td>2.905</td>
<td>49.099</td>
</tr>
<tr>
<td>7</td>
<td>1.460</td>
<td>2.704</td>
<td>51.803</td>
</tr>
<tr>
<td>8</td>
<td>1.384</td>
<td>2.563</td>
<td>54.367</td>
</tr>
<tr>
<td>9</td>
<td>1.260</td>
<td>2.334</td>
<td>56.701</td>
</tr>
<tr>
<td>10</td>
<td>1.218</td>
<td>2.255</td>
<td>58.956</td>
</tr>
<tr>
<td>11</td>
<td>1.119</td>
<td>2.073</td>
<td>61.029</td>
</tr>
<tr>
<td>12</td>
<td>1.073</td>
<td>1.988</td>
<td>63.016</td>
</tr>
<tr>
<td>13</td>
<td>1.034</td>
<td>1.915</td>
<td>64.931</td>
</tr>
<tr>
<td>14</td>
<td>1.005</td>
<td>1.861</td>
<td>66.793</td>
</tr>
</tbody>
</table>
A scree test was performed to illustrate the range of prospective attention factors. The use of eigenvalues greater than one can lead to an overestimation of the number of factors to retain. The scree plot is more useful in identifying central factors (Floyd & Widaman, 1995). A marked gap existed between the first factor and the remaining factors and moderate gaps existed between the second and third factors as well as the fourth and fifth factors (see Figure 4.1). Therefore, based on a visual inspection of the scree plot, no fewer than 3 factors were extracted. Additional extractions between 3 and 6 factors were specified using SPSS.

*Figure 4.1. Scree Plot of the 54-Item MAA.*
The rotated factor structures between 3 and 6 resulted in various combinations of the attention dimensions represented in the item pool: MAA-Sustained Test I, Test II, MAA-Selective Test III, Test IV, MAA-Divided Test V, and Test VI. The three-factor rotation produced a complex factor structure that spread loadings for one factor across several sections of the MAA. The three-factor rotation resulted in three separate components. The distribution of factor loadings indicated a combination of: (a) MAA-Sustained Test I, Test II, MAA-Selective Test III, and Test IV, and MAA-Divided Test V, Test VI; (b) MAA-Sustained Test I, Test II, MAA-Selective Test III, and Test IV; and (c) MAA-Selective Test III, Test IV, MAA-Divided Test V, and Test VI (See Table 4.5). The interpretation of the first three factors in this solution suggested that a less complex solution than a three-factor solution existed.

Table 4.5

*Three-Factor Structure*

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA-Sustained Test I, Test II</td>
<td>MAA-Sustained Test I, Test II</td>
<td>MAA-Selective Test III, Test IV</td>
<td></td>
</tr>
<tr>
<td>MAA-Selective Test III, Test IV</td>
<td>MAA-Selective Test III, Test IV</td>
<td>MAA-Divided Test V, Test VI</td>
<td></td>
</tr>
<tr>
<td>MAA-Divided Test V, Test VI</td>
<td>MAA-Divided Test V, Test VI</td>
<td>MAA-Divided Test V, Test VI</td>
<td></td>
</tr>
</tbody>
</table>
The four-factor rotation resulted in four separate components. The distribution of factor loadings indicated a combination of: (a) MAA-Sustained Test I, Test II, MAA-Selective Test III, and Test IV; (b) MAA-Sustained Test I, Test II, MAA-Selective Test III, and Test IV; (c) MAA-Divided Test V, and Test VI; and (d) MAA-Selective Test III, Test IV, MAA-Divided Test V, and Test VI (See Table 4.6). Three- and four-factor structures were not retained because complex factors were comprised of multiple subtests as well as cross-loaded items, which refers to items that have strong relationships with more than one factor, leading to problems when interpreting the resulting factors (Hair et al., 2010).

Table 4.6

*Four-Factor Structure*

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA-Sustained Test I, Test II</td>
<td>MAA-Sustained Test I, Test II</td>
<td>MAA-Divided Test V, Test VI</td>
<td>MAA-Selective Test III, Test IV</td>
</tr>
<tr>
<td>MAA-Selective Test III, Test IV</td>
<td>MAA-Selective Test III, Test IV</td>
<td></td>
<td>MAA-Divided Test V, Test VI</td>
</tr>
</tbody>
</table>

The five-factor rotation resulted in five separate components. The distribution of factor loadings indicated a combination of: (a) MAA-Sustained Test I, Test II, MAA-Selective Test III, and Test IV; (b) MAA-Sustained Test I, Test II, MAA-Selective Test III, and Test IV; (c) MAA-Divided Test V, and Test VI; (d) MAA-Selective Test III, Test IV, MAA-Divided Test V, and Test VI; and (e) MAA-Selective Test III (See Table 4.7).
Table 4.7

*Five-Factor Structure*

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>MAA-Sustained Test I, Test II</td>
<td>MAA-Sustained Test I, Test II</td>
<td>MAA-Divided Test V, Test VI</td>
<td>MAA-Selective Test III, Test IV</td>
<td>MAA-Selective Test III</td>
</tr>
<tr>
<td></td>
<td>MAA-Selective Test III, Test IV</td>
<td>MAA-Selective Test III, Test IV</td>
<td>MAA-Divided Test V, Test VI</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The six-factor solution continued the pattern of cross loading. The six factor solution yielded the factors of: (a) MAA-Sustained Test II, MAA-Selective Test III, Test IV, and MAA-Divided Test VI; (b) MAA-Sustained Test I, Test II, MAA-Selective Test III, and Test IV; (c) MAA-Selective Test IV, MAA-Divided Test V, and Test VI; (d) MAA-Divided Test V and Test VI; (e) MAA-Selective Test III; and (f) MAA-Sustained Test I, Test II, and MAA-Selective Test III (See Table 4.8).

Factor solutions beyond seven factors continued the pattern of cross loading. Since the purpose of the exploratory factor analysis was to establish a simple factor solution, the analyses with more than seven-factor solutions were not acceptable. The factor loadings for the three-, four-, five-, and six- factor solutions are presented in Appendices M, N, O, and P.

Ultimately, the five-factor model was retained for further analyses. The model demonstrated that factors were easily distinguishable and identifiable (at least 3 test items solely loading under each factor at greater than .30). The distribution of factor loadings illustrated the cluster of interrelated items in each category.
The second half of this research question investigated test items that were good indicators of each factor construct. The principal axis factoring method using direct oblimin rotation was conducted again, this time restricting the factor analysis to a five-factor solution. The pattern matrix was examined to identify the test items with the highest loadings on the factor they were selected to represent. Test items of the MAA were selected based on the pattern matrix obtained.

Emergent factors that met all of the following criteria were retained: (a) factors with an eigenvalue greater than 1.0, (b) factors above the critical point as identified by the scree plot, and (c) factors with two or more items loading at significant levels (i.e., factor loading equaled or exceeded 0.30) (Floyd & Widaman, 1995). This process was repeated until all items loaded under only one factor with loadings greater than .30.
Groups of test items that were cross-loaded and that had factor loadings less than .30 were not considered for inclusion on future analyses of the MAA.

Forty-five test items out of fifty-four were selected for inclusion on the MAA. Factor loadings on the final forty-five test items are shown in Table 4.9. In Table 4.9, Factor 1, color-coded pink, represents performance on MAA-Selective and MAA-Divided where test items consisted of two separate melodic contours presented at short to long length. Factor 2, color-coded yellow, represents performance on MAA-Sustained where test items consisted of one melodic contour presented at short length. Factor 3, color-coded green, represents performance on MAA-Divided where test items consisted of two separate melodic contours presented at long length. Factor 4, color-coded light blue, represents MAA-Sustained where test items were one melodic contour presented at medium to long length. Factor 5, color-coded dark blue represents MAA-Selective where test items were one melodic contour heard against an environmental noise. A total of nine test items were eliminated and not included for further analysis.

Each factor was labeled: (a) Selective & Divided (Factor 1), (b) Sustained-Short (Factor 2), (c) Divided-Long (Factor 3), (d) Sustained-Med to Long (Factor 4), and (e) Selective-Noise (Factor 5). The test items were distributed as follows: (a) 16 test items for Factor 1, (b) 4 test items for Factor 2, (c) 6 test items for Factor 3, (d) 13 test items for Factor 4, and (e) 6 test items for Factor 5. Items selected for the MAA had higher loadings on the factor that they were selected to represent than any other factor. For example, a test item chosen for the Selective & Divided factor had a highest loading on Factor 1.
### Table 4.9

*Finalized Factor Loadings for the 45-item MAA*

<table>
<thead>
<tr>
<th>Test items</th>
<th>Factors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td>Melody-Instrument-Length-Direction</td>
<td></td>
</tr>
<tr>
<td>Direction: Up (U), Same (S), Down (D)</td>
<td></td>
</tr>
<tr>
<td>Melody1-Piano-Short-(U)</td>
<td>.180</td>
</tr>
<tr>
<td>Melody1-Piano-Short-(S)</td>
<td>-.122</td>
</tr>
<tr>
<td>Melody1-Piano-Short-(D)</td>
<td>-.116</td>
</tr>
<tr>
<td>Melody1-Piano-Long-(D-S-U)</td>
<td>.239</td>
</tr>
<tr>
<td>Melody1-Piano-Long-(U-D-S)</td>
<td>.123</td>
</tr>
<tr>
<td>Melody1-Piano-Long-(S-U-D)</td>
<td>.301</td>
</tr>
<tr>
<td>Melody1-Piano-Short-(S)</td>
<td>-.005</td>
</tr>
<tr>
<td>Melody1-Piano-Short-(U)</td>
<td>.148</td>
</tr>
<tr>
<td>Melody1-Guitar-Med-(D-S)</td>
<td>-.022</td>
</tr>
<tr>
<td>Melody1-Piano-Med-(S-U)</td>
<td>-.183</td>
</tr>
<tr>
<td>Melody1-Flute-Med-(D-S)</td>
<td>.173</td>
</tr>
<tr>
<td>Melody1-Guitar-Long-(U-D-S)</td>
<td>.320</td>
</tr>
<tr>
<td>Melody1-Flute-Long-(S-U-D)</td>
<td>.052</td>
</tr>
<tr>
<td>Melody1-Piano-Long-(U-D-U)</td>
<td>.246</td>
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Table 4.9 continues
<table>
<thead>
<tr>
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<th>3</th>
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<td>Direction: Up (U), Same (S), Down (D)</td>
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<tr>
<td>Melody1-Guitar-Short-(D) Rain</td>
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<td>.040</td>
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<td>-.031</td>
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<td>-.024</td>
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<td>-.035</td>
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<td>.843</td>
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<td>.040</td>
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<td>Melody1-Flute-Long-(U-D-U) Melody2-Piano-Long-(S-U-D)</td>
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<td>-.021</td>
<td>.637</td>
<td>.051</td>
<td>.049</td>
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<td>Melody1-Piano-Short-(U) Melody2-Piano-Short-(S)</td>
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<td>-.078</td>
<td>.166</td>
<td>.006</td>
<td>-.021</td>
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<td>Melody1-Guitar-Short-(D) Melody2-Guitar-Short-(D)</td>
<td>.305</td>
<td>-.083</td>
<td>.066</td>
<td>-.144</td>
<td>-.122</td>
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<tr>
<td>Melody1-Flute-Short-(U) Melody2-Flute-Short-(D)</td>
<td>.315</td>
<td>-.044</td>
<td>.101</td>
<td>-.090</td>
<td>-.023</td>
</tr>
<tr>
<td>Melody1-Guitar-Med-(U-D) Melody2-Guitar-Med-(S-D)</td>
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<td>-.002</td>
<td>.215</td>
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<td>-.042</td>
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<tr>
<td>Melody1-Piano-Med-(U-D) Melody2-Piano-Med-(D-U)</td>
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<td>.019</td>
<td>.250</td>
<td>-.030</td>
<td>-.060</td>
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<tr>
<td>Melody1-Flute-Long-(S-D-U) Melody2-Flute-Long-(U-S-U)</td>
<td>.119</td>
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<td>.440</td>
<td>.022</td>
<td>-.037</td>
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<tr>
<td>Melody1-Piano-Long-(D-U-D) Melody2-Piano-Long-(S-U-S)</td>
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<td>.008</td>
<td>.590</td>
<td>-.040</td>
<td>-.036</td>
</tr>
<tr>
<td>Melody1-Piano-Long-(U-D-U) Melody2-Piano-Long-(D-S-D)</td>
<td>-.040</td>
<td>.003</td>
<td>.504</td>
<td>-.077</td>
<td>-.030</td>
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</table>
The factor loadings obtained in this exploratory factor analysis ranged from -.706 to .701. Larger magnitude factor loadings indicated a stronger relationship between a given test item and the principal factor. All MAA test items except four items maintained low secondary loadings of .30 or below. The four test items (i.e., MAA-Sustained Test I Item 9, Test II Item 7, Selective Test III Item 8, and Test IV Item 9) had secondary loadings above .30. However, retaining the items was considered appropriate for the purpose of the MAA since removing these test items proved problematic in subsequent analyses.

To confirm the stability of the identified factor structure, confirmatory factor analysis was performed on the 45 selected test items. The principal axis factoring method with direct oblimin rotation was used to confirm the five-factor solution. The results were examined for the following basic criteria (Asmus, 1989): (a) factors with an eigenvalue greater than 1.0, (b) factors above the critical point as identified by the scree plot, and (c) distribution of factor loadings.

The Kaiser-Meyer-Oklin Measure of Sampling Adequacy (MSA) was .869 with a subject-to-variable ratio of 4.16:1 (see Table 4.10). The percentage of variance accounted for by this five-factor structure was 48.832% (see Table 4.11). Both are deemed appropriate according to the criteria presented by Asmus (1989). The results of the confirmatory factor analysis as well as the reliability analysis established the stability of the five-factor structure.
Table 4.10

*Measure of Sampling Adequacy for the 45-item MAA*

<table>
<thead>
<tr>
<th>Measure of Sampling Adequacy</th>
<th>Chi-square</th>
<th>df</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaiser-Meyer-Oklin Measure of Sampling Adequacy</td>
<td>4357.388</td>
<td>990</td>
<td>.000</td>
</tr>
<tr>
<td>Bartlett’s Test of Sphericity</td>
<td>4357.388</td>
<td>990</td>
<td>.000</td>
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Table 4.11

*Final Eigenvalues and Variance Analysis of the 45-item MAA*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Eigenvalue</th>
<th>% of Variance</th>
<th>Cumulative %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Selective &amp; Divided</td>
<td>13.686</td>
<td>30.413</td>
<td>30.413</td>
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<tr>
<td>Sustained-Short</td>
<td>2.957</td>
<td>6.572</td>
<td>36.985</td>
</tr>
<tr>
<td>Divided-Long</td>
<td>2.061</td>
<td>4.580</td>
<td>41.565</td>
</tr>
<tr>
<td>Sustained-Med to Long</td>
<td>1.773</td>
<td>3.940</td>
<td>45.505</td>
</tr>
<tr>
<td>Selective-Noise</td>
<td>1.497</td>
<td>3.327</td>
<td>48.832</td>
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</table>
Research Question #2: What are the item properties and the reliabilities of the MAA, in relation to the exploratively obtained factor constructs?

Item Properties

The second research question addressed the item properties of the 45-item of the MAA. To answer the research question, item properties were analyzed by computing the indices of item difficulty (item mean, $M$) and item discrimination (corrected item-total
correlation, $r$). Test reliability was examined by calculating split-half coefficients with Spearman-Brown correction ($r$) and Cronbach’s $alpha$ coefficients ($\alpha$). The analyses were conducted using SPSS version 17.0.

Item analysis was performed to examine whether (a) the item means were normally distributed, and 2) whether the test items fell above the conventional minimum thresholds of item discrimination (i.e., corrected item-total correlation $> .20$) and Cronbach’s $alpha$ (i.e., $\alpha > .80$). Item difficulty was calculated by the percentage of participants who answered a given item correctly (i.e., the item mean score). Item discrimination was calculated by the correlation between participants’ responses to a given test item and their total item scores not including the test item (i.e., corrected item-total correlation). Additionally, Chronbach’s $alpha$ for the individual test items indicates what the $alpha$ statistics for the subtest would be if the item were deleted. Item analysis statistics are shown in Table 4.12.

**Item difficulty.** Item difficulty ranged from .048 to .962, indicating a wide range of item difficulty. Seventeen test items were shown at the moderate level of item difficulty (i.e., $0.4 \leq p < 0.8$). Twenty-one test items of the MAA-Sustained Test I and Test II, and MAA-Selective Test III were very easy (i.e., $0.8 \leq p < 1$), while seven test items of MAA-Divided Test V and Test VI were relatively difficult (i.e., $0 < p < 0.4$).
Table 4.12

*Test Item Analysis Statistics for the 45-Item MAA*

<table>
<thead>
<tr>
<th>Factor</th>
<th>Item</th>
<th>Mean</th>
<th>SD</th>
<th>Corrected item-total correlation</th>
<th>alpha if the item deleted</th>
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<td>.190</td>
<td>.389</td>
<td>.939</td>
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<tr>
<td></td>
<td>2</td>
<td>.983</td>
<td>.126</td>
<td>.307</td>
<td>.940</td>
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<tr>
<td></td>
<td>3</td>
<td>.962</td>
<td>.190</td>
<td>.466</td>
<td>.939</td>
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<td></td>
<td>4</td>
<td>.957</td>
<td>.203</td>
<td>.432</td>
<td>.939</td>
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<td>.621</td>
<td>.938</td>
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<td>2</td>
<td>.860</td>
<td>.347</td>
<td>.616</td>
<td>.938</td>
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<td>3</td>
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<td>.462</td>
<td>.603</td>
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<th>Mean</th>
<th>SD</th>
<th>Corrected item-total correlation</th>
<th>$alpha$ if the item deleted</th>
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<td>MAA-Divided-Long</td>
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<td>.940</td>
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</table>

**Item discrimination.** Item discrimination, as computed by corrected item-total correlation, ranged from .218 to .714. The corrected item-total correlations met the conventional minimum thresholds of 0.20 for all test items, indicating that no individual
items had exceptionally poor correlations with their subtests and total test as well. Cronbach’s alpha for the subtest after dropping the item (i.e., alpha if the item was deleted) indicated that deleting any test item would not significantly improve the overall alpha. In fact, deleting any other test items from their correspondent subtests would worsen the internal consistency for the subtest (see Table 4.12).

**Test Reliability**

The second research question also addressed the reliability of the 45 items of the revised version of the MAA. To answer the research question, reliability was examined by computing a split-half coefficient with Spearman-Brown correction and Cronbach’s alpha coefficient. The SPSS version 17.0 was used for this analysis.

**Split-half reliability.** Split-half reliability is useful to determine reliability of a measure (Cohen & Swerdlik, 2002). The measure being investigated is divided into two halves (i.e., odd and even numbered items), and then scores of the one half of the measure are compared to the scores of the remaining half. If the scores of both halves have a strong correlation, this is evidence of reliability of the measure (Kaplan & Saccuzzo, 2009).

The split-half coefficient of the 54-item MAA was estimated at .853. The coefficients for each of the theoretically-driven three constructs of the 54-item MAA ranged from .765 to .898 (see Table 4.13). After eliminating cross-loaded test items, the split-half coefficient of the 45-item MAA remained high ($r = .836$). The coefficients for each of the exploratively obtained five-factor constructs of the 45-item MAA ranged from .634 to .891 (see Table 4.14). The high split-half coefficients for both versions indicate the MAA possesses good reliability.
Table 4.13

*Split-half Reliability Coefficients of the 54-item MAA*

<table>
<thead>
<tr>
<th>Factor</th>
<th>No. of Items</th>
<th>Lowest</th>
<th>Highest</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA-Sustained</td>
<td>18</td>
<td>.820</td>
<td>.867</td>
<td>.898</td>
</tr>
<tr>
<td>MAA-Selective</td>
<td>18</td>
<td>.789</td>
<td>.857</td>
<td>.808</td>
</tr>
<tr>
<td>MAA-Divided</td>
<td>18</td>
<td>.738</td>
<td>.745</td>
<td>.765</td>
</tr>
<tr>
<td>MAA-Total</td>
<td>54</td>
<td>.887</td>
<td>.939</td>
<td>.853</td>
</tr>
</tbody>
</table>

*Note:* Split-half coefficients were calculated with $N = 187$.

Table 4.14

*Split-half Reliability Coefficients of the 45-item MAA*

<table>
<thead>
<tr>
<th>Factor</th>
<th>No. of Items</th>
<th>Lowest</th>
<th>Highest</th>
<th>Median</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA-Sustained-Short</td>
<td>4</td>
<td>.561</td>
<td>.790</td>
<td>.811</td>
</tr>
<tr>
<td>MAA-Sustained-Med to Long</td>
<td>13</td>
<td>.824</td>
<td>.825</td>
<td>.891</td>
</tr>
<tr>
<td>MAA-Selective-Noise</td>
<td>6</td>
<td>.756</td>
<td>.794</td>
<td>.810</td>
</tr>
<tr>
<td>MAA-Selective &amp; Divided</td>
<td>16</td>
<td>.759</td>
<td>.829</td>
<td>.843</td>
</tr>
<tr>
<td>MAA-Divided-Long</td>
<td>6</td>
<td>.573</td>
<td>.594</td>
<td>.634</td>
</tr>
<tr>
<td>MAA-Total</td>
<td>45</td>
<td>.880</td>
<td>.930</td>
<td>.836</td>
</tr>
</tbody>
</table>

*Note:* Split-half coefficients were calculated with $N = 187$. 
**Internal consistency reliability.** Measuring internal consistency is a widely used method for investigating the reliability of a measure. It investigates the internal structure of the measure by examining the responses on each individual item and their relation to the total scores (Murphy & Davidshofer, 1998). Cronbach’s *alpha* coefficient estimates the internal consistency for both dichotomous and polytomous test items (Schmidt & Emberston, 2003).

The internal consistency for the 54-item MAA was .946 as computed by Cronbach *alpha*. The *alpha* coefficients for each of the theoretically driven three constructs of the 54-item MAA ranged from .835 to .914, (see Table 4.15). After eliminating cross-loaded test items, the internal consistency for the 45-item MAA was estimated at .934 with the exploratively obtained five-factor constructs ranging from .695 to .901 (see Table 4.16). The high *alpha* coefficients for each of the five constructs indicated good homogeneity among the test items.

The *alpha* value decreased from .946 to .940, which was estimated prior to item deletion. This decrease was explained by the initial Cronbach’s *alpha* of the revised MAA where test items were highly correlated, so deleting one item would minimally increase Cronbach’s *alpha*, but mostly could decrease the overall *alpha* reliability.
Table 4.15

*Cronbach's alpha Coefficients of the 54-item MAA*

<table>
<thead>
<tr>
<th>Factor</th>
<th>No. of Test items</th>
<th>Cronbach’s alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA-Sustained</td>
<td>18</td>
<td>.914</td>
</tr>
<tr>
<td>MAA-Selective</td>
<td>18</td>
<td>.884</td>
</tr>
<tr>
<td>MAA-Divided</td>
<td>18</td>
<td>.835</td>
</tr>
<tr>
<td>MAA-Total</td>
<td>54</td>
<td>.946</td>
</tr>
</tbody>
</table>

*Note:* Cronbach’s alpha was calculated with N=187.

Table 4.16

*Cronbach's alpha Coefficients of the 45-item MAA*

<table>
<thead>
<tr>
<th>Factor</th>
<th>No. of Items</th>
<th>Cronbach’s alpha</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA-Sustained-Short</td>
<td>4</td>
<td>.812</td>
</tr>
<tr>
<td>MAA-Sustained-Med to Long</td>
<td>13</td>
<td>.901</td>
</tr>
<tr>
<td>MAA-Selective-Noise</td>
<td>6</td>
<td>.841</td>
</tr>
<tr>
<td>MAA-Selective &amp; Divided</td>
<td>16</td>
<td>.880</td>
</tr>
<tr>
<td>MAA-Divided-Long</td>
<td>6</td>
<td>.695</td>
</tr>
<tr>
<td>MAA-Total</td>
<td>45</td>
<td>.940</td>
</tr>
</tbody>
</table>

*Note:* Cronbach’s alpha was calculated with N=187.
**Research Question #3:** What differences in MAA performance are found between healthy adults and patients with TBI, in relation to the exploratively obtained factor constructs?

**Group Differences**

The third research question examined differences between groups on each of the exploratively obtained five-factor constructs of the MAA. To address this research question, a multivariate analysis of variance (MANOVA) was conducted using SPSS version 17.0.

The independent variable, group, included two levels: healthy adults and patients with TBI. The dependent variables, the factor scores in relation to each of the exploratively obtained five-factor constructs of the MAA, included five levels: MAA-Sustained-Short, MAA-Sustained-Med to Long, MAA-Selective-Noise, MAA-Selective & Divided-Two Melodies, and MAA-Divided-Long. The results of the analysis, shown in Table 4.17, include the number of patients (n), sum of squares (SS), degree of freedom (df), F-ratio (F), and significance (p).

A factor score is “a linear composite of the optimally-weighted observed variables (Hatcher, 1994, p. 31).” Factor scores are obtained by taking an individual’s standardized score on each variable, multiplying by the corresponding factor loadings of the variable for the given factor, and summing them up (Child, 2006). The factor score provides the purest view of the constructs with no extraneous error that would happen if the researcher simply produced summed scores from the raw item data for each construct (Asmus & Radocy, 2006; Hair, Anderson, Tatham, & Black, 2010). The use of factor score can increase the likelihood of detecting differences between groups (Asmus & Radocy, 2006).
In the current study, therefore, the factor scores were used to represent the scale scores for the each of the five-factor constructs of the 45-item MAA and compare differences between healthy adults and patients with TBI.

The core underlying assumptions in the MANOVA procedure include equality of variance/covariance, equality of error variance, and multicollinearity. The assumption of equality of variance/covariance was tested with Box’s M. However, the Box’s M could not be computed due to insufficient cell sample size. The assumption of equality of error variance was checked with Levene’s test. Levene’s test was not significant for only one of the dependent variables, the MAA-Selective & Divided ($p > .05$). Therefore, the alpha level was set at a more conservative value of .01 (Tabachnick & Fidell, 2007). Lastly, the assumption of multicollinearity was tested by investigating correlations among the five-factor constructs. Correlations among the factor constructs ranged from -.536 to .518, indicating a moderate level of correlation among dependent variables. After testing the assumptions, the MANOVA was conducted.

The results of the MANOVA showed that there was a significant main effect of group on the combined dependent variables using Pillai’s Trace, $F(5, 181) = 11.852, p < .001$. This finding indicated that the factor scores of the five-factor constructs of the 45-item MAA were significantly different between the healthy adult group and the TBI patient group, except for the MAA-Sustained-Short (see Table 4.17).
Table 4.17

*Multivariate Analyses of Variance for the 45-item MAA by Group*

<table>
<thead>
<tr>
<th>Source</th>
<th>Dependent Variable</th>
<th>SS</th>
<th>df</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group</td>
<td>MAA-Sustained-Short</td>
<td>3.535</td>
<td>1</td>
<td>3.831</td>
<td>.052</td>
</tr>
<tr>
<td></td>
<td>MAA-Sustained-Med to Long</td>
<td>29.919</td>
<td>1</td>
<td>40.352</td>
<td>.000***</td>
</tr>
<tr>
<td></td>
<td>MAA-Selective-Noise</td>
<td>10.364</td>
<td>1</td>
<td>14.139</td>
<td>.000***</td>
</tr>
<tr>
<td></td>
<td>MAA-Selective &amp; Divided</td>
<td>24.476</td>
<td>1</td>
<td>32.848</td>
<td>.000***</td>
</tr>
<tr>
<td></td>
<td>MAA-Divided-Long</td>
<td>21.072</td>
<td>1</td>
<td>29.251</td>
<td>.000***</td>
</tr>
</tbody>
</table>

*Notes: N=187 for this MANOVA. ***p < .001.*

Follow-up tests were conducted to evaluate pairwise differences between groups (see Table 4.18). Mean and standard deviation of each group on each of the five subtests are shown in Table 4.18. Factor scores of MAA-Sustained-Short were not significantly different between the two groups. However, the factor scores of the remaining four-factor constructs were significantly different between the groups. Factor scores of MAA-Sustained-Med to Long, and MAA-Selective-Noise were significantly higher in the TBI patient group than the healthy adult group, indicating that patients with TBI did not perform as well as healthy adults. Factor scores of the MAA-Selective & Divided, and the MAA-Divided-Long were significantly higher in the healthy adult group than TBI patient group, indicating that healthy adults performed better than patients with TBI.
Table 4.18

Pairwise Comparisons of Factor Scores of the 45-item MAA

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Mean (±SD)</th>
<th>Mean Difference</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Healthy adults</td>
<td>TBI patients</td>
</tr>
<tr>
<td></td>
<td>(n = 165)</td>
<td>(n = 22)</td>
</tr>
<tr>
<td>MAA-Sustained-Short</td>
<td>-.050 (± .075)</td>
<td>.377 (± .205)</td>
</tr>
<tr>
<td>MAA-Sustained-Med to Long</td>
<td>-.146 (± .067)</td>
<td>1.095 (± .184)</td>
</tr>
<tr>
<td>MAA-Selective-Noise</td>
<td>.184 (± .066)</td>
<td>.919 (± .181)</td>
</tr>
<tr>
<td>MAA-Selective &amp; Divided</td>
<td>.132 (± .067)</td>
<td>-.991 (± .184)</td>
</tr>
<tr>
<td>MAA-Divided-Long</td>
<td>.086 (± .067)</td>
<td>-.645 (± .645)</td>
</tr>
</tbody>
</table>

Notes: N=187 for this post hoc analysis. *p < .05.

Factor scores were obtained from an individual’s standardized score on each variable multiplied by the factor loadings on the variable for the given factor. Due to negative factor loadings on the MAA-Sustained-Short, MAA-Sustained-Med to Long, and MAA-Selective-Noise, the higher factor scores on the three factors were inferred to be associated with individuals’ negative standardized scores, which meant a value below the mean. Therefore, the finding indicated that overall MAA performances were better for individuals in the healthy adult group than for those in the TBI patient group.
Chapter 5

Discussion

The following is a discussion of the research hypotheses in light of the study’s findings and the related literature. The discussion consists of a brief review of the study, discussion of the research hypotheses, conclusions, limitations of the study, and lastly, recommendations for future research.

Brief Review of the Study

The purpose of the study was to use a factorial approach to identify the latent constructs that underlie a researcher-developed music-based attention assessment (MAA) for patients with TBI. The study investigated the item properties of test reliabilities imposed on each of the exploratively obtained factor constructs underlying the MAA. Differences in MAA performance between healthy adults and patients with TBI were also examined in relation to the exploratively obtained constructs of the MAA. Participants included healthy adults ($n = 165$) recruited from the University of Miami undergraduate research participant pool and patients with TBI ($n = 22$) recruited from Jackson Health System (JHS) in Florida.

The MAA, a 54-item, multiple-choice, melodic contour identification test, was developed to provide precise diagnostic information regarding the three sub-types of attention impairments common in patients with TBI. The three attention sub-types (i.e., sustained attention, selective attention, divided attention) were chosen from an existing conceptual framework (e.g., Sohlberg & Matter, 1987) and experimental studies concerning the different types of attention triggered by auditory and non-auditory stimuli (Johnson & Zatorre, 2006; Johnson et al., 2007; Lawrence et al., 2003; Loose et al., 2000;
The different types of attention were examined for their applicability in music listening tasks. Neuroanatomical findings from previous research provided support for the foreshowing of three different types of attention to music (Bengtsson et al., 2009; Janata et al., 2002; Ortuño et al., 2002; Satoh et al., 2001; Stephan et al., 2002). Additionally, behavioral studies reported that listening to single/multi-voice music activated these three types of attention (Bigand et al., 2000; Byo, 1997; Crawley et al., 2002; Davison & Banks, 2003; Dowling, 1973; Gallun et al., 2007; Shinn-Cunningham & Ihlefeld, 2004). The tentative model of the MAA, therefore, included three attention subtests that each consisted of two sections.

Melodic contours, a series of nine tones moving in one of three different directions (i.e., ascending, stationary, descending), were used to create the 48 test items of the MAA. For each subtest, the melodic contours were designed to measure primarily one of the three types of attention. Construction of the item pool was based on previous findings concerning the effect of the structural components of music on attention, such as the number of simultaneously presented melodic contours, the type of music listening tasks, instrument timbres, and pitch register (Bigand et al., 2000; Byo, 1997; Crawley et al., 2002; Davison & Banks, 2003; Dowling, 1973; Gallun et al., 2007; Shinn-Cunningham & Ihlefeld, 2004).

Two separate pilot studies conducted with samples of patients with TBI ($n = 15$) and typical adults ($n = 30$) preceded the present study. An issue was found when the obtained data from the typical adults were analyzed. The mean score of the MAA-Total
was estimated at 46.4 ($SD = 3.11$) out of a perfect score of 48. Consequently, the researcher revised the initial version of the MAA to vary item difficulty.

In the present study, the latent constructs of the revised version of the MAA and additional psychometric properties of the 54 test items (i.e., item properties, reliability) were investigated. Participants’ ($n = 187$) responses to test items were scored to create the variables of item scores. Three- to six-factor models that could underlie the test items of the MAA were explored. Ultimately, the five factor solution yielded the factors of: (a) *Sustained-Short*, (b) *Sustained-Med to Long*, (c) *Selective-Noise*, (d) *Selective & Divided*, and (e) *Divided-Long*. Test items that had factor loadings of less than .30 or items that were cross-loaded were eliminated, resulting in a 45-item MAA.

In regard to the finalized 45-item MAA, item properties were examined to determine their difficulty and discrimination. Item means were used as an indicator of item difficulty. The means ranged from easy to difficult, indicating a wide range of item difficulty. Corrected item-total correlations were used as an indicator of item discrimination. All test items were above the conventional threshold (i.e., $r > .20$), indicating that the items were of an acceptable to high discrimination value. Additionally, split-half coefficients with Spearman-Brown correction and Cronbach’s *alpha* coefficients were computed as an indicator of the reliability of the 45-item, five-factor constructs MAA. Both coefficients demonstrated adequate and sufficient reliability of the 45-item MAA.

Based on the responses from the entire pool of participants, factor scores for each of the five-factor constructs were significantly different between individuals in the healthy adult group and those in the TBI patient group. Total performance on the MAA
was significantly better for individuals in the healthy adult group than for those in the TBI patient group. Aggregate findings support the MAA as a potentially reliable and valid measure.

**Discussion of the Research Hypotheses**

**Exploratory Factor Analysis**

The first research question sought to identify emergent factor solutions from the obtained data. It was predicted that the 54 test items of the MAA would be factored into at least three different factor domains. It was further predicted that each factor domain would be predicted by at least four test items that were unique to their respective factor domain.

Exploratory factor analyses were performed to identify the existing factor structures that underlie the 54 test items of the revised MAA. The initial, unrestricted factor analysis produced a 14-factor solution with eigenvalues greater than one, which explained 66.79% of the variance in the total scores of the revised MAA. Based on the visual inspection of the scree plot, between 3 and 6 factors were extracted in a restricted manner and factor loadings were analyzed. Three- and four-factor solutions grouped different attention components together. More than six-factor solutions resulted in numerous cross-loadings, so the discarding of a fairly large number of items was inevitable. Three-, four-, and six-factor models, therefore, were not retained because the resulting factors grouped test items together in ways that violated theoretically reasonable assumptions in regards to attention sub-types.

The five-factor model, ultimately, was considered the simplest item grouping on each factor. The five factors were labeled as follows: (a) Sustained-Short, (b) Sustained-
Med to Long, (c) Selective-Noise, (d) Selective & Divided, and (e) Divided-Long. These groupings were consistent with previous theoretical findings.

In order to identify good indicators for each factor construct, cross-loaded test items that have strong relationships with more than one factor were not considered for inclusion. Test items from the original MAA that represented each of the attention factors were retained based on their factor loadings. The remaining test items had high loadings on one of the five factors and relatively low loadings on the remaining four factors. The final MAA consisted of a total of 45 test items. The number of test items that represent each factor are as follows: (a) Sustained-Short: 4 test items, (b) Sustained-Med to Long: 13 test items, (c) Selective-Noise: 6 test items, (d) Selective & Divided-Two melodies: 16 test items, and (e) Divided-Long: 6 test items. The finalized 45-item MAA satisfied the minimum requirement of a subject-to-variable ratio (i.e., 4.16:1).

An additional factor analysis was performed on the 45-item version of the MAA. The factor analysis confirmed the stability of the five-factor model that was produced from the initial exploratory factor analysis. The Kaiser-Meyer-Oklin Measure of Sampling Adequacy (MSA) was estimated at .869 and total variance explained was 48.832%, indicating that the finalized structure explains slightly less variance than the initial version of the MAA.

Since no other studies used a factorial approach to validate the construct of a music-based attention measure, it is difficult to compare the current findings directly to the factor structures found in other previous research. However, the groupings of test items on each factor can be related to previous behavioral findings that reflect the factors identified in the current study. A description and discussion in regards to each factor are
presented as follows: (a) Sustained-Short, (b) Sustained-Med to Long, (c) Selective-Noise, (d) Selective & Divided, and (e) Divided-Long.

**Sustained-Short.** Test items that loaded on this factor included items that were originally generated for the MAA-Sustained Test I and Test II. Since these test items consisted of a single melodic contour of which the time duration was short, the factor was labeled as MAA-Sustained-Short.

Three studies have reported brain activation in broad regions during sustained attention performance on music listening tasks (Bengtsson et al., 2009; Ortuno et al., 2002; Stephan et al., 2002). The regions of the brain included the reticular formation, cerebellum, and thalamus (subcortical areas), and the primary sensory, parietal, anterior cingulate, and prefrontal cortices (cortical areas). The subcortical and cortical area indicated arousal responses to external sensory stimuli and conscious effort to maintain the arousal, respectively (Sarter et al., 2001).

Test items grouped on the Sustained-Short factor consisted of single, five-tone melodic contours. Considering that the items are short and the given task is simple, the brain responses to these items might be called an arousal response. Similar brain regions and neural pathways that modulate the arousal response, therefore, were perhaps activated while listening to and identifying the directions of the items grouped on the Sustained-Short factor.

Also, the current findings reflect short durations in attention following TBI (Arciniegas et al., 2000; Corrigan et al., 2004; Draper & Posford, 2008; Mathias & Wheaeton, 2004; Willmott et al., 2009). As described, the items grouped on this Sustained-Short factor were single melodic contours that consisted of a set of five tones.
presented independently. The task associated with this group of items was considered the easiest and simplest task across all of the factors. The current findings, therefore, suggest that the Sustained-Short factor could be used to detect a basic level of sustained attention of patients with TBI, even though the patients are in an acute phase.

**Sustained-Med to Long.** Test items clustered together on this factor were items that were originally created for the MAA-Sustained Test I and Test II. Since the test items were a single melodic contour consisting of either medium or long duration with various instrument timbres, the factor was labeled as MAA-Sustained-Med to Long.

The three test items originally selected for the MAA-Selective Test III were intended to cluster on different factors; however, the items loaded on the MAA-Sustained-Med to Long factor. The test items were melodic contours sounded along with environmental noise. The target contours of two of the test items were heard against a bird singing, while the target contour of the third test item contour was presented against a laughing sound.

The reason for the three items being loaded on this factor might be due to the function of distractors. That is, bird singing and laughing sounds were merged with target melodic contours due to similar pitch range, and perhaps were not perceived as distractors. Instead, distractors might have combined with target melodic contours and enhanced saliency of the target contours. The increases in saliency of the target contour may have led the participants to perceive the two sound streams in the MAA-Selective in the same way they perceived the one sound stream given in the MAA-Sustained. Consequently, the participants identified the three test items in the MAA-Selective in the same fashion as they identified the test items in the MAA-Sustained-Med to Long.
Sarter et al. (2001) suggested that sustained attention performance utilizes broad regions in the brain, which reflects arousal of the brain to external sensory stimuli as well as more conscious effort to hold and monitor the perceived stimuli. According to Sarter et al.’s (2001) neuro-schematic model, three neural pathways modulated sustained attention performance. Sensory perception and its projection to the thalamus and basal forebrain mediate arousal states. The activated states are delivered to the fronto-parietal cortices via parietal pathways and to the medial frontal and dorsolateral prefrontal cortices via anterior pathways. The latter two pathways involve the processing of stimuli that are more complex or contain the large amount of information.

Four neuroanatomical studies supported Sarter et al.’s (2001) model. These finding revealed that simple sustained attention performance activated subcortical brain regions, while a more complex sustained attention performance activated the cortical brain regions, more specifically toward prefrontal cortices (Bengtsson et al., 2009; Lawrence et al., 2003; Ortuno et al., 2002; Stephan et al., 2002). For example, as rhythmic patterns became more unpredictable, there was obvious evidence revealing more involvement of the anterior cingulate and prefrontal cortices (Bengtsson et al., 2009; Stephan et al., 2002). Auditory imagination while performing a sustained attention task may have also activated similar brain activation (Ortuno et al., 2002).

For the present study, test items grouped on the Sustained-Med to Long factor consist of single, ten to fifteen-tone melodic contours. They are presented in longer time duration and contain larger amounts of auditory information, as compared to the items grouped on the Sustained-Short factor. The items clustered on the Sustained-Med to Long factor, therefore, are more likely to reflect mental effort to maintaining the perceived
stimuli over time. In this respect, the current factorial findings indicated that the cortical brain areas and the parietal- and anterior-attention systems may have been utilized and activated while listening to and identifying the directions of the items grouped on the Sustained-Med to Long factor.

The findings from both of the preceding factors indicated that test items originally selected for the MAA-Sustained were categorized into two different domains depending on the time duration of the item. The current findings concur with previous findings that examined the effects of overall time length of stimuli on sustained attention performance (Justus & List, 2005; Kinchla & Wolfe, 1979; Robertson, 1996).

Attention should be drawn to both of the preceding factors, the Sustained-Short and Sustained-Med to Long. The two factors indicated that test items originally selected for the MAA-Sustained were categorized into two different domains depending on the time duration of the items. The two separate groupings of test items could be addressed from a theoretical as well as empirical perspective.

The theoretical definition of sustained attention supported the current factorial findings. According to the researcher-presented definition (Cohen et al., 1993; Koelega, 1996; Mirsky et al., 1991; Ponsford, 2008), sustained attention has been defined as an ability to continuously maintain an individual’s focus on external stimuli relevant to a given task. Also, this attention type has been considered identical to vigilance, which refers to the ability to achieve and sustain the alert state (Fernandez-Duque & Posner, 2001).

Also, several researchers reported that sustained attention performance did differ by the overall time length of stimuli presented (Kinchla & Wolfe, 1979; Robertson,
1996). Given these definitions, a “time” factor, which concerns overall amount of information that perceived stimuli convey, appears to be central to efficacy of sustained attention performance. For the current study, therefore, the two independent groupings of test items given in the MAA-Sustained reflect this essential characteristic of sustained attention.

**MAA-Selective-Noise.** High loading items on this factor were originally meant to represent the MAA-Selective Test III. Test items in this group were one target melodic contour heard against environmental noise. Thus, the factor was labeled MAA-Selective-Noise.

The current findings are relevant with existing neuroanatomical studies that have investigated selective auditory attention performance in the presence of visual distraction (Johnson & Zatorre, 2006; Loose et al., 2000; Talsma & Kok, 2001). In general, brain activations were modality-specific. When different types of sensory stimuli were parallel simultaneously, the poly-sensory areas were activated. Brain activation in this area indicates that cross-modal areas exist to modulate selective attention from multiple sensory modalities (Johnson & Zatorre, 2006; Loose et al., 2000; Talsma & Kok, 2001). More specific to auditory stimuli, broader regions in the brain were activated with a delayed latency as compared to visual stimuli (Talsma & Kok, 2001).

Two studies examined selective auditory attention in the presence of distracting musical sounds (Janata et al., 2002; Satoh et al., 2001). Brain activation specific to selective attention through music was observed in the superior temporal, primary motor, parietal, and frontal cortices (Janata et al., 2002). Additional brain regions, such as the
anterior cingulate and occipital cortices, were activated to detect errors embedded in a pre-determined voice (Satoh et al., 2001).

For the present study, test items grouped on the Selective-Noise factor consisted of short to long length, single melodic contours presented with environmental noise. Given that the items consisted of musical target against environmental distraction, the aforementioned two neuroanatomical studies (Janata et al., 2002; Satoh et al., 2001) might be associated with the current factorial findings. The items clustered on the Selective-Noise factor, therefore, reflect selective auditory attention in a simulated auditory environment where distracting sounds are present and presumably activate the brain regions as listed above.

Also, the current findings reflect increased vulnerability to distraction following TBI, which in turn leads to attention impairments in this population (Arciniega et al., 2000; Godefroy et al., 1996; Hattiangadi et al., 2005). As described earlier, the items grouped on this Selective-Noise factor consisted of target melodic contours presented simultaneously with environmental noise. The environmental noise likely increased distractibility of patients with TBI and possibly decreased overall performance on this group of test items. The current findings, therefore, suggest that the Selective-Noise factor could be used to detect distractibility following TBI, a main cause of attention impairments.

Since test items in the MAA-Selective Test IV were loaded on the same factor as test items in the MAA-Divided Test V and Test VI, the researcher determined that this group of test items measured operationally defined selective attention ability across the three attention subtests of the MAA. Additionally, the use of environmental noise as a
distractor in the MAA-Selective was deemed effective to generate test items that aimed to measure selective attention. The use of the second melodic contour as a distractor was considered relatively less appropriate for this purpose.

**Selective and Divided.** Three groups of test items were highly loaded on this factor. They were (1) the MAA-Selective Test IV, (2) the MAA-Divided Test V, and (3) the MAA-Divided Test IV. The common characteristic across the three groups was the number of melodic contours presented simultaneously, regardless of the type of music listening task. For this reason, the factor was labeled Selective & Divided.

The three groups of test items intended to load on different factors. The first group included the test items that were originally selected for the MAA-Selective Test IV. For the current factorial findings, the first group of test items involves identifying target melodic contours presented with distracting melodic contours. The two melodic contours, a target and distractor, were presented by different instrument timbres. For example, when a target melodic contour was presented with the piano, a distracting melodic contour was presented with either guitar or flute. The time duration of the items ranged from short to long.

The purpose of using the second melodic contour for the MAA-Selective Test IV was to increase the level of distraction as contrasted with the MAA-Selective Test III that used environmental noise as distracting stimuli. The use of the second melodic contour also aimed to simulate a real-world auditory environment where selective attention to relevant information is necessary. The researcher, thus, expected that the items representing different listening tasks given in the MAA-Selective Test III, Test IV, and the MAA-Divided Test V would be grouped into different factor constructs.
The resulting factors partially satisfied the researcher’s expectation. That is, the items in the MAA-Selective Test III were separately grouped from the items in the MAA-Selective Test IV. However, the items in the MAA-Selective Test IV were merged with the items in the MAA-Divided Test V and Test VI.

The findings were inconsistent with earlier studies, which reported that selective and divided attention performance differed by different music listening tasks (Bigand et al., 2000; Crawley et al., 2002; Gallun et al., 2007; Janata et al., 2002; Satoh et al., 2001). The inconsistency found in the current study is probably due to the increased amount of perceptual demands imposed on the test items in the MAA-Selective Test IV, creating the same degree of imposition as found in items of the MAA-Divided Test V and Test VI.

The resulting factors were also inconsistent with existing neuroanatomical evidence concerning selective and divided attention in music listening. Janata et al. (2002) reported that differences between activated brain regions were discernable by the type of given music listening tasks. According to their findings, different types of music listening tasks utilized different attention subtypes and activated different brain regions, such as (a) the inferior frontal gyrus, the inferior precentral sulcus, frontal and parietal areas, and the larger superior temporal areas (in the selective listening condition), and (b) the left intra-parietal sulcus, the parietal cortex, the superior frontal cortex, the ventro-rostral part of the middle frontal gyrus, and the anterior cingulate cortex (Janata et al., 2002).

For the test items in the MAA-Selective Test IV, target melodic contours paired with the distracting melodic contours tended to be perceived as two independent target contours. That is, the perceptual demands dominated the role of the various music
listening tasks given to differentiate attention sub-types. Consequently, the test items in the MAA-Selective Test IV created similar response patterns to the test items in the MAA-Divided Test V and Test VI. As a result, it was thought that the test items in the MAA-Selective Test IV, which were supposed to be loaded on different constructs, were clustered together on the same factor with the items in the MAA-Divided Test V and VI, regardless of the different contour identification tasks given in each attention sub-test.

The second group of items included those that were originally meant for the MAA-Divided Test V. This group of test items required participants to identify two target melodic contours that were presented simultaneously by different instrument timbres. The purpose of using different instrument timbres was to provide a perceptual cue to split the focus of attention to track two melodic contours continuously and separately.

The third group of items included those that were originally selected for the MAA-Divided Test VI. The task here was to identify two target melodic contours that were played simultaneously by the same instrument timbre. For both groups, the time duration of the items included short and medium lengths.

The purpose of using the same instrument timbres for the test items in the MAA-Divided Test VI was to increase the level of competition between two melodic contours as compared to the MAA-Divided Test V that used different instrument timbres. In the MAA-Divided Test VI, the same-timbred melodic contours were presented apart in pitch range. The pitch distance between the two melodic contours was separate, ranging from the major forth to a thirteenth. The researcher, thus, assumed that the two melodic contours played by the same timbre would compete for the limited attentional resources
and expected that the items representing different listening tasks given in the MAA-Divided Test V and Test VI would be grouped into different factor constructs.

The resultant factorial findings did not meet with the researcher’s expectation. That is, test items in the MAA-Divided Test V and those in the MAA-Divided Test VI were grouped together on the same factor. These findings were similar to two earlier studies, which reported that pitch register and instrument timbre between two concurrent stimuli were not effective to differentiate attention performance (Davison & Banks, 2003; Robertson, 1996). Robertson (1996) reported that individuals are likely to attend to only one auditory stream out of two regardless of the frequency ranges of the streams. Also, Davison and Banks (2003) found that instrument timbre did not affect attention performance on two melodic contours simultaneously presented.

The controversy in the present study can be addressed by conceptual theories and experimental findings concerning perceptual integration in processing same-timbred melodic contours (Bigand et al., 2000; Crawley et al., 2002; Davison & Banks, 2003; Deutsch, 1982; Dowling, 1973). Deutsch (1982) specified the musical elements that were influential on auditory scene analysis, which explains attention to two or more simultaneously sounded music contours (Bregman, 1999). According to Deutsch (1982), a series of tones that are close in similarity of time, spatial location, and intensity are likely to form a single stream. Even though she did not mention the effect of timbre, the same instrument timbres used in the present study is deemed congenial with the musical elements that Deutsch (1982) described.

Auditory scene analysis is applicable to multi-voice music as in the two melodic contour-items of the MAA-Divided. When individuals listen to multi-voice polyphonic
music, they are likely to process two or more sound streams separately or integrate multi-
sound streams into one (Bigand et al., 2000; Crawley et al., 2002). Experimental findings
support the idea that perceptual integration is enhanced by juxtaposed melodic contours
and/or playing the same instrument timbres simultaneously (Davison & Banks, 2003;

In the present study, it was deemed that the use of the same instrument timbre did
not increase the level of competition between two melodic contours and, rather, triggered
perceptual integration. The use of a separate pitch range also turned out to be ineffective
in providing a perceptual cue that guides divided attention over two melodic contours.
Due to the combined influence of these two perceptual factors, participants responded to
the test items in the MAA-Divided Test VI in a similar way to the items in the MAA-
Divided Test V. Subsequently, the three groups of test items in the MAA-Selective Test
IV, MAA-Divided Test V and Test VI were clustered together on the same factor, labeled
as Selective & Divided.

**Divided-Long.** This factor indicated a grouping of items that originated from the
MAA-Divided Test V and Test VI. Test items clustered on this factor were two
simultaneous melodic contours presented with the longer time duration as compared to
the test items grouped to Selective and Divided factor. This factor, therefore, was labeled
Divided-Long.

Analyses revealed that time variation influenced the clustering of test items in the
MAA-Divided into two independent factor constructs: the MAA-Selective and Divided
and the MAA-Divided Long. The finding suggests that divided attention performance is
influenced by the time component as is sustained attention performance. According to the
researcher-presented definition, divided attention is an ability to track two different stimuli simultaneously to obtain relevant information that is coming from both sources (Cohen et al., 1993; Koelega, 1996; Mirsky et al., 1991; Ponsford, 2008). Given this definition, time component is probably not a primary characteristic that represents divided attention. However, considering that divided attention occupies a superior position in the hierarchy of attention, divided attention should be assisted by sustained attention. From this aspect, the current findings are consistent with previous studies, which reported that attention performance differed by the overall length of time to stimuli presented (Kincha & Wolfe, 1979; Robertson, 1996).

Additionally, considering that divided attention is assisted by sustained attention, it is further suggested that the fundamental mechanism of the two types of attention, sustained attention and divided attention, might be specific to each type and may also partially overlap with each other. In fact, there exist common brain regions, such as the reticular formation at the brain stem, thalamus, and primary sensory cortices, responsible for both divided attention and sustained attention. The earlier neuroanatomical evidence supports this assumption (Cohen et al., 1993; Koelega, 1996; Johnson et al., 2007; Johnson & Zatorre, 2006; Loose et al., 2000; Mirsky et al., 1991; Ponsford, 2008; Sarter et al., 2001).

Also, the current findings reflect the difficulties that patients with TBI have in completing attention tasks over time. These difficulties are referred to as cognitive fatigue (Stuss et al., 1989). As described earlier, the items grouped on this Divided-Long factor consisted of two melodic contours presented simultaneously with the longest time duration. Attention demands imposed from this group of test items were higher than any
other test items, and, consequently the perceived degree of cognitive fatigue was greater. The current findings, therefore, suggest that the Divided-Long factor can detect the level of cognitive fatigue of patients with TBI.

Lastly, the resulting factors suggested a possible relationship with other cognitive constructs. The purpose of varying time duration of test items at the time of test revision was to vary the level of task difficulty in each of the three attention subtests of the MAA. Additional effort to hold the perceived stimuli necessary while taking test items given in the MAA was considered extended sustained attention. The researcher also assumed that the varied degree of sustained attention might affect selective and divided attention performance since this attention type plays a fundamental role in the attention hierarchy.

In a study about the relationship between attention and working memory, Chun (2011) stated sustained attention and working memory activated while processing visual stimuli are closely related. According to the author, the essential function of working memory, such as encoding and maintenance of information, in fact, is identical with the function of sustained attention. This point of view is consistent with the current definition of attention, which states that this function is necessary to deal with both external sensory stimuli and internal thought processes.

Additionally, the top-down aspect of attention (Legrain et al., 2009; Sarter et al., 2001) involves a similar function in both sustained attention and working memory. According to Legrain et al. (2009), top-down attention processes incoming stimuli that are task-relevant or -irrelevant and filters how much attentional effort is exerted. This process overlaps with the function of working memory. Anterior and posterior pathways,
two systems of sustained attention (Sarter et al., 2001), support the overlapping and somewhat identical relationship between sustained attention and working memory.

In the current study involvement of other types of cognitive structures was not expected at the time of model development and item pool construction. The Divided-Long factor could have some part in the working memory component, which refers to the interface at which attentional functions select task-relevant, external stimuli and maintain the selected stimuli as internal representations within the mind (Chun, 2011). Even though there might be a possibility of other cognitive structures being involved, the current findings suggest that this factor could provide evidence of ecological validity as it measures attention-related functions that are necessary for everyday life.

**Summary.** The aggregate findings indicated that test items originally created for the MAA-Sustained were factored into two separate factor constructs depending on the time duration of the item. Test items generated for the MAA-Selective were clustered into two independent factor constructs depending on the level of distraction between two melodic contours. Along with a part of test items the MAA-Selective, mostly test items given in Test IV, test items originally generated for the MAA-Divided were factored into two different domains depending on the time duration of the item, as in the MAA-Sustained.

The resulting factors provided evidence that the number of melodic contours presented either independently or simultaneously primarily contributed to the test items being separately grouped into the theoretically driven constructs of the MAA, which are the MAA-Sustained, the MAA-Selective, and the MAA-Divided. The findings were concurrent with earlier studies which reported that attention performance to multi-voice...
music differed by the number of melodies that were simultaneously presented (Bigand et al., 2000; Byo, 1997; Crawley et al., 2002; Davison & Banks, 2003; Fujioka et al., 2005; Gallun et al., 2007; Satoh et al., 2001; Shinn-Cunningham & Ihlefeld, 2004).

The five-factor solution also revealed that the time factor contributed to the categorization of the test items that were originally created for the respective MAA-Sustained into two sub-groups and MAA-Divided into two sub-groups. The various combinations of sounds (i.e., environmental noise, different instrument timbres) led to the sub-categorization of test items that were originally generated for the MAA-Selective into two groups.

The unexpectedly loaded three groups of items on the Selective and Divided factor unveiled that the amount of perceptual demands tied together the items representing different tasks. Also, the use of the same instrument timbres led to perceptual integration, contributing to clustering of the items on the same factor. In the current study, the two aspects of perceptual processes (i.e., the amount of perceptual demands, perceptual integration due to the use of the same timbres) were deemed to cause the three groups of items to bind to the same factor. It is further suggested that the same instrument timbres is probably insufficient to provide a cue to split an individual’s attentional focus over two melodic contours.

In summary, the test items in the MAA-Sustained and the MAA-Divided were sub-categorized into two independent factor constructs, respectively. Accordingly, the five-factor constructs of the 45-item MAA include the Sustained-Short, the Sustained-Med to Long, the Selective-Noise, the Selective & Divided, and the Divided-Long. These resultant five-factor constructs underlying the test items of the 45-item MAA, therefore,
justify the structured use of the melodic contours to measure the different attention subtypes.

**Item Properties and Test Reliability**

The second research question addressed item properties and reliability of the 45-item MAA. It was predicted that test items would possess a wide range of item difficulty and fall above the conventional minimum threshold of item discrimination. It was further predicted that the MAA would adequately provide evidence of reliability as computed by split-half coefficients and Cronbach’s *alpha* coefficients. This predication was based on the results from the two pilot studies.

**Item properties.** Item difficulty indices of the revised version of the MAA ranged from .048 to .962, indicating a wider range of item difficulty as compared to the initial version of the MAA. Corrected item-total correlations ranged from .218 to .714, indicating an acceptable to high level of item discrimination. The high item discrimination indices also indicated the degree to which an item and the test as a whole measure identical attention abilities. The findings also suggest that the test items of the revised version of the MAA are appropriately created to differentiate between participants who are capable of performing a given attention task and those who are less capable (Osterlind, 2006). The psychometric results of the 45 test items of the MAA support the potential for using the MAA as a reliable measure to assess attention performance both in healthy adults and in patients with TBI.

**Test reliability.** The high split-half coefficients indicated that the MAA is a reliable measure. The split-half coefficient of the 45-item MAA was estimated at .836, with the coefficients from the five exploratively obtained factor constructs ranging
from .634 to .891. Except for the MAA-Divided-Long, all of the factor constructs had high split-half reliability. The Cronbach’s alpha coefficient for the 45-item MAA was estimated at .940, with the alpha coefficients for the five-factor constructs ranging from .695 to .901. Both split-half reliability and internal consistency coefficients indicated strong consistency between the test items of the finalized MAA. Both reliability coefficients also indicated that the test items in each of the five-factor constructs were homogeneous, meaning that items were internally consistent, both by themselves and when split. Additionally, the high alpha values provide support for the construct validity of the MAA since Cronbach’s alpha indicates the degree to which the test items consistently measure underlying latent constructs (Henson, 2001).

Results from the revised version of the MAA were also consistent with the results of the two pilot studies, which reported high internal consistency reliabilities. The internal consistency from the initial version of the MAA was estimated at .949 for patients with TBI and at .917 for healthy adults. The high alpha values from the two pilot studies further support that the MAA measure is a reliable measure for both populations. As compared to the previous studies concerning validation of a researcher-developed assessment tools (York, 1994; Lipe, 1995; Lipe et al., 2000; Magee, 2007), the current study findings support the use of musical stimuli in a form of pencil and paper based test as an internally consistent and thus reliable music-based assessment measure.

**Group Differences**

The third research question asked whether there were any significant differences in MAA performance between groups. It was predicted that the scores on each of the exploratively obtained factor constructs would be significantly better in healthy adults
than patients with TBI. This prediction was based on the results of two pilot studies as well as previous research findings.

Differentiated performance with the MAA was expected and was consistent with results found in the research literature that reported attention impairments following TBI. Results of the MANOVA demonstrated that there was no significant difference between groups in the factor scores on the MAA-Sustained-Short \( (F(1, 185) = 3.831, p > .05) \). However, the remaining four factors did show significant group differences: MAA-Sustained-Med to Long \( (F(1, 185) = 40.352, p < .001) \), the MAA-Selective-Noise \( (F(1, 185) = 14.139, p < .001) \), the MAA-Selective & Divided-Two Melodies \( (F(1, 185) = 32.848, p < .001) \), and the MAA-Divided-Long \( (F(1, 185) = 29.251, p < .001) \). Post-hoc analysis of each of these exploratively obtained four-factor constructs revealed that overall MAA performance was significantly higher in the healthy adult group than in the TBI patient group.

The insignificant difference in the factor scores of the MAA-Sustained-Short between groups was probably due to a level of task difficulty. The four test items in the MAA-Sustained-Short were a single melodic contour of which time duration was short. The task given in this group of test items was very simple and believed to activate and measure a fundamental type of attention. Patients with TBI might answer the items correctly similar to healthy adults. The finding, therefore, suggests that certain aspect of sustained attention is intact for patients with TBI when they process a very small amount of information during a limited period of time.

The differences in the factor scores across the other four-factor constructs are concurrent with previous studies that reported pervasive attention impairments in TBI as
compared to healthy adults (Arciniegas et al., 2002; Draper & Ponsford, 2008; Kaipio et al., 1999, 2000; Kewman et al., 1988; Mathias & Wheaton, 2007; Niemann et al., 1996; Park et al., 1999; Ponsford, 2008; Ponsford & Willmot, 2004; Ponsford et al., 2008; Solbakk et al., 2002; Stuss et al., 1989; Willmott et al., 2009). As compared with healthy, non-brain injured adults, patients with TBI showed reduced information processing speed, difficulties in focused and selective attention, inability to maintain attentional focus and supervisory attention control, and dysfunction of divided attention. The current findings, therefore, support the idea that brain injuries can potentially affect all levels and types of attention ability.

The MANOVA findings suggest that each of the four subtests, which are based on the exploratively identified factors, could be used (a) the Sustained-Short Subtest as a measure of a basic level of sustained attention of patients with TBI in acute phase, (b) the Sustained-Med to Long Subtest as a measure of a more advanced level of sustained attention, (c) the Selective-Noise Subtest as a measure of increased vulnerability for auditory distraction, (d) the Selective and Divided Subtest as a measure of divided auditory attention to measure, and (e) the Divided-Long Subtest as a measure of a more advanced level of divided attention as well as cognitive fatigue.

In summary, the MANOVA results indicated that significant differences on each of the remaining four-factor constructs of the 45-item MAA existed between patients with TBI and healthy adults. The findings of MANOVA, therefore, suggest that the MAA has the potential to differentiate between different types of attention ability that exist between groups of healthy adults and patients with TBI. Additionally, the MAA has
implications for attention rehabilitation in that it could be used to evaluate functional outcomes following appropriately selected interventions.

**Conclusions**

Attention is the first stage in the process of perceiving and understanding sensory stimuli from any given environment. Attention impairments are commonly seen in patients with TBI. While attention assessment measurements have been rigorously developed and frequently utilized in cognitive neurorehabilitation, there is a paucity of ecologically valid auditory attention assessment instruments with presence of distractions that more closely simulate the nature of auditory environment. Researchers agree that music is an excellent source to directing and maintaining attention, which implies that musical stimuli can be used as an effective assessment tool. The researcher-developed Music-based Attention Assessment (MAA), therefore, had theoretical support but required a statistical examination to support the theoretically-driven constructs of the measure.

An attention assessment measure is needed to provide objective diagnostic knowledge regarding the degree and type of attention deficits in patients with TBI. The factorial approach is one method of successfully constructing measurements that provide diagnostic knowledge in regards to attention; however, no previous research that used this approach to examine the latent construct of a researcher-developed music-based attention assessment exists in the field of neuropsychology, neurorehabilitation, music psychology, or music therapy. This study verifies the use of the factorial approach as an objective and reliable method of developing the researcher-developed MAA. Psychometric evaluation to the obtained factor constructs was also performed.
The test item pool of the initial version of the MAA was created and the initial measure was piloted with patients with TBI \( (n = 15) \) and healthy adults \( (n = 30) \). Cronbach’s \( \alpha \) reliability was estimated at .949 with the clinical population and .917 with the typical population; however, the researcher decided to revise the initial MAA due to a ceiling effect observed in the typical population. The revised version of the MAA was piloted with both typical and clinical populations.

Exploratory factor analysis procedures were used to identify the underlying latent factor constructs that influenced MAA performance in relation to the different types of attention factors. The factors identified in this study were Sustained-Short, Sustained-Med to Long, Selective-Noise, Selective & Divided, and Divided-Long. The resulting five-factor constructs supported that attention sub-types involved in music contour identification were grouped primarily into three domains, including sustained, selective and divided attention, depending on the number of melodic contour(s) presented either independently or simultaneously. The researcher categorized sustained and divided attention into two sections based on the time duration of the test items. Several items of the MAA-Selective Test IV and the MAA-Divided Test V and Test Vi were grouped together based on the heavier load of perceptual demands, thus, creating the Selective and Divided factor.

The current findings also suggest that participants perhaps utilize brain regions, such as (a) the reticular formation, cerebellum, thalamus, primary sensory, parietal, occipital, and prefrontal cortices (b) the primary sensory cortices and poly-sensory association areas, and (c) the anterior cingulated and dorsolateral prefrontal cortex, which are commonly activated while performing (a) sustained, (b) selective, and (c) divided
attention to both non-musical and musical stimuli, respectively (Bengtsson et al., 2009; Janata et al. 2002; Johnson & Zatorre, 2006; Johnson et al., 2007; Lawrence et al., 2003; Loose et al., 2000; Macaluso et al., 2002; Ortuño et al., 2002; Sarter et al., 2001; Satoh et al., 2001; Serences & Yantis, 2007; Stephan et al., 2002; Talsma & Kok, 2001). The five exploratively obtained factor constructs in the current study, therefore, supported the theoretically driven constructs of attention underlying the MAA namely, sustained attention, selective attention, and divided attention and, as well, the structured use of the melodic contours for the purpose of measuring different levels and types of attention.

An additional confirmatory factor analysis was performed on the 45 test items retained in the revised version of the MAA. The factor analysis established the stability of the five-factor model that was produced from the initial unrestricted factor analysis. The Kaiser-Meyer-Olkin Measure of Sampling Adequacy (MSA) was estimated at .869 with a subject to variable ratio of 4.16:1. Total variance explained was 48.832%, indicating that the finalized structure explains slightly less variance of the 45-item MAA than the 54-item MAA. This reduction in variance can be partially explained by the smaller item pool. Despite some loss in total variance explained, these factors still explain a large portion of the variance.

Item indices indicated that all test items showed a wide range of item difficulty and were above the conventionally accepted minimum thresholds of item discrimination (i.e., corrected item-total correlation > 0.2). Reliabilities as computed by split half coefficients (r = .836) and Cronbach’s alpha (α = .940) were high, indicating that the 45-item MAA is a reliable measure to assess different types of attention. Additionally, the factor scores imposed on each of the exploratively obtained four-factor constructs were
significantly different between the healthy adult group and the TBI patient group, indicating the 45-item MAA measure differentiates attention ability between healthy adults and patients with TBI. The aggregate findings of psychometric validation, therefore, suggest that the MAA is a valid and reliable measure of the auditory attention of patients with TBI.

The present findings support the use of the MAA to assess attention deficits that are relevant to the three sub-types most commonly found to be impaired among patients with TBI. More specifically, the factor constructs fall into the levels of difficulty that reflect basic and more advanced levels of the three sub-types of auditory attention. The “Sustained-Short” factor reflects a basic level of sustained attention and the “Sustained-Med to Long” factor assesses a more advanced level of sustained attention. The “Selective-Noise” factor may evaluate selective auditory attention that extracts and processes task-relevant information from auditory environments. Lastly, the “Selective & Divided” factor and the “Divided-Long” factor are thought to gauge basic and more advanced levels of divided auditory attention. Each of the five factors can measure attention abilities of patients in different TBI stages, for example patients in an acute phase (i.e., Sustained-Short), in a more stabilized phase (i.e., Sustained-Med to Long), in where distracting sounds are present (i.e., Selective-Noise), in where a multiple foci are is necessary (i.e., Selective and Noise), and in a fatigue state (i.e., Divided-Long). Therefore, a renaming of the factor constructs is recommended as follows: MAA-Sustained-Basic, MAA-Sustained-Advanced, MAA-Selective, MAA-Divided-Basic, and MAA-Divided-Advanced.
Limitations of the Study

Limitations of this study include the small sample size and heterogeneity of the sample. The hypothesized construct of MAA was investigated with a relatively small sample size ($n = 187$). Even though a subject-to-variable ratio of $4.16:1$ met the criteria regarding minimum sample size for factor analysis (Asmus, 1989), the conventional criterion recommends a ratio of $5:1$ or more.

The sample size of the patient group ($n = 22$) was small as compared to the healthy adult group ($n = 165$). The idea of including a clinical as well as nonclinical population was drawn from previous measurement development studies (Advokat et al., 2007; Hufford & Fastenau, 2005; Meyers & Rohling, 2004). While equal sample size between the groups was considered in the planning of the study, it became evident that the patient recruitment sites had a limited patient pool during the given timeframe. Even with the relatively small sample size of the patient group, the proportion represented was higher in the current study than in the general population.

Between-group demographic differences also existed. While attempting to maintain demographic equivalence during the planning of the study, age, gender, ethnicity, and music education were not matched between the groups due to practicality concerns. The demographic differences of age and music education were likely due to the research participant recruitment strategy. Participants from the university versus those from the community resulted in a convenience sample that was not necessarily representative of the general adult population. Patients with TBI were recruited based on a clinically convenient sampling strategy. An attempt to control demographic variables could not be carried out for the current study. If demographic variables were controlled,
the MAA performance on each of the five subtests, which are based on the identified factors, could be more easily generalized. Future studies with a normative sample from the population would be recommended.

Additionally, general trends in brain injury incidence and regional characteristics of Miami were reflected. The significantly higher proportion of males in the TBI patient group as opposed to the healthy adult group for this study was consistent with gender trends in TBI (e.g., mean percentage of males being approximately 70%, Kraus & McArthur, 2000). The higher proportion of Hispanics in the TBI patient group than healthy adult group was consistent with the regional population characteristics of Miami.

Due to the size of the TBI patient group and convenience sampling strategy, the researcher decided not to examine the effect of demographic differences on MAA performance. This decision was deemed to be appropriate due to the exploratory nature of the study. Thus, this consideration should be implemented in a future study.

The MAA, however, could provide a theoretically appropriate and practically useful measure of auditory attention. As aforementioned, the five-factor constructs of the MAA represent basic and more advanced levels of auditory attention sub-types (i.e., the MAA-Sustained-Short as a measure of a basic level of sustained attention, the MAA-Sustained-Med to Long as a measure of an advanced level of sustained attention, the MAA-Selective-Noise as a measure of selective auditory attention, the MAA-Divided-Short to Med as a measure of a basic divided attention, and the MAA-Divided-Long a measure of an advanced divided attention).

The identified factor-constructs of the MAA relevant to the different types of attention will provide assessment knowledge regarding attention deficits commonly
observed in TBI. For example, a low test score in the MAA-Selective-Noise indicates a patient’s deficit in selective auditory attention. Further, the MAA will provide diagnostic information regarding auditory attentional ability in a more ecologically valid context where distracting or competing sounds are present. The MAA, therefore, will be valuable in identifying the level of attention impairments of patients with TBI, and useful in selecting appropriate tasks in attention rehabilitation and assessing functional outcome.

**Recommendations for Future Research**

There are many possible implications for future research. This study could be replicated with a larger sample of patients with TBI as well as healthy adults. The study could be replicated with a large enough TBI sample, thus allowing the researcher to explore and generalize the factor structure unique to the attention performance of patients with TBI. Similarly, replication with healthy adults would provide an opportunity to confirm the factor constructs obtained from the current study. Further, a comparison of different factor structures from each population would help identify differences in attention performance in response to musical stimuli. Once the factor structures of the revised MAA are stabilized, this study could be replicated with a larger group of patients with TBI as well as healthy adults to confirm whether the identified factor structures exist consistently (i.e., confirmatory factor analysis). For future replication, deleting cross-loaded test items should be carefully considered to maintain the high *alpha* reliability estimated by the 54-item MAA.

Criterion validity of the MAA could be investigated in relation to frequently used neuropsychological assessment measurements (e.g., WAIS-IV Digit Span Test, D-KEFS Color Word Interference Test). The investigation should be done with a larger group of
persons with TBI (e.g., 40-50 patients). Once these psychometric properties are established (i.e., reliability, construct validity, criterion validity), rehabilitation professionals could then confidently use the measure to assess attentional abilities of patients with TBI. The MAA also could be used as an outcome measure to evaluate the effect of an intervention on attention in other fields of medicine, such as psychopharmacology (i.e., the effect of medication on attention).

Construct validity as well as criterion validity could be investigated by using exploratory factor analysis and confirmatory factor analysis with a group of healthy adults and healthy children. Attention deficits are pervasive among various clinical populations, such as those with alcohol dependence, depression, attention deficit hyperactivity disorder (ADHD), and several other developmental disorders. Therefore, a norm for typical adults as well as typical children should be established prior to application of the MAA to various clinical populations.

A computerized version of the MAA would be desirable. As mentioned previously, attention is a hierarchical structure, consisting of a variety of components. Even though reaction time (i.e., processing speed) is not considered in the MAA, time could be another critical attention factor. By computerizing the test items, reaction time or latency of response to the test items would be automatically recorded and considered to provide assessment knowledge regarding auditory attention in clinical and nonclinical populations.

Actual brain-imaging investigation as observed by diagnostic devices (i.e., EEG, fMRI, and PET) during completion of the MAA would be useful to further validate the assumed subscales of the MAA. Taken together, these types of studies will provide
valuable support to help confirm the attention hierarchy identified and supported by the MAA.
References


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Appendix A

Informed Consent Form A

**Informed Consent of Patient**

**TITLE:** Music-Based Attention Assessment for Patients with Traumatic Brain Injury

**PROTOCOL NO.:** 20081058

**SPONSOR:** N/A

**INVESTIGATOR:** Teresa L. Lesiuk, Ph. D., MT-BC, MTA

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305) 284-3650

Eunju Jeong,

786) 486-7922

Dr. Ireland

305)585-1267

**INVESTIGATOR(S):** Eunju Jeong, MED., MT-BC

Susan J. Ireland, Ph.D.
PURPOSE: The purpose of this study is to construct a quantitative music-based attention assessment, suitable for administration to patients diagnosed with Traumatic Brain Injury.

PROCEDURES: You will first be asked to complete a questionnaire that addresses your general background and your experience in music. You will then be asked to complete both a Music-Based Attention Assessment and a verbal-based attention assessment. For the Music-Based Attention Assessment, you will listen to music and mark the direction of the music on a given answer sheet. For the neurological assessment, you will be presented with numbers, letters, and words, and asked to answer verbally to given questions. You will be given a 10-minute break between the Music-Based Attention Assessment and the verbal-based attention assessment.

RISKS: There are no known risks to the participants in this study. The only potential risks might be mild distress associated with being faced with attention deficits if you perceive that you are performing poorly on the measures.

BENEFITS: There is no direct benefit to you from your participation in this research study. We believe the information will lead to a better understanding of the effect of music on attention process, and further contribute to development of music attention training program for patients with Traumatic Brain Injury.

ALTERNATIVES: The alternative is to not participate in the research.
NEW FINDINGS: There are currently no studies of music-based assessment for patients with Traumatic Brain Injury.

COSTS: There will be no additional costs to participate this study.

PAYMENT TO SUBJECTS: There will be no payment to subjects.

SOURCE OF FUNDING: There will be no source of funding.

CONFIDENTIALITY: By signing this content, you authorize the Investigators(s) and his/her/their staff to access your study information and medical records as may be necessary for purposes of this study. Your records and results will not be identified or shared in any way without your expressed permission. The investigators and their assistants will consider your records confidential to the extent permitted by law. The U.S. Department of Health and Human Services (DHHS) may request to review and obtain copies of your records. Your records may also be reviewed for audit purposes by authorized University or other agents who will be bound by the same provisions of confidentiality.

RIGHT TO WITHDRAW: Your participation in this research study is voluntary. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw at any time. If you do withdraw
from this study, it will not affect your future care or ability to receive healthcare at the
Jackson Memorial Hospital.

OTHER PERTINENT INFORMATION: N/A

CONSENT: I have read the information in this consent form. I have had the chance to
ask any questions I have about this study and they have been answered for me. I freely
give my consent to be a participant in this study. A copy of this consent form will be
provided to you.

_________________________________________________
Printed Name of Participant

_________________________________________________
Signature of Participant Date

_________________________________________________
Name of Person Conducting Informed Consent Discussion

_________________________________________________
Signature of Person Conducting Informed Consent Discussion Date
Appendix B

Informed Consent Form B

**Informed Consent of Proxy**

**Information for People Who Give Proxy Consent to Take Part in Research Studies**

**TITLE:** Music-Based Attention Assessment for Patients with Traumatic Brain Injury

**PROTOCOL NO.:** 20081058

**SPONSOR:** N/A

**INVESTIGATOR:** Teresa L. Lesiuk, Ph. D., MT-BC, MTA

**SITE(S):** Rehabilitation Hospital Center

Jackson Memorial Hospital

1611 Northwest 12th Avenue

Miami, Florida 33136-1096

**STUDY-RELATED**

**PHONE NUMBER(S):** Dr. Lesiuk

305) 284-3650

Eunju Jeong,

786) 486-7922

Dr. Ireland

305)585-1267

**SUB-**

**INVESTIGATOR(S):** Eunju Jeong, MED., MT-BC

Susan J. Ireland, Ph.D.
Finding the best person to give consent by proxy:

Under certain circumstances, someone can give consent and research authorization for another person to take part in this research study. This person is the “subject by proxy.” The proxy can make choices for the subject, if the subject is not able to make choices for himself or herself. A proxy can be any of the people listed in Section A below.

A. Look at the list and write Proxy in the space next to the description of the person who will give consent and research authorization for the person participating in this study. If there is a person with a higher authority, write in the space why that person is not available, willing, or able to act as proxy. The following is an example:

Health Care Surrogate: No one was named
Spouse: Spouse has died
Adult Child: Unable to reach by phone after several tries
Parent: PROXY

(1) A **guardian** of the person, appointed by the court. He/she must be authorized to give consent to medical treatment: ________________________________

(2) **Health Care Surrogate** named by person: ________________________________

(3) The person's **spouse**: ________________________________

(4) An **adult child** of the person. If the person has more than one adult child, a majority of the adult children who are reasonably available for consultation:  

_____________________.


(5) A parent of the person: _______________________________________.

(6) The adult sibling of the person. If the person has more than one sibling, a majority of the adult siblings who are reasonably available for consultation:
     _______________________________________.

(7) An adult relative of the person who has shown special care and concern for the person. This adult relative has kept regular contact with the person. He/she knows how the person feels about things, what the person likes to do, what the person’s health is like, what the person believes and thinks is right
     _______________________________________.

(8) A close friend of the person: _______________________________________.

(9) A clinical social worker licensed pursuant to Chapter 491, or who is a graduate of a court-approved guardianship program. Such a proxy must be selected by the provider’s bioethics committee and must not be employed by the provider. If the provider does not have a bioethics committee, then such a proxy may be chosen through an arrangement with the bioethics committee of another provider. The proxy will be notified that, upon request, the provider shall make available a second physician, not involving in the subject’s care to assist the proxy in evaluating treatment. Decisions to withhold or withdraw life-prolonging procedures will be reviewed by the facility’s bioethics committee.
     Documentation of efforts to locate proxies from prior classes must be recorded in the subject record.
Proxy’s Statement of Consent:

I, __________________________, hereby agree to serve as the proxy (representative) for ___________________________ (“the subject”), with the power to make research participation decisions for the subject if she/he is unable to do so her/himself. I bear the following relationship to the subject: ________________________________.

I understand that my power as the subject’s proxy begins when the doctor decides and documents in the subject’s medical record that the subject is unable to make health care or research participation decisions for her/himself and ends as soon as the subject can make those health care or research participation decisions.

In making research participation decisions for the subject, I agree to make the decisions which I think the subject would have made in that situation. If I do not know what the subject would have chosen, then I should decide what treatment or care would be best for her/him.

I understand that if I am asked to make a decision about stopping or not starting life-prolonging procedures related to the research participation, my decisions must be based on facts that the decision would have been the one chosen by the subject if she/he had been able to decide. If there is no indication of what she/he would have chosen, then I will make the decision that would be best for the subject. However, before making any decision with regard to stopping or not starting life-prolonging procedures, related to the research participation, I must determine that: 1) the subject cannot recover to the point of
being able to decide for her or himself; and 2) the subject has an unchangeable disease, illness, or injury that cannot be cured or corrected by the doctors, or the subject has a disease, illness or injury from which he/she will not get better and will probably die, or the subject is permanently unconscious and cannot move by him/herself and cannot communicate.

If the subject has made a living will or left other written instructions about the health care he/she would like to have or research she/he would like to participate in or designated someone else as a surrogate or proxy, I will get a copy of these instructions and follow what they say or contact such surrogate or proxy.

I understand that as the subject’s proxy, I have the following responsibilities:

1) To act for the subject and to make all research participation decisions for the subject which I think the subject would have made in that situation. If I do not know what the subject would have chosen, I will decide what research participation would be best for the subject.

2) Talk with the health care providers to give informed consent about the health care or research participation for the subject.

3) To give written permission using the right forms whenever consent is necessary.

4) To look at and read the appropriate medical records of the subject.

5) To apply for benefits, like Medicare and Medicaid, for the subject and to be allowed to see information about the subject’s income, belongings, banking, and financial records that are needed to apply for public benefits.
6) To give permission for the release of medical records and other information if it will help the subject receive the necessary health care.

7) To give permission for the subject to be admitted, transferred or discharged from the hospital or other health facility.

_________________________________  _______________________
Signature of Proxy  Date

_________________________________
Street Address

_________________________________
City, State

_________________________________
Phone

The remainder of this form is written as if you, the Proxy, are being asked to participate in a research study entitled “Music-Based Attention Assessment for Patients with Traumatic Brain Injury.” This helps you think in terms of what the person for whom you are providing consent would do or what is best for that person.
PURPOSE: The purpose of this study is to construct a quantitative music-based attention assessment, suitable for administration to patients diagnosed with Traumatic Brain Injury.

PROCEDURES: You will first be asked to complete a questionnaire that addresses your general background and your experience in music. You will then be asked to complete both a Music-Based Attention Assessment and a verbal-based attention assessment. For the Music-Based Attention Assessment, you will listen to music and mark the direction of the music on a given answer sheet. For the neurological assessment, you will be presented with numbers, letters, and words, and asked to answer verbally to given questions. You will be given a 10-minute break between the Music-Based Attention Assessment and the verbal-based attention assessment.

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SOURCE OF FUNDING: There will be no source of funding.

CONFIDENTIALITY: By signing this content, you authorize the Investigators(s) and his/her/their staff to access your study information and medical records as may be necessary for purposes of this study. Your records and results will not be identified or shared in any way without your expressed permission. The investigators and their assistants will consider your records confidential to the extent permitted by law. The U.S. Department of Health and Human Services (DHHS) may request to review and obtain copies of your records. Your records may also be reviewed for audit purposes by authorized University or other agents who will be bound by the same provisions of confidentiality.

RIGHT TO WITHDRAW: Your participation in this research study is voluntary. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw at any time. If you do withdraw
from this study, it will not affect your future care or ability to receive healthcare at the
Jackson Memorial Hospital.

OTHER PERTINENT INFORMATION: N/A

CONSENT: I have read the information in this consent form. I have had the chance to
ask any questions I have about this study and they have been answered for me. I freely
give my consent to be a participant in this study. A copy of this consent form will be
provided to you.

_________________________________________________
Printed Name of Participant

_________________________________________________
Printed Name of Proxy

_________________________________________________
Signature of Proxy                                      Date

_________________________________________________
Name of Person Conducting Informed Consent Discussion

_________________________________________________
Signature of Person Conducting Informed Consent Discussion  Date
Appendix C
Participant Information Form A

Demographics for Music-based Attention Assessment A

University of Miami
Frost School of Music
Department of Music Education and Music Therapy
Coral Gables, Florida

This survey is designed to obtain basic information from participants who will be administered in Music-Based Attention Assessment. You should complete the survey either by filling in the box with a mark ✓ or writing a short answer. I appreciate your participation in this study, and your responses will be kept strictly confidential.

1. What is your gender? ☐ Male ☐ Female

2. What is your age? ___________ years

3. What is your ethnicity?
☐ ☐ ☐ ☐ ☐ ☐
Caucasians African Americans Hispanics Asian/Pacific Islanders Others
4. When did your brain injury occur? Date: _____/_____/_____

5. What is the highest level of education that you have completed?
   - □ Primary school
   - □ Some secondary school
   - □ Completed high school
   - □ Some additional training (e.g., apprenticeship, TAFE courses etc.)
   - □ Undergraduate studies (e.g., bachelor)
   - □ Postgraduate studies (e.g., master, doctor, post doc)
   How many years have you studied altogether? ________ years

6. How many years did you study music in school? ________ years

7. How many hours do you listen to music in a week? ________ hours

8. Are you currently involved in any type of musical activity? If yes, which type of musical activity are you involved in and how many years have you played/sung?
   - □ Chorus ____________ years
   - □ Instrumental ensemble ____________ years
   - □ Private lessons ____________ years
   - □ Other (______________) ____________ years
Appendix D

Initial Version of MAA: Script

Tr. #

01 Music-Based Attention Assessment

02 This is an attention test. Listen to the instructions and circle the answer that you have decided as correct. Sample questions will be given before the test begins. There is only one correct answer for each question.

03 Part A-Sustained Attention

04 Test I. Music

05 Practice Session: Listen to the direction of the music

06 No. 1

07 This is music that goes up.

08 [music]

09 No. 2

10 This is music that stays the same

11 [music]

12 No. 3

13 This is music that goes down

14 [music]

15 Practice Exercise: Listen carefully and circle the direction of the music

16 No. 1

17 [music]

18 The music was going up.
No. 2

[music]

No. 3

[music]

The music was going down.

Test Items: Listen carefully and circle the correct direction of the music

No. 1

[music]

No. 2

[music]

No. 3

[music]

No. 4

[music]

No. 5

[music]

No. 6

[music]

No. 7

[music]

No. 8

[music]
Test II. Instruments

Practice Session: Listen to the music and match the sound with the picture of the instrument

No. 1
This is music played by the piano.

No. 2
This is music played by the flute.

No. 3
This is music played by the string.

Practice Exercise: Listen to the music and circle the correct picture of the instrument

No. 1
This is music played by the flute.

No. 2
This is music played by the string.

No. 3
This is music played by the piano.
Test Items: Listen carefully and circle the correct picture of the instrument

No. 1 [music]
No. 2 [music]
No. 3 [music]
No. 4 [music]
No. 5 [music]
No. 6 [music]
No. 7 [music]
No. 8 [music]

Part B-Selective Attention

Test III. Music and noise

Test Items: You will hear an instrument and noise. Listen carefully and circle the correct direction of the music

No. 1 [music]
Test IV. Two instruments

Test Items: You will hear two different instruments. Listen carefully and circle the direction of the given instrument.
Part C - Divided Attention

Test V. Two instruments with different directions

Practice Session: Listen carefully to the direction of each instrument.

No. 1

The music played by the string was going up. The music played by the flute was staying the same.

Practice Exercise: Listen carefully and circle the direction of the music played by each instrument.

No. 1

The music played by the piano was going down. The music played by the string was staying the same.
Test Items: You will hear two different instruments. Listen carefully and circle the direction of the music played by each instrument.

No. 1 [music]
No. 2 [music]
No. 3 [music]
No. 4 [music]
No. 5 [music]
No. 6 [music]
No. 7 [music]
No. 8 [music]

Test VI. Same instruments with different directions

Practice session: Listen carefully to two of the same instrument playing.

No. 1 [music]
The music played by the flute. One music was going down, and the other music
was staying the same.

**Practice Exercise:** Listen carefully and circle the direction of the music played by each instrument.

150 No. 1

151 [music]

152 The music played by the piano. One music was going down, and the other music was staying the same.

**Test Items:** You will hear two of the same instrument playing. Listen carefully and circle the direction of the music played by each instrument.

154 No. 1

155 [music]

156 No. 2

157 [music]

158 No. 3

159 [music]

160 No. 4

161 [music]

162 No. 5

163 [music]

164 No. 6

165 [music]

166 No. 7

167 [music]
168  No. 8

169  [music]
Appendix E

Initial Version of the MAA: Answer Sheet

Music Attention Assessment
Part A – Sustained Attention

Test I. Music
Practice session
Instruction: Listen to the direction of the music.
1. Up
   ↑

2. Same
   →

3. Down
   ↓

Practice Exercise
Instruction: Listen carefully and circle the direction of the music.
1. Up Same Down Not sure
   ↑ → ↓ ?

2. Up Same Down Not sure
   ↑ → ↓ ?

3. Up Same Down Not sure
   ↑ → ↓ ?

Date: ______/_____/_____
Name: ___________________
**Test Items**
Instruction: Listen carefully and circle the correct direction of the music.

1. | Up | Same | Down | Not sure |
   | ↑  | →   | ↓    | ?        |

2. | Up | Same | Down | Not sure |
   | ↑  | →   | ↓    | ?        |

3. | Up | Same | Down | Not sure |
   | ↑  | →   | ↓    | ?        |

4. | Up | Same | Down | Not sure |
   | ↑  | →   | ↓    | ?        |

5. | Up | Same | Down | Not sure |
   | ↑  | →   | ↓    | ?        |

6. | Up | Same | Down | Not sure |
   | ↑  | →   | ↓    | ?        |

7. | Up | Same | Down | Not sure |
   | ↑  | →   | ↓    | ?        |

8. | Up | Same | Down | Not sure |
   | ↑  | →   | ↓    | ?        |
Test II. Instruments

Practice Session
Instruction: Listen to the music and match the sound with the picture of the instrument.

Practice Exercise
Instruction: Listen to the music and circle the correct picture of the instrument.
1. Piano  Flute  Guitar  Not sure
2. Piano  Flute  Guitar  Not sure
3. Piano  Flute  Guitar  Not sure
**Test Items**  
Instruction: Listen carefully and circle the correct direction of the music.

<p>| | | | | |</p>
<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Up</td>
<td>Same</td>
<td>Down</td>
<td>Not sure</td>
</tr>
<tr>
<td></td>
<td>↑</td>
<td>→</td>
<td>↓</td>
<td>?</td>
</tr>
<tr>
<td>2.</td>
<td>Up</td>
<td>Same</td>
<td>Down</td>
<td>Not sure</td>
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<tr>
<td></td>
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<tr>
<td>3.</td>
<td>Up</td>
<td>Same</td>
<td>Down</td>
<td>Not sure</td>
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<td>?</td>
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<td>4.</td>
<td>Up</td>
<td>Same</td>
<td>Down</td>
<td>Not sure</td>
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<tr>
<td>5.</td>
<td>Up</td>
<td>Same</td>
<td>Down</td>
<td>Not sure</td>
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<tr>
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<tr>
<td>6.</td>
<td>Up</td>
<td>Same</td>
<td>Down</td>
<td>Not sure</td>
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<tr>
<td>7.</td>
<td>Up</td>
<td>Same</td>
<td>Down</td>
<td>Not sure</td>
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<td></td>
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<td>→</td>
<td>↓</td>
<td>?</td>
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<tr>
<td>8.</td>
<td>Up</td>
<td>Same</td>
<td>Down</td>
<td>Not sure</td>
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<tr>
<td></td>
<td>↑</td>
<td>→</td>
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<td>?</td>
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</tbody>
</table>
**Part B – Selective Attention**

Test III. Instrument and noise.

*Test Items*
Instruction: You will hear an instrument and noise. Listen carefully and circle the correct direction of the music.

1. **Up** | **Same** | **Down** | **Not sure**
   | ↑ | → | ↓ | ?

2. **Up** | **Same** | **Down** | **Not sure**
   | ↑ | → | ↓ | ?

3. **Up** | **Same** | **Down** | **Not sure**
   | ↑ | → | ↓ | ?

4. **Up** | **Same** | **Down** | **Not sure**
   | ↑ | → | ↓ | ?

5. **Up** | **Same** | **Down** | **Not sure**
   | ↑ | → | ↓ | ?

6. **Up** | **Same** | **Down** | **Not sure**
   | ↑ | → | ↓ | ?

7. **Up** | **Same** | **Down** | **Not sure**
   | ↑ | → | ↓ | ?

8. **Up** | **Same** | **Down** | **Not sure**
   | ↑ | → | ↓ | ?
Test IV. Two instruments.

**Test Items**

Instruction: You will hear two different instruments. Listen carefully and circle the direction of the given instrument.

<table>
<thead>
<tr>
<th></th>
<th>Piano</th>
<th>Flute</th>
<th>Guitar</th>
<th>Flute</th>
<th>Piano</th>
<th>Guitar</th>
<th>Flute</th>
<th>Piano</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Up</td>
<td>Same</td>
<td>Down</td>
<td>Not sure</td>
<td>Up</td>
<td>Same</td>
<td>Down</td>
<td>Not sure</td>
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<tr>
<td>2.</td>
<td>Flute</td>
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<tr>
<td>3.</td>
<td>Guitar</td>
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<td>4.</td>
<td>Flute</td>
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<td>5.</td>
<td>Piano</td>
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<tr>
<td>6.</td>
<td>Guitar</td>
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<td>7.</td>
<td>Flute</td>
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<td>8.</td>
<td>Piano</td>
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<td>?</td>
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</tbody>
</table>
Part C – Divided Attention

Test V. Two Instruments with different directions.

Practice Session
Instruction: Listen carefully to the direction of each instrument.

1.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Up</th>
<th>Same</th>
<th>Down</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Guitar</td>
<td>↑</td>
<td>→</td>
<td>↓</td>
<td>?</td>
</tr>
<tr>
<td>Flute</td>
<td>↑</td>
<td>→</td>
<td>↓</td>
<td>?</td>
</tr>
</tbody>
</table>

Practice Exercise
Instruction: Listen carefully and circle the direction of the music played by each instrument.

1.

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Up</th>
<th>Same</th>
<th>Down</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piano</td>
<td>↑</td>
<td>→</td>
<td>↓</td>
<td>?</td>
</tr>
<tr>
<td>Guitar</td>
<td>↑</td>
<td>→</td>
<td>↓</td>
<td>?</td>
</tr>
</tbody>
</table>
**Test Items**

Instruction: You will hear two different instruments. Listen carefully and circle the direction of the music played by each instrument.

1. | Piano | Up | Same | Down | Not sure |
   |      | ↑  | →    | ↓    | ?       |
   | Guitar | Up | Same | Down | Not sure |
      | ↑  | →    | ↓    | ?       |

2. | Flute | Up | Same | Down | Not sure |
   |      | ↑  | →    | ↓    | ?       |
   | Guitar | Up | Same | Down | Not sure |
      | ↑  | →    | ↓    | ?       |

3. | Flute | Up | Same | Down | Not sure |
   |      | ↑  | →    | ↓    | ?       |
   | Piano | Up | Same | Down | Not sure |
      | ↑  | →    | ↓    | ?       |

4. | Flute | Up | Same | Down | Not sure |
   |      | ↑  | →    | ↓    | ?       |
   | Guitar | Up | Same | Down | Not sure |
      | ↑  | →    | ↓    | ?       |
5. **Piano**  
- **Up**: ↑  
- **Same**: →  
- **Down**: ↓  
- **Not sure**: ?  

**Flute**  
- **Up**: ↑  
- **Same**: →  
- **Down**: ↓  
- **Not sure**: ?

6. **Guitar**  
- **Up**: ↑  
- **Same**: →  
- **Down**: ↓  
- **Not sure**: ?  

**Piano**  
- **Up**: ↑  
- **Same**: →  
- **Down**: ↓  
- **Not sure**: ?

7. **Flute**  
- **Up**: ↑  
- **Same**: →  
- **Down**: ↓  
- **Not sure**: ?  

**Piano**  
- **Up**: ↑  
- **Same**: →  
- **Down**: ↓  
- **Not sure**: ?

8. **Flute**  
- **Up**: ↑  
- **Same**: →  
- **Down**: ↓  
- **Not sure**: ?  

**Piano**  
- **Up**: ↑  
- **Same**: →  
- **Down**: ↓  
- **Not sure**: ?
Test VI. Same instruments with different directions

**Practice Session**
Instruction: Listen carefully to two of the same instrument playing.

1.

<table>
<thead>
<tr>
<th>Flute</th>
<th>Up</th>
<th>Same</th>
<th>Down</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑</td>
<td>→</td>
<td>↓</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

**Practice Exercise**
Instruction: Listen carefully and circle the direction of the music played by each instrument.

1.

<table>
<thead>
<tr>
<th>Piano</th>
<th>Up</th>
<th>Same</th>
<th>Down</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑</td>
<td>→</td>
<td>↓</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Piano</th>
<th>Up</th>
<th>Same</th>
<th>Down</th>
<th>Not sure</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑</td>
<td>→</td>
<td>↓</td>
<td>?</td>
<td></td>
</tr>
</tbody>
</table>
Test Items

Instruction: You will hear two of the same instrument playing. Listen carefully and circle the direction of the music played by each instrument.

1. Flute
   Up   Same   Down   Not sure
   ↑   →   ↓   ?

   Flute
   Up   Same   Down   Not sure
   ↑   →   ↓   ?

2. Piano
   Up   Same   Down   Not sure
   ↑   →   ↓   ?

   Piano
   Up   Same   Down   Not sure
   ↑   →   ↓   ?

3. Guitar
   Up   Same   Down   Not sure
   ↑   →   ↓   ?

   Guitar
   Up   Same   Down   Not sure
   ↑   →   ↓   ?

4. Flute
   Up   Same   Down   Not sure
   ↑   →   ↓   ?

   Flute
   Up   Same   Down   Not sure
   ↑   →   ↓   ?
5. Piano  Up  Same  Down  Not sure
   ↑  →  ↓  ?

5. Piano  Up  Same  Down  Not sure
   ↑  →  ↓  ?

6. Flute  Up  Same  Down  Not sure
   ↑  →  ↓  ?

6. Flute  Up  Same  Down  Not sure
   ↑  →  ↓  ?

7. Piano  Up  Same  Down  Not sure
   ↑  →  ↓  ?

7. Piano  Up  Same  Down  Not sure
   ↑  →  ↓  ?

8. Flute  Up  Same  Down  Not sure
   ↑  →  ↓  ?

8. Flute  Up  Same  Down  Not sure
   ↑  →  ↓  ?
Appendix F
Initial Version of the MAA: Results and Discussion

Results

Demographics

The study began with sixteen patients, but one was withdrawn because of a psychiatric diagnosis. Data from the remaining fifteen patients were retained for analysis. Demographic results showed that the participants were between 29 and 59 years of age ($M = 29.87$, $SD = 10.10$). Approximately 47% of the participants were Hispanic, 27% were African-American, 13% were Caucasian and 13% were Asian/Pacific Islander. The participants’ average years of education were 13.33 years ($SD = 3.33$) with an average of 3.33 years of music education ($SD = 4.14$).

With an average of 20.87 months since the date of traumatic brain injury ($SD = 30.67$), the participants’ levels of awareness and cognitive functioning were obtained from their medical records as measured by the Glasgow Coma Scale (GCS) and the Rancho Los Amigos Scale (RLAS) scores. An average GCS score of 6.40 ($SD = 3.40$) indicated that the participants were at a moderate level of awareness at the time of admission to the hospital. The average RLAS score of 7.80 ($SD = 0.41$) indicated that the participants were at either the automatic-appropriate (VII) or purposeful-appropriate (VIII) stage at the time of brain injury assessment.
**Item Characteristics**

Item difficulty and item discrimination of test items were computed from the obtained data. Item difficulty was calculated by the percentage of correct answers to which the participants responded. Item discrimination was calculated by the correlation between participants’ test items and their sum of item scores without including the test item (i.e., corrected item-total correlation). Item difficulty indices and item discrimination indices are shown in Table 1.
Table 1

Item Difficulty (IF) and Item Discrimination (ID) Indices

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Test Item Number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
<th>11</th>
<th>12</th>
<th>13</th>
<th>14</th>
<th>15</th>
<th>16</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA- sustained</td>
<td>IF</td>
<td>1</td>
<td>.93</td>
<td>1</td>
<td>.67</td>
<td>.93</td>
<td>.8</td>
<td>.8</td>
<td>.8</td>
<td>.73</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>.8</td>
<td>.73</td>
<td>.8</td>
</tr>
<tr>
<td></td>
<td>ID</td>
<td>0</td>
<td>.69</td>
<td>0</td>
<td>.64</td>
<td>.69</td>
<td>.68</td>
<td>.68</td>
<td>.25</td>
<td>.36</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>.86</td>
<td>.77</td>
<td>.86</td>
</tr>
<tr>
<td>MAA-selective</td>
<td>IF</td>
<td>1</td>
<td>.73</td>
<td>.93</td>
<td>.93</td>
<td>.93</td>
<td>.8</td>
<td>.87</td>
<td>1</td>
<td>.73</td>
<td>.93</td>
<td>.87</td>
<td>.93</td>
<td>.8</td>
<td>.67</td>
<td>.8</td>
<td>.4</td>
</tr>
<tr>
<td></td>
<td>ID</td>
<td>0</td>
<td>.83</td>
<td>.69</td>
<td>.69</td>
<td>.69</td>
<td>.76</td>
<td>.56</td>
<td>0</td>
<td>.44</td>
<td>.69</td>
<td>.48</td>
<td>.69</td>
<td>.86</td>
<td>.5</td>
<td>-.2</td>
<td>.51</td>
</tr>
<tr>
<td>MAA-divided</td>
<td>IF</td>
<td>.73</td>
<td>.6</td>
<td>.8</td>
<td>.6</td>
<td>.93</td>
<td>.53</td>
<td>.73</td>
<td>.33</td>
<td>.93</td>
<td>.73</td>
<td>.73</td>
<td>.8</td>
<td>.4</td>
<td>.8</td>
<td>.6</td>
<td>.6</td>
</tr>
<tr>
<td></td>
<td>ID</td>
<td>.28</td>
<td>.64</td>
<td>-.2</td>
<td>.67</td>
<td>.42</td>
<td>.63</td>
<td>.58</td>
<td>.42</td>
<td>.69</td>
<td>.41</td>
<td>.63</td>
<td>.86</td>
<td>.36</td>
<td>.86</td>
<td>.76</td>
<td>.27</td>
</tr>
</tbody>
</table>

The quality of test items in each of the three types of attention subtests was determined by principles such as (a) the test items that fall in the range between an item difficulty index of 0.4 and 0.6 are considered valuable items when there is a representative sample of participants and there is a normal distribution of responses (Garrett, 1966; Schmidt & Emberston, 2003), (b) the test items that fall in the range between an item discrimination index of 0.3 and 0.5 are considered valuable items (Oosterhof, 2001), and (c) an item discrimination index of 0.2 is considered the lowest acceptable value (Golden, Sawicki, & Franzen, 1984).

**Item difficulty.** Distributions of item difficulty are presented in Table 2. Test items with an item difficulty index below 0.4 were considered difficult, those with an item difficulty index between 0.4 and 0.6 were considered moderate, and those with an
item difficulty index between 0.6 and 1 were considered easy. Test items with an item
difficulty index of 1 indicate that every participant answered these test items correctly.
These test items with an item difficulty index of 1 have zero variance and therefore
contribute to an item discrimination index of 0.

Table 2

<table>
<thead>
<tr>
<th>Item Difficulty Distributions over Test Items</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 ≤ IF &lt; 0.4</td>
</tr>
<tr>
<td>MAA-sustained</td>
</tr>
<tr>
<td>MAA-selective</td>
</tr>
<tr>
<td>MAA-divided</td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

**Item discrimination.** Distributions of item discrimination are presented in Table
3. Test items with an item discrimination index between 0 and 0.2 were considered as
having a low discrimination value, while those with an item discrimination index
between 0.2 and 0.5 were considered as having an acceptable discrimination value, and
those with an item discrimination index above 0.5 were considered as having a high
discrimination value. Test items with an item discrimination index of 0 indicate that these
items provide no variance among test items due to an item difficulty index of 1.
Generally, test items with a negative index indicate that the items were keyed incorrectly,
were constructed poorly, thus need to be eliminated or revised for future use (Boyle, &
Radocy, 1987).
Analyses of contour, congruence, and interference. Distributions of correct responses to contour items are given in Table 4. The analysis was applied to test items that consisted of one melodic contour (i.e., as found in the MAA-sustained, and the first half of the MAA-selective). There were three possible contours consisting of moving upward, stationary, or moving downward.

Table 4

*Distributions of Contour of Test Items*

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Contour</th>
<th>$0 &lt; IF \leq 0.4$</th>
<th>$0.4 \leq IF \leq 0.6$</th>
<th>$0.6 &lt; IF &lt; 1$</th>
<th>$IF = 1$</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA-sustained</td>
<td>Up</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Stationary</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Down</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>MAA-selective</td>
<td>Up</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Stationary</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Down</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>0</td>
<td>0</td>
<td>16</td>
<td>8</td>
</tr>
</tbody>
</table>
The melodic contour of test items contributed to the level of item difficulty in which 29% of test items with an item difficulty index above 0.6 (i.e., 7 test items out of 24) consisted of a “stationary” melodic contour. Moreover, 63% of the test items with an item difficulty index of 1 (i.e., 5 test items out of 8) had the “stationary” melodic contour. Participants appeared to identify this melodic contour more easily as compared to the two other melodic contours.

Analyses of congruence and interference were applied to the test items that consisted of two simultaneous melodic contours (i.e., as found in the second half of MAA-selective, and the MAA-divided). Congruence indicated the direction of the two simultaneous melodic contours (i.e., congruent=stationary and incongruent=different). Interference indicated whether the two simultaneous melodic contours lines intersected each other (i.e., crossed each other or moved parallel). The results are shown in Table 5.

Table 5

*Distributions of Congruence and Interference of Test Items*

<table>
<thead>
<tr>
<th>Subtest</th>
<th>Contour</th>
<th>0 &lt; IF &lt; 0.4</th>
<th>0.4 ≤ IF ≤ 0.6</th>
<th>0.6 &lt; IF ≤ 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA-selective</td>
<td>Congruent</td>
<td>0</td>
<td>0</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Incongruent</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Interfering</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Non-interfering</td>
<td>0</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>MAA-divided</td>
<td>Congruent</td>
<td>0</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Incongruent</td>
<td>1</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Interfering</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Non-interfering</td>
<td>0</td>
<td>2</td>
<td>5</td>
</tr>
</tbody>
</table>
Sixteen test items with an item difficulty index above 0.6 included 56% of incongruent test items (i.e., 4 test items in the MAA-selective and 5 test items in the MAA-divided) and 44% of congruent test items. The proportion of incongruent test items increased as the level of item difficulty increased. Eight test items with an item difficulty index below 0.6 included 75% of incongruent test items (i.e., 1 test items in the MAA-selective and 5 test items in the MAA-divided) and 25% of congruent test items. The results indicate that the level of item difficulty increase as the proportion of incongruent test items increase.

In addition, eight test items with an item difficulty index above 0.6 included 44% of interfering test items (i.e., 3 test items in the MAA-selective and 4 test items in the MAA-divided) and 56% of non-interfering test items. The proportion of interfering test items increased as the level of item difficulty increased. That is, 16 test items with an item difficulty below 0.6 included 75% of interfering test items (i.e., 1 test item in the MAA-selective and 5 test items in the MAA-divided) and 25% of non-interfering test items. The results indicate that the level of item difficulty increase as the proportion of interfering test items increase.

**Scale Characteristics**

Table 6 shows that patient scores of sustained attention obtained the highest mean, while scores of divided attention received the lowest mean.
Table 6

Means and Standard Deviations of the MAA (n=15)

<table>
<thead>
<tr>
<th></th>
<th>Mean</th>
<th>SD</th>
<th>Min.</th>
<th>Max.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAA-sustained</td>
<td>14</td>
<td>2.93</td>
<td>8</td>
<td>16</td>
</tr>
<tr>
<td>MAA-selective</td>
<td>13.33</td>
<td>3.33</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>MAA-divided</td>
<td>10.60</td>
<td>4.19</td>
<td>3</td>
<td>16</td>
</tr>
<tr>
<td>MAA-total</td>
<td>37.93</td>
<td>9.35</td>
<td>14</td>
<td>48</td>
</tr>
</tbody>
</table>

Internal consistency. Cronbach’s alpha is the most widely used estimate of internal consistency for both dichotomous and polytomous test items (Schmidt & Emberston, 2003). Cronbach’s alpha is calculated based on the number of test items and the average inter-correlation among test items (Kline, 2005). Cronbach’s alpha coefficient for internal consistency in the current study was very high, $\alpha = .95$, indicating that the set of test items in the MAA was closely related as a group.

Discussion

The current study was an initial attempt to develop the MAA, a melodic contour identification test designed to assess the three types of attention (i.e., sustained attention, selective attention, and divided attention) of patients with TBI. The study field-tested the researcher-developed MAA with fifteen patients with TBI to evaluate the readability and comprehensibility of the test items on each proposed subtest. Additionally, this study examined the preliminary psychometric properties of the scale and test items.

The term “psychometrics” refers to theories and methods that are concerned with measuring mental functions of human beings, such as intelligence, attitude, and
personality traits (Furr & Bacharach, 2008). In classical test theories test items and scales are investigated to establish reliability and validity (Osterlind, 2006). In general a preliminary psychometric investigation of a researcher-developed measure begins with item property analyses (i.e., item difficulty, item discrimination) with an internal consistency examination (Osterlind, 2006).

**Item Difficulty**

Variability in the item difficulty indices equates to variance among test items which in turn contributes to the variability of total test scores. In other words, variability in the item difficulty indices suggests that the test items of the MAA were designed appropriately to measure a wide range of attentional ability of persons with TBI.

In addition, the level of item difficulty increased as the task demands of each subtest increased, suggesting a hierarchical structure of the MAA. Item difficulty indices confirmed the trend that three types of attention have separate levels of item difficulty. One hundred percent of the test items with an item difficulty index above 0.6 (i.e., were considered easy test items) were in the MAA-sustained, while 94% were in the MAA-selective, and 56% were in the MAA-divided. However, approximately 6% of the test items with an item difficulty index below an item difficulty of 0.6 (i.e., were considered moderate to difficult test items) were in the MAA-selective, while 44% were in the MAA-divided. This finding suggests that (a) the more test items with an item difficulty index above 0.6 in a subtest, the easier the entire subtest, and (b) each of the three attention subtests is differentiated by the proportion of test items that are found to be difficult. These reported findings are echoed by previous experimental studies in which listeners performed better in a selective auditory attention task than in a divided auditory
attention task (Bigand et al., 2000; Crawley et al., 2002; Gallun et al., 2007; Shinn-Cunningham & Ihlefeld, 2004). In the present study, the level of item difficulty is consistent with the categories of test items, or the three types of attention subtests, assumed by the investigators.

**Item Discrimination**

The test-item discrimination indices provided the preliminary psychometric support for the use of the MAA as an auditory attention assessment measure. From 48 test items of the MAA, 27 test items were above a discrimination index of 0.5. Given that a reasonable expectation for item discrimination indices in a multiple-choice test is between 0.3 and 0.5, this reported index suggests that there is an acceptable differentiation between participants who were capable of performing a given attention task and those who were less capable (Osterlind, 2006). In parallel, the high item discrimination index indicated that a participant who answered a highly discriminating item correctly was more likely to obtain a higher total score than a participant who answered that item incorrectly. However, two test items (i.e., Item 15 in MAA-selective, Item 3 in MAA-divided) were found to have a negative discrimination value, thus further investigation of the MAA is recommended with revision to the two items that had a negative discrimination index.

**Contour, Congruence, and Interference Analyses**

Additional analyses of melodic-contours of test items in each of the three attention subtests revealed that musical characteristics influence the level of item difficulty. Five out of eight test items with an item difficulty index of 1 as found in the MAA-sustained subtest and the first half of the MAA-selective subtest consisted of a
melodic contour that stayed stationary. This finding suggests that items with “stationary” melodic contour are the easiest to perceive among the three contours.

Further, analysis of congruence with items in the MAA-selective subtest and the MAA-divided subtest revealed that they became more difficult when two melodic contours moved in an incongruent manner (e.g., one had a “goes up” contour and another had a “goes down” contour). The influence of congruence on item difficulty was more pronounced as confirmed in comparison of easy test items (i.e., an item difficulty index above 0.6) with moderate to difficult test items (i.e., an item difficulty index below 0.6). These findings suggest that (a) incongruence between two competing melodic contours contributes to increasing the level of difficulty of the test items of the MAA, and (b) the more test items with incongruent melodic contours in a subtest, the more difficult the entire subtest. Similarly, Davison and Banks (2003) reported that presenting incongruent contours between two-tone melodic fragments (i.e., two short melodies that move in contrary motion) increased the level of difficulty in a selective auditory attention task.

Lastly, the frequency analysis of interference with test items in the MAA-selective and the MAA-divided subtests revealed that test items become more difficult when two melodic contours intersect at one point. The influence of interference on item difficulty was more pronounced as confirmed in comparison of easy test items (i.e., an item difficulty index above 0.6) with moderate to difficult test items (i.e., an item difficulty index below 0.6). The findings suggest that (a) interference between two competing melodic contours contribute to increasing the level of difficulty of the test items of the MAA, and (b) the more test items with two interfering melodic contours in a subtest, the more difficult the entire subtest. These results from the interference analysis
are consistent with Deutsch (1982) who found that participants more easily identified a melody from two concurrent melodies when they were presented with sufficient pitch distance. The results are also consistent with researchers (Davison & Banks, 2003; Dowling, 1973) who found that participants correctly identified two well-known nursery melodies when pitch registers of the two melodies did not overlap.

**Internal Consistency**

In spite of the small sample size ($N=15$), the internal consistency of the MAA test items was high as computed by Cronbach’s alpha = 0.95. Further, the high alpha value provides support for the construct validity of the MAA since Cronbach’s alpha indicates the degree to which the test items measure consistently underlying latent constructs (Henson, 2001).

**Conclusions and Recommendations**

The current study aimed to describe the development of the MAA and a preliminary evaluation of item and scale properties. In summary, the item difficulty and item discrimination indices, as well as the high alpha value of internal consistency, suggests that test items of the MAA are homogenous. Therefore, the measure has potential to provide diagnostic information in regards to auditory attention of patients with TBI. Given that the current study was a pilot study and the sample size was small, the authors cannot recommend that the MAA be used at this time to measure attentional ability of patients with TBI. Although not an official measure of the study, participants offered verbal comments following the MAA that included (a) that the music test was enjoyable, (b) that they felt they could complete the test because the music was “fun” and
(c) that the test was well organized and held their interest because it became progressively more challenging.

Further investigation with a large sample of approximately 150-200 typical population is recommended to confirm the construct validity and internal consistency of the MAA. Criterion validity of the MAA as correlated with frequently used neuropsychological assessment measurements should be investigated with a larger group of persons with TBI (e.g., 40-50 patients). Thus the next step in development of the MAA is to establish both construct and criterion validity. Once these psychometric properties are established, music therapists and other related professionals can be confident in its use to assess attention. Lastly, actual brain-imaging investigation as observed by diagnostic devices (i.e., EEG, fMRI, and PET) during listening to the MAA would be useful to further validate the assumed subscales of the MAA. Taken together, these types of studies will provide valuable support to help confirm the attention hierarchy required in the music listening assessment.
Appendix G

Informed Consent Form C

**Informed Consent of Participant**

**Title of Study:** Music Based Attention Assessment for Patients with
Traumatic Brain Injury

**Protocol No:** Protocol #20081058

**Principal Investigator:** Teresa L. Lesiuk, Ph.D., MT-BC, MTA
University of Miami
Philip and Patricia Frost School of Music
Department of Music Education and Music Therapy
Coral Gables, FL 33124

**Co-Investigator:** Eunju Jeong, MED, MT-BC
Ph.D. student, Music Therapy
University of Miami
Philip and Patricia Frost School of Music
Department of Music Education and Music Therapy
Coral Gables, FL 33124

Susan Ireland, Ph.D.
Jackson Memorial Hospital Rehabilitation Hospital Center
1611 Northwest 12th Avenue
Miami, FL 33136
Site:
University of Miami
Jackson Memorial Hospital
Rehabilitation Hospital Center
1611 Northwest 12th Avenue
Miami, Florida 33136-1096

Contact Info:
Teresa L. Lesiuk, Ph. D., MT-BC, MTA
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tlesiuk@miami.edu

Eunju Jeong, MED., MT-BC
786) 486-7922
e.jeong@umiami.edu

Susan Ireland, Ph.D.
305) 585-1267
SIreland@jhsmiami.org
You are being asked to take part in a pilot study, which is a part of a research study entitled “Music-Based Attention Assessment for Patients with Traumatic Brain Injury (TBI).” This consent form provides information so that you can decide whether you wish to participate in the present study.

PURPOSE OF THE STUDY: The purpose of this pilot study is to test a Music-Based Attention Assessment.

DURATION OF STUDY: The study will be approximately twenty minutes.

PROCEDURES: You will first be asked to complete a questionnaire that addresses your general background and your experience in music. You will then be asked to complete the Music-Based Attention Assessment. You will listen to music and mark the direction of the music on a given answer sheet.

RISKS: There are no known risks to the participants in this study. The only potential risks might be mild distress associated with being faced with attention deficits if you perceive that you are performing poorly on the measures.

BENEFITS: There is no direct benefit to you from your participation in this research study. We believe the information will lead to a better understanding of the effect of music on attention process, and further contribute to development of music attention training program for patients with TBI.
**RIGHT TO WITHDRAW:** Your participation in this research study is voluntary. You may refuse to sign this form and not participate in this study. You should be aware that even if you agree to participate, you are free to withdraw at any time.

**CONFIDENTIALITY:** Your records and results will not be identified or shared in any way without your expressed permission. The investigators and their assistants will consider your records confidential to the extent permitted by law. The U.S. Department of Health and Human Services (DHHS) may request to review and obtain copies of your records. Your records may also be reviewed for audit purposes by authorized University or other agents who will be bound by the same provisions of confidentiality.

**WHOM TO CONTACT:** If you have any questions or concerns about this research study, feel free to ask for additional information from the principal investigator, Dr. Teresa Lesiuk, at (305) 284-3650. You can also contact the co-investigator Eunju Jeong at (786) 486-7922 about any questions or concerns regarding your participation in this study. If you have questions about your rights as a research subject you may contact Human Subjects Research Office at the University of Miami, at (305) 243-3195.

**CONSENT:** I have read and understand this consent form. This study has been explained to my satisfaction and all of my questions have been answered. If I have any further questions regarding this study, I should contact the appropriate person named above. Based on this information, I voluntarily agree to take part in this research study. A copy of this consent form will be provided to you.
Printed name of Participant

Signature of Participant  Date

Person Obtaining Consent  Date
Appendix H

Participant Information Form B

Demographics for Music-based Attention Assessment

University of Miami
Frost School of Music
Department of Music Education and Music Therapy
Coral Gables, Florida

This survey is designed to obtain basic information from participants who will be administered in Music-Based Attention Assessment. You should complete the survey either by filling in the box with a mark ✓ or writing a short answer. I appreciate your participation in this study, and your responses will be kept strictly confidential.

1. What is your gender? ☐ Male ☐ Female

2. What is your age? ____________ years

3. What is your ethnicity?
☐ ☐ ☐ ☐ ☐
Caucasians African Americans Hispanics Asian/Pacific Islanders Others
4. What is the highest level of education that you have completed?

☐ Primary school

☐ Some secondary school

☐ Completed high school

☐ Some additional training (e.g., apprenticeship, TAFE courses etc.)

☐ Undergraduate studies (e.g., bachelor)

☐ Postgraduate studies (e.g., master, doctor, post doc)

How many years have you studied altogether? __________ years

5. How many years did you study music in school? ___________ years

6. How many hours do you listen to music in a week? ____________ hours

7. Are you currently involved in any type of musical activity? If yes, which type of musical activity are you involved in and how many years have you played/sung?

☐ Chorus ____________________ years

☐ Instrumental ensemble ________________ years

☐ Private lessons ________________ years

☐ Other (______________) ________________ years
Appendix I

Revised Version of MAA: Script

Tr.#

01 Music-Based Attention Assessment

02 This is a test of attention to music. Listen to the instructions and then circle the correct answer. Before you begin the test, you will hear some sample music and you will do some practice items.

03 Practice Session I. You will hear some samples of music. This part will explain some of the words that are used in the test. Listen to the direction of the music.

04 No. 1

05 This is music that goes up.

06 [music]

07 No. 2

08 This is music that stays the same.

09 [music]

10 No. 3

11 This is music that goes down.

12 [music]

13 Practice Session II. You will hear music played by three different instruments. Listen to the sound that goes with the picture of each instrument.

14 No. 1

15 This is music played by the piano.
No. 2
This is music played by the guitar.

No. 3
This is music played by the flute.

Practice Exercise. Now you will do some practice test items. Listen carefully to the direction of the music played by different instruments. Wait until the beep and then circle the answer.

No. 1
This music has one set of five tones.

No. 2
This music has two sets of five tones.

Now you can circle the answer.

Now you can circle both answers.
This music has three sets of five tones.

Now you can circle all three answers.

Now go to the next page.

Part A-Sustained Attention

Test I. Music

You will hear music played by the piano. Listen carefully to the direction of the music. Wait until the beep, and then circle the answer.

Same format continues for track no. 53 through no. 86.

Test II. Instruments

You will hear music played by different instruments. Listen carefully to the direction of the music played by the instrument. Wait until the beep, and then circle the answer.
Part B - Selective Attention

Test III. Instrument and noise

You will hear an instrument and some noise at the same time. Listen carefully to the direction of the music played by the instrument. Wait until the beep, and then circle the answer.

No. 1

[music]

[beep]

[time]

Same format continues for track no. 134 through no. 167.

Test IV. Two instruments

You will hear two different kinds of instruments playing at the same time. Listen carefully to the direction of the instrument in the picture. Wait until the beep, and then circle the answer.

No. 1

[music]

[beep]

[time]

Same format continues for track no. 174 through no. 207.
Test V. Two instruments with different directions

You will hear two different instruments playing at the same time. Listen carefully to the direction of the music played by each instrument. Wait until the beep, and then circle the answers.

No. 1
[music]
[beep]
[time]

Same format continues for track no. 215 through no. 250.

Test VI. Same instruments with different directions

You will hear two of the same kind of instrument playing at the same time. Listen carefully to the two directions of the music played by the same instruments. Wait until the beep, and then circle the answers.

No. 1
[music]
[beep]
[time]

Same format continues for track no. 258 through no. 292.

This is the end of the test.
Appendix J

Revised version of MAA: Score

MAA-Sustained

Test I. Music

1. Piano

2. Piano

3. Piano

4. Piano

5. Piano

6. Piano

7. Piano

8. Piano

9. Piano
Test II. Instruments

1. Piano

2. Flute

3. Piano

4. Guitar

5. Piano

6. Flute

7. Guitar

8. Flute

9. Piano

MAA-Selective

Test III. Instrument and Noise

1. Rain

Guitar
2. Clapping
   Piano

3. Bird singing
   Flute

4. Laughing
   Piano

5. Clapping
   Guitar

6. Bird singing
   Piano

7. Rain
   Flute

8. Laughing
   Guitar
9. Bird singing

Flute

Test IV. Two Instruments

1. Flute

Guitar

2. Guitar

Piano

3. Piano

Flute

4. Flute

Guitar

5. Flute

Piano
6. Piano
   Guitar

7. Piano
   Flute

8. Flute
   Guitar

9. Piano
   Flute

MAA-Divided

Test V. Two Instruments with Different Directions

1. Piano
   Guitar

2. Flute
   Piano
3. Guitar

Flute

4. Flute

Piano

5. Flute

Guitar

6. Guitar

Piano

7. Piano

Flute

8. Piano

Guitar
Test VI. Same Instruments with Different Directions

1. Piano

2. Guitar

3. Flute

4. Guitar

5. Flute
6. Piano

7. Flute

8. Piano

9. Piano

*CD is available upon request.
Appendix K

Revised Version of MAA: Answer sheet

Date: _____/_____/_____  Name of participant: ___________________

Music-based Attention Assessment

Practice session I
Instructions: You will hear some samples of music. This part will explain some of the words that are used in the test. Listen to the direction of the music.

1. Up 2. Same 3. Down

Practice Session II
Instructions: You will hear music played by three different instruments. Listen to the sound that goes with the picture of each instrument.

1. Piano 2. Guitar 3. Flute

Practice Exercise
Instructions: Now you will do some practice test items. Listen carefully to the direction of the music played by different instruments. Wait until the beep, and then circle the answer.

1. Up Same Down Not sure
   ↑ → ↓ ?

2. Up Same Down Not sure  Up Same Down Not sure
   ↑ → ↓ ? ↑ → ↓ ?

3. Up Same Down Not sure  Up Same Down Not sure  Up Same Down Not sure
   ↑ → ↓ ? ↑ → ↓ ? ↑ → ↓ ?
Part A – Sustained Attention

Test I. Music

**Test Items**

Instructions: You will hear music played by the piano. Listen carefully to the direction of the music. Wait until the beep, and then circle the answer.

<table>
<thead>
<tr>
<th></th>
<th>Up</th>
<th>Same</th>
<th>Down</th>
<th>Not sure</th>
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</thead>
<tbody>
<tr>
<td>1.</td>
<td>↑</td>
<td>→</td>
<td>↓</td>
<td>?</td>
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<td>2.</td>
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<td>→</td>
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<td>?</td>
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<td>→</td>
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<td>?</td>
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<td>8.</td>
<td>↑</td>
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<td>9.</td>
<td>↑</td>
<td>→</td>
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<td>?</td>
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</tbody>
</table>
Test II. Instruments

Test Items
Instructions: You will hear music played by different instruments. Listen carefully to the direction of the music played by the instrument. Wait until the beep, and then circle the answer.

<table>
<thead>
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<th></th>
<th>Up</th>
<th>Same</th>
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<th>Not sure</th>
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<th>Up</th>
<th>Same</th>
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<th>Not sure</th>
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<td>Up</td>
<td>Same</td>
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<td>Not sure</td>
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<th>Up</th>
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<td>5</td>
<td>↑</td>
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<th>Not sure</th>
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<tr>
<td>7</td>
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<th></th>
<th>Up</th>
<th>Same</th>
<th>Down</th>
<th>Not sure</th>
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<td>8</td>
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<tr>
<th></th>
<th>Up</th>
<th>Same</th>
<th>Down</th>
<th>Not sure</th>
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<td>9</td>
<td>↑</td>
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<td>?</td>
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</tbody>
</table>
Part B – Selective Attention

Test III. Instrument and noise.

Test Items
Instructions: You will hear an instrument and some noise at the same time. Listen carefully to the direction of the music played by the instrument. Wait until the beep, and then circle the answer.

1.  Up  Same  Down  Not sure
   ↑  →  ↓  ?

2.  Up  Same  Down  Not sure
   ↑  →  ↓  ?

3.  Up  Same  Down  Not sure
   ↑  →  ↓  ?

4.  Up  Same  Down  Not sure  Up  Same  Down  Not sure
   ↑  →  ↓  ?  ↑  →  ↓  ?

5.  Up  Same  Down  Not sure  Up  Same  Down  Not sure
   ↑  →  ↓  ?  ↑  →  ↓  ?

6.  Up  Same  Down  Not sure  Up  Same  Down  Not sure
   ↑  →  ↓  ?  ↑  →  ↓  ?

7.  Up  Same  Down  Not sure  Up  Same  Down  Not sure  Up  Same  Down  Not sure
   ↑  →  ↓  ?  ↑  →  ↓  ?  ↑  →  ↓  ?

8.  Up  Same  Down  Not sure  Up  Same  Down  Not sure  Up  Same  Down  Not sure
   ↑  →  ↓  ?  ↑  →  ↓  ?  ↑  →  ↓  ?

9.  Up  Same  Down  Not sure  Up  Same  Down  Not sure  Up  Same  Down  Not sure
   ↑  →  ↓  ?  ↑  →  ↓  ?  ↑  →  ↓  ?
Test IV. Two instruments.

*Test Items*
Instructions: You will hear two different kinds of instruments playing at the same time. Listen carefully to the direction of the instrument in the picture. Wait until the beep, and then circle the answer.

<table>
<thead>
<tr>
<th></th>
<th>Flute</th>
<th>Guitar</th>
<th>Piano</th>
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<tbody>
<tr>
<td>1</td>
<td>![Flute Image]</td>
<td>![Guitar Image]</td>
<td>![Piano Image]</td>
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<tr>
<td></td>
<td><strong>Up</strong></td>
<td><strong>Same</strong></td>
<td><strong>Down</strong></td>
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<tr>
<td>2</td>
<td>![Flute Image]</td>
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<td>3</td>
<td>![Flute Image]</td>
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<td><strong>Same</strong></td>
<td><strong>Down</strong></td>
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<td>![Flute Image]</td>
<td>![Guitar Image]</td>
<td>![Piano Image]</td>
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<td><strong>Same</strong></td>
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<td>![Piano Image]</td>
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<td>![Flute Image]</td>
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Part C – Divided Attention

Test V. Two Instruments with different directions.

Test Items
Instructions: You will hear two different instruments playing at the same time. Listen carefully to the direction of the music played by each instrument. Wait until the beep, and then circle the answers.

1. Piano
   - Up
   - Same
   - Down
   - Not sure
   - ↑ → ↓ ?

2. Guitar
   - Up
   - Same
   - Down
   - Not sure
   - ↑ → ↓ ?

3. Flute
   - Up
   - Same
   - Down
   - Not sure
   - ↑ → ↓ ?

4. Piano
   - Up
   - Same
   - Down
   - Not sure
   - ↑ → ↓ ?
<table>
<thead>
<tr>
<th></th>
<th>Flute</th>
<th></th>
<th>Guitar</th>
<th></th>
<th>Guitar</th>
<th></th>
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<th>Flute</th>
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<th>Piano</th>
<th></th>
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<tbody>
<tr>
<td>5.</td>
<td>![Flute Icon]</td>
<td>Up</td>
<td>Same</td>
<td>Down</td>
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Test VI. Same instruments with different directions

**Test Items**

Instructions: You will hear two of the same kind of instrument playing at the same time. Listen carefully to the two directions of the music played by the same instruments. Wait until the beep, and then circle the answers.

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Specify any comments:
Appendix L

Statistical Methods

Item analysis

For the current study, item properties were analyzed to reveal problematic test items prior to factor analysis. Item analysis was conducted to investigate item difficulty (i.e., item mean) and item discrimination (i.e., corrected item-total correlation) of each test item and each composite score as well. Additionally, correlation analysis among composite scores and three attention subtest scores were conducted.

First, item difficulty and item discrimination of test items were computed from the obtained data. Item difficulty refers to the proportion of the respondents who answered a given test item correctly and is described by the item mean. Item discrimination was calculated by the correlation between participants’ test items and their sum of item scores without including the test item (i.e., corrected item-total correlation). The quality of test items in each of the three types of attention subtests was determined by (a) the item means falling in the range between an item difficulty index of 0.4 and 0.6 being considered valuable items when there is a representative sample of participants and there is a normal distribution of responses (Garrett, 1966; Schmidt & Emberston, 2003), (b) the corrected total-item correlation that falls in the range between 0.3 and 0.5 is considered a valuable item (Oosterhof, 2001), and (c) a corrected total-item correlation of 0.2 is considered the lowest acceptable value to retain test items within the subscale (Golden, Sawicki, & Franzen, 1984; Muijen et al., 1999).
Internal consistency

For the current study, internal consistency was investigated to test reliability of the revised version of the MAA. Internal consistency estimates the reliability of a test (Murphy & Davidshofer, 1998). Cronbach’s alpha is the most widely used estimate of internal consistency for both dichotomous and polytomous test items (Schmidt & Emberston, 2003). Cronbach’s alpha is calculated based on the number of test items and the average inter-correlation among test items within a scale (Kline, 2005). A small Cronbach’s alpha may suggest that a test has a problem in terms of its length (e.g., too few items) or the test items do not reliably measure a common construct. An alpha of .80 or greater is generally considered an indicator of acceptable scale reliability (Bernard, 2000).

Exploratory factor analysis

For the current study exploratory factor analysis was investigated to identify the latent factors that underlie 54 test items of the revised version of the MAA. Exploratory factor analysis was conducted to identify emergent factor solutions and determine whether the data supported alternative factor solutions. Factor analysis examines the patterns of correlations or covariance among the observed variables and induces one or more common factors based on the linear function among the variables. In other words, factor analysis estimates the amount of variance among observed variables explained by common factors and error terms (Fabrigar, Wgener, MacCallum, & Strahan, 1999).

Factor rotation is to spin the factor axes in order to find a solution for which each variable has only a small number of factors with large loadings. After factor rotation, the
loadings of the variables on the factors will change, but the amount of variance explained remains the same. Two types of rotation exist: orthogonal and oblique. Orthogonal rotations are most widely used when factors are uncorrelated, while oblique rotations are used for those correlated. Quartimin rotation, promax rotation, and direct oblimin could be used for oblique rotation (Costello & Osborne, 2005; Fabrigar, Wgener, MacCallum, & Strahan, 1999).

The method used in the current study was principal axis factoring, a preferred method to examine the underlying latent structures among variables (Denison & Spreitzer, 1991). Oblique rotation is a commonly used method when there exist correlations among the latent structures or factors, including Promax, Direct Oblimin, and Quartamax (Floyd & Widaman, 1995). The use of oblique rotation in this study was based on the assumption that three subtypes of attention constitute altogether a hierarchy of attention. Once factor structures based on oblique rotation were obtained, emergent factors that met all of the following criteria were retained: (a) factors with an eigenvalue greater than 1.0, (b) factors above the critical point as identified by the scree plot, (c) factors with two or more items loading at significant levels (i.e., factor loading equaled or exceeded 0.30) (Floyd & Widaman, 1995).
Appendix M

Three-factor Structure

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Appendix N

Four-factor Structure

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<td>DIV61 ( 0.155 ), ( -0.227 ), ( 0.480 ), ( 0.361 ), ( -0.160 ), ( 0.235 )</td>
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<td>SEL44 ( 0.221 ), ( -0.113 ), ( 0.582 ), ( 0.204 ), ( -0.256 ), ( 0.245 )</td>
<td>DIV62 ( 0.500 ), ( -0.307 ), ( 0.396 ), ( 0.257 ), ( -0.238 ), ( 0.315 )</td>
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<td>SEL45 ( 0.493 ), ( -0.283 ), ( 0.605 ), ( 0.369 ), ( -0.320 ), ( 0.379 )</td>
<td>DIV63 ( 0.254 ), ( -0.180 ), ( 0.410 ), ( 0.275 ), ( -0.132 ), ( 0.282 )</td>
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<td>SEL46 ( 0.384 ), ( -0.035 ), ( 0.173 ), ( 0.002 ), ( -0.151 ), ( 0.162 )</td>
<td>DIV64 ( 0.384 ), ( -0.204 ), ( 0.486 ), ( 0.396 ), ( -0.172 ), ( 0.265 )</td>
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<td>SEL47 ( 0.497 ), ( -0.349 ), ( 0.419 ), ( 0.252 ), ( -0.274 ), ( 0.488 )</td>
<td>DIV65 ( 0.033 ), ( -0.155 ), ( 0.411 ), ( 0.339 ), ( -0.152 ), ( 0.254 )</td>
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<td>SEL48 ( 0.401 ), ( -0.258 ), ( 0.621 ), ( 0.290 ), ( -0.210 ), ( 0.361 )</td>
<td>DIV66 ( 0.333 ), ( -0.176 ), ( 0.483 ), ( 0.413 ), ( -0.195 ), ( 0.242 )</td>
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<td>SEL49 ( 0.479 ), ( -0.301 ), ( 0.553 ), ( 0.403 ), ( -0.384 ), ( 0.426 )</td>
<td>DIV67 ( 0.165 ), ( -0.115 ), ( 0.257 ), ( 0.492 ), ( -0.117 ), ( 0.138 )</td>
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<td>MAA-Divided</td>
<td>DIV68 ( 0.101 ), ( -0.087 ), ( 0.079 ), ( 0.560 ), ( -0.075 ), ( 0.131 )</td>
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<td>DIV69 ( 0.159 ), ( -0.123 ), ( 0.168 ), ( 0.503 ), ( -0.084 ), ( 0.192 )</td>
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