Exploring Music-based Cognitive Rehabilitation Following Acquired Brain Injury: A Randomized Control Trial Comparing Attention Process Training and Musical Attention Control Training

by

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Abstract

Cognitive impairment is the most common sequelae following an acquired brain injury (ABI) and results in significant impact on the individual’s potential for rehabilitation, functional independence, and on their quality of life. Because of the recently emerging evidence of the influence of music on brain function, music may serve as a unique and powerful cognitive rehabilitation tool following ABI. Although the research literature supports a rationale for music-based cognitive rehabilitation, there is a limited number of experimental studies investigating the clinical benefits of music-based cognitive rehabilitation. This study used a Randomized Control Trial. The control group participated in three standardized attention training sessions: Attention Process Training (APT) (Sohlberg & Mateer, 2001). The
experimental group participated in three Neurologic Music Therapy (Thaut & Hoemberg, 2014) sessions using a standardized intervention: Music Attention Control Training (MACT). Pre-and post-testing used standard neuropsychological tests included Trail Making A & B, Digit Symbol, and the Brown-Peterson Task. No significant difference was found within or between the groups for Trail A Test, Digit Symbol, or Brown-Peterson Task. The MACT group showed a statistically significant improvement (p=0.4) on the Trail B in contrast to the APT group when using paired t-tests to compare pre-versus post-test. However, a repeated measures ANOVA analysis for Trail B did not support statistically significant findings between the two conditions (p=0.051). The mean difference time between pre- and post-test showed no significant difference between APT and MACT using a two-sample t-test. However, a non-parametric follow-up test (Mann Whitney) (p=0.029) indicated significant differences in favor of MACT. Therefore, close significance values and partial evidence from nonparametric testing suggest only mixed support or potential trends in favor of MACT over APT. Although MACT outcomes performed comparable to the well established attention training technique of APT, further research with a larger sample size and more statistical power is needed to investigate specific benefits of MACT to improve attention.
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Chapter 1

Introduction

1 Introduction

1.1 Background and Need

Approximately 160,000 Canadians sustain an acquired brain injury (ABI) each year. The most common sequelae following an ABI is cognitive impairment (Dikmen, Machamer, Winn & Temkin, 1995; Goldstein & Levin, 1996; Gronwall, 1987; Van Zomeren & Brouwer, 1994). Cognitive impairment significantly impacts an individual’s ability to participate in various rehabilitation therapies, new learning, social interactions, the level of functional independence, and quality of life. Caregivers report that cognitive impairment is the most significant source of stress in their lives following ABI (Morton & Wehman, 1995; Brooks et al., 1987; Knight et al., 1998). Due to the scope of implications of cognitive impairment in the lives of those living with an ABI, their caregivers, and families, it is imperative to have ongoing research into cognitive rehabilitation and the development of effective cognitive rehabilitation interventions. This need has been noted by the National Institute of Neurological Disorders and Stroke (NINDS) who has encouraged a shift in research from the emphasis on diagnosis and descriptive analysis of neuropsychological assessment following ABI towards research investigating the development of evidence-based interventions (Cicerone et al., 2006). Because
attention is foundational to cognitive processing, specifically investigating attention deficit should be a primary goal in cognitive rehabilitation research.

Literature indicates that cognitive abilities are “not fixed” but rather can be changed or improved through practice (Cicerone et al., 1992; Cicerone et al., 2000; Cicerone et al., 2005; Gray et al., 2003; Kelly & Garavan, 2005; Klingbert et al., 2002; Levine et al., 2000). Kelly et al. (2006) state that “deficits in cognitive performance occurring as a consequence of impairment in fundamental mechanisms of attentional or cognitive control may be ameliorated or rehabilitated through practice and training on tasks that specifically tap attentional control” (p.6).

Music’s arousal of attentional processes (Bialystok & Depape, 2009; Pallesen et al., 2010; Moreno et al., 2011) and the increased cognitive control of musicians (Pallesen et al., 2010; Moreno & Bidleman, 2014) suggest that music may serve as a unique and effective attention training intervention and this warrants further investigation. The use of music-based cognitive rehabilitation tasks is an emerging field with sparse research literature support. There is a need for research into the development of evidence-based cognitive rehabilitation interventions. In particular, there is a need in the literature regarding the effectiveness of music-based cognitive rehabilitation interventions.

1.2 Purpose of Study

The primary purpose of this study is to investigate the potential effectiveness of music-based cognitive rehabilitation to remediate cognitive impairment following
an acquired brain injury. This thesis explored the topic of the benefit of music-based cognitive rehabilitation in two ways: first, by discussing literature which supports the hypothesis for music-based cognitive rehabilitation and secondly, by using a randomized control trial to investigate the question: “can music-based cognitive rehabilitation interventions be effective in remediation of cognitive impairment following an acquired brain injury?”. This question was investigated using a standardized Neurologic Music Therapy (NMT) attention training intervention: Music Attentional Control Training (MACT) (Thaut & Hoemberg, 2014) for the experimental group and a standardized a non-music-based cognitive rehabilitation intervention, Attention Process Training (APT) (Sohlberg & Mateer, 2001), for the control group. Because attention is foundational to cognitive functioning, this study placed an emphasis on the remediation of attention rather than compensatory strategies.

A secondary purpose of this study is to enlarge the literature regarding the use of music-based interventions in cognitive rehabilitation. While the literature discussed in this thesis supports the hypothesis of the potential effectiveness of music-based cognitive rehabilitation, there is sparse research evidence. This study is one of the first to investigate NMT for rehabilitation of cognitive functions and can contribute to the small body of research literature on cognitive rehabilitation following acquired brain injury. Results from this study may inform future studies and the development of music-based cognitive rehabilitation and its clinical applications.
The use of music for cognitive rehabilitation has been investigated by a small number of studies with varied methodologies (Morton et al., 1990; Wit et al., 1994; Knox & Jutai, 1996; Gregory, D., 2002; Knox et al., 2003; Sarkamo et al., 2008; Thaut et al., 2009; Jong et al., 2011; Hegde, 2014), all highlighting the need for more research and literature on this topic. Thaut (2010) highlights two contributing factors to the sparse literature regarding music therapy and cognitive rehabilitation: the historic view of music therapy used primarily in a psychotherapeutic context and the only recent advances in technology that allow for non-invasive research tools to study the brain and cognition in vivo. The shift within the music therapy profession to include a neuroscience-based approach to music as therapy such as Neurologic Music Therapy has already, and will continue, to spur new research (Baker & Roth, 2004; Thaut, 2005; Koelsch, 2009). Other disciplines such as music cognition and rehabilitation science are becoming increasing aware of the therapeutic value of music applications, which in turn may generate more studies to contribute to the literature base of music and cognitive rehabilitation.

In addition, through the discussion of related literature supporting the hypothesis for the potential effectiveness of music-based cognitive rehabilitation, this paper will try to link cognitive neuroscience and music cognition science to the rational for, and clinical application of, music-based cognitive rehabilitation. It is important that the development of cognitive rehabilitation interventions be grounded in attention and rehabilitation theory. NINDS noted the importance of this link, encouraging increased partnership between basic cognitive neuroscientists and
clinicians in order to explore the potential for cognitive rehabilitation (Cicerone et al., 2006).

Remarkably, a majority of rehabilitation efforts have not been grounded in theory (Bach-y-Rita, 1992; Mateer and Kerns, 2000; Ceravolo, 2006; Chen et al. 2006). In addition, as noted by Burgess & Robertson (2002), there is a gap between cognitive experimental research and treatment applications. This exploration of the hypothesis of music-based cognitive rehabilitation and the investigation using MACT are an attempt to address this gap and to provide treatment applications for rehabilitation that are informed by the research and grounded in attention theory.

1.3 Construct Definitions and Descriptions

1.3.a Acquired brain injury

Acquired brain injury, defined as any injury to the brain after birth, can result in significant, life-long impairment(s) in one or more areas including cognition, motor control, and speech. A brain injury may be described as traumatic or non-traumatic. A traumatic brain injury (TBI) is an injury to the brain that is a result of force or a blow to the head. Examples include automobile accident, assault, or fall. A non-traumatic brain injury is a result of a lack of oxygen to the brain or a vascular injury. Examples include suffocation, near drowning, aneurysm, and stroke.
Combining traumatic and non-traumatic brain injury, approximately 1.3 million Canadians are living with an ABI. Ontario brain injury associations estimate that 53% percent of homeless persons, 20% of children with emotional difficulties, and 30% of students identified as having learning disabilities have experienced an ABI. Between 32% -52% of stroke survivors experience cognitive impairment (Whyte et al. 2011). It is estimated that 150-200 million people annually, worldwide, experience a TBI resulting in severe disability (Whyte et al. 2001).

1.3.b Cognitive impairment

Cognitive impairment is the most common sequelae following an ABI (Dikmen, Machamer, Winn & Temkin, 1995; Goldstein & Levin, 1996; Gronwall, 1987; Van Zomeren & Brouwer, 1994) and can impede or prevent progress in rehabilitation therapies, is a determining factor in an individual’s ability to successfully participate in work or school, and is a major source of stress for caregivers (Brooks, 1987; Van Zomeren & Van Den Burg, 1985; Kinsella et al, 1997; Whyte et al., 2011).

Deficits in attention, working memory, processing speed, and executive functioning are the most common cognitive impairments following ABI (Beers, 1992; Donders, 1993; Kaufamnn, Fletcher, Levin & Minor, 1993; Whyte et al. 2001;Ballard et al., 2003; Jaillard et al., 2009; Michel, C. & Mateer, C.A., 2006;Zinn et al., 2007). Persons with cognitive impairment may experience difficulties in orienting to novel stimuli, processing speed, remaining on task, shifting tasks, divided attention, working memory, new learning, and over-coming automated responses (Mateer et al., 1996;
van den Broek, 1999; Sohlberg et al., 2000; Michael & Mateer, 2006). These cognitive challenges manifest themselves in real-life situations in various ways including the difficulty sequencing the tasks required for self-care or preparing a meal, following or engaging in a conversation, learning the “rules” or components of speech therapy or physiotherapy, responding appropriately to new situations, completing a task, following instructions, and initiation. Cognitive impairment may also result in perseveration of speech or action, increased distractibility, impulsive behavior, and mood swings.

Because cognitive impairment impacts the ability for new learning (Beers, 1992; Dennis et al., 1996; Mateer & Mapou, 1996; Kinsella, G. J., 1998; Sohlberg & Mateer, 2001; Whyte et al., 2011), it plays a key role in a person’s potential to regain a level of independence, to participate in activities of daily living (ADL’s), or return to work or school following an ABI. Social implications resulting from cognitive impairment can negatively impact relationships with others, including caregivers.

1.3.c Cognitive rehabilitation

Cognitive rehabilitation has the potential to enable a person living with cognitive deficits following an ABI to regain a level of independence, function, socialization, and to experience an improved quality of life. The most commonly referenced definition of cognitive rehabilitation is that of Harley et al. (1992) which describes cognitive rehabilitation as:

“a systematic, functionally oriented service of therapeutic cognitive activities, based on an assessment and understanding of the person’s brain-behaviour
deficits. Services are directed to achieve functional changes by (1) reinforcing, strengthening, or reestablishing previously learned patterns of behavior, or (2) establishing new patterns of cognitive activity or compensatory mechanisms for impaired neurological systems.” (as cited in Institute of Medicine, 2011, p. 78).

Haskins (2012) states that the primary goal of cognitive rehabilitation is to “ameliorate injury-related deficits in order to maximize safety, daily functioning, independence, and quality of life” (p. 3).

The modern practice of cognitive rehabilitation emerged during the 1970s to address the needs of individuals who had experienced an ABI. There are two approaches used in cognitive rehabilitation: compensatory and remedial. The compensatory approach seeks to support independence and function in daily activities for the cognitively impaired individual by providing strategies and environmental supports. Examples include teaching internal skills of self-regulation such as Stop-Think-Plan (Levine et al., 2000), the use of a notebook for memory, or modifications to the environment such as labeling cupboard doors as to the contents. The remedial approach seeks to address the underlying brain areas affected, using training of specific functions to encourage a neuroplastic response and the remediation of impairment. This study and its hypothesis are based on a remedial approach to cognitive rehabilitation.

1.3.d Attention Process Training

An example of a remedial approach to cognition is Attention Process Training (APT) developed by Solhberg and Mateer (1987). Their theory is that “it is possible to
train underlying attentional processes, which will in turn improve higher, more complex cognitive functions” (Michel and Mateer, 2006 p. 64) and that “attentional abilities can be improved by providing opportunities for exercising a particular aspect of attention” (Mateer and Mapou, 1996, p. 10).

APT exercises are designed to “improve the underlying attention deficit by reducing the deficit itself. The premise is that attentional abilities can be improved by providing structured opportunities for exercising particular domains of attention” (Sohlberg & Mateer, APT-3 Manuel, p. 3). APT is designed to be used in collaboration with other attention interventions such as pharmacological management, compensatory strategies, and metacognition training. Tasks are designed to address specific aspects of attention such as sustained, selective, alternating, and suppression of distraction.

1.3.e Music Attention Control Training

Music Attention Control Training (MACT) is defined as “structured active or receptive musical exercises involving pre-composed performance or improvisation in which musical elements cue different musical responses to practice attention functions” (Thaut, 2005, p. 196).

Thaut (2014) identifies a number of therapeutic mechanisms underlying MACT interventions. He states that the rhythmic patterns of the music interact with attention oscillators through coupling mechanisms, thereby, driving attentional
focus. In addition, music recruits “shared or parallel brain systems that assist the frontal lobes with alternating attention” (p.260). Thaut also highlights several aspects of music that support attentional response including the timing and grouping within music elements that provide organization to engage sustained attention; the multi-dimensional stimuli of music such as melody and rhythm that flow simultaneously and sequentially, engaging alternating attention; and the emotional and motivational qualities of music that encourage attentional effort by the individual.

The goal of MACT is to remediate attentional deficits by targeting and practicing specific components of attention in exercise structures that use musical cues and patterns to drive selective, sustained, divided, or alternating attention responses which will also transfer outside of music to activities of daily living. This study used tasks based on the MACT protocol, designed specifically to target sustained, selective, and divided attention.

1.4 Hypothesis: Music-based Cognitive Rehabilitation

This study will explore the hypothesis that music-based cognitive rehabilitation interventions, grounded in the neuroscience of attention mechanisms and cognitive rehabilitation theory, could be used to remediate cognitive impairment following ABI. A music-based intervention is one in which the components of music (melody, rhythm, harmony) are used, either singly or in combination, as a primary stimulus in an intervention designed to target a specific aspect of cognition. The patient is
actively engaged in the intervention and may or may not include components of
music in their response.

Music-based interventions may provide unique and effective stimuli for the injured
brain. Hegde (2014) states:

“Creatively working with various dynamic features of music such as pitch
and rhythm is known to involve attentional networks and executive
functions...Temporal cues in music and rhythm engage not only the motor
system but play a crucial role in arousal, orientation, and sustenance of
attention. Listening to polyphonic music has shown to engage neural circuits
underlying multiple forms of working memory, attention, semantic
processing, target detection, and motor imagery, in turn indicating that music
listening engages brain areas that are involved in general functions rather
than music-specific areas” (p.3).

Hegde further states that “it seems plausible that engaging in music would not only
stimulate the various centers of the brain including the emotion areas but music can
also be systematically used in alternating and regulating the cognitive processes
involved, which can be further generalized to non-musical domains of functioning”
(p.3).

This hypothesis was informed by literature discussing the neuroscience of attention,
theories of cognitive rehabilitation, neuroplasticity of the brain, evidence of music’s
influence on the brain by comparison of musicians and non-musicians, the transfer
of cognitive benefit of music training, and clinical observations made by the author
where cognitive abilities of brain injured persons improved, first within the musical
context in which training was given, and appeared to eventually transfer to non-
musical contexts.
For the purpose of an experimental study the research hypothesis is stated that MACT-training will result in significantly better test performances compared to APT-training in the Trail A and B, the Digit Span, and the Brown-Peterson tests.

To test the research hypothesis statistically the following Null Hypotheses are stated:

- **HO1**: There will be NO statistically significant difference between MACT and APT on pre and posttest scores for Trail A and B, Digit Span, and Brown Peterson tests.
- **HO2**: there will be NO statistically significant difference between MACT and APT on mean difference times between pre- and post-test for Trail A and B, Digit Span, and Brown Peterson tests.
Chapter 2
Related Literature

2 Related Literature

The purpose for this study was informed by the literature discussing the neuroscience of attention, theories of cognitive rehabilitation, neuroplasticity of the brain, and evidence of music's influence on the brain by comparison of musicians and non-musicians, including the transfer of cognitive benefit of music training to parallel cognitive functions in nonmusical tasks.

2.1 Attention

2.1.a Attention: The foundation for cognitive rehabilitation

Although cognition is divided in the literature between the components of attention, memory, and executive function, these areas are functionally interconnected. However, because attention is foundational to other cognitive functioning, it should be highlighted as a primary goal area in cognitive rehabilitation.

The importance of rehabilitation of attention was noted during World Wars I and II as scientists began to investigate the outcomes of ABI and to explore rehabilitation approaches. However, Ben-Yishay and colleagues in the 1970's were the first researchers to highlight attention deficits following ABI and developed exercises to retrain attentional abilities (Ben-Yishay, Piasetsky & Rattock, 1987; Ben-Yishay,
Recent research supports the importance of the rehabilitation of attention. Ceravolo (2006) states that:

“There is an increasing awareness of the prejudicial role of unrecognized and untreated cognitive impairment on motor relearning and mobility dysfunction. Namely, attention, being a precursor and prerequisite to information processing and related cognitive tasks, should be regarded as a key factor in the success of all rehabilitation efforts.” p. 49.

Michael and Mateer (2006) state:

“...intact attention is required so that an effective utilization of higher functions may take place. Without attending to information and being able to hold information in mind, one is unlikely to be able to remember or to use that information to help solve problems and guide appropriate behaviour” (p. 59).

Because of attention’s foundational role in higher cognitive processes such as memory and executive function, and thus impacting functional independence, rehabilitation of attentional processes should be a primary goal following ABI. The potential for transfer of benefit of attention rehabilitation is supported by studies of attention rehabilitation that demonstrated improved memory functioning in addition to attention (Mateer, C.A. & Sohlberg, M.M. 1988; Mateer C.A., Sohlberg, M.M. & Yougman, P., 1990; Mateer C.A., 1992; Niemann, H., Ruff, R.M. & Baser, C.A., 1990).

In addition to being recognized as foundational to other cognitive processes, attention is also a primary contributor to appropriate responses or actions toward environmental stimuli. Impaired attending is a key factor in a number of cognitive and behavioural deficits experienced by individuals with ABI, further highlighting
the importance of targeting attention deficits in cognitive rehabilitation which can improve the ability to attend to stimuli, suppress distraction, and execute goal-directed behavior.

2.1.b **Attention: definitions and theories**

Cognitive rehabilitation interventions should seek to address attention because attention deficits may affect underlying mechanism for a range of cognitive deficits. The development of these interventions for other cognitive deficits must be grounded in part on the neuroscience and theories of attention.

A number of definitions for attention and theories of cognition have been proposed to define and describe cognitive processing. This reflects the complexity of cognition and the interconnectedness of various components of cognitive functioning, the state of emerging data, and unanswered questions. Although these factors may impede cognitive rehabilitation to an extent, there does remain enough evidence with which one can move forward, even with the constraints of current literature, to develop interventions of benefit to the patient. New information regarding the brain and its function will continue to emerge through on-going research in various fields, enabling cognitive rehabilitation treatments to be modified and improved accordingly.

In addition to the complexity of cognition, attention itself is a multidimensional construct, with interactions between networks involved in various aspects of
attentional processing (see Table 2.1). Cohen (1993) describes this interaction of attentional networks as:

“a set of processes which interact dynamically to allow the individual to direct themselves to appropriate aspects of external environmental effects and internal operations. Attention facilitates the selection of salient information and the allocation of cognitive processing appropriate to that information. Therefore, attention acts as a gate for information flow in the brain” (as cited in Ponsford, 1999, p.508).

As a result of the complexities noted above, there is no single definition of attention.

Mesulam (2010) defines attention as “the preferential allocation of neuronal resources to events that have temporarily become relevant” (p. 128). He states that “attention can be distributed globally or focally; it can act on stimuli in parallel or serially; and it can be attracted exogenously by external events, or directed endogenously to mental phenomena” (p. 128). The attentional matrix described by Mesulam (2010) is “reflected by phenomena such as detection efficiency, focusing power, concentration-span, vigilance level, novelty-seeking tendencies, resistance to interference, and online processing capacity represents the collective manifestation of all attentional modulations” (p.128).

Attention is defined by Schmitter-Edgecombe (1996) as “one or more reservoirs of capacity-limited processing resources that can be allocated to cognitive operation in a flexible and continuous fashion” (p.18). The attention resource model proposes that attention is a limited supply processing resource and that “at any one moment human systems possess only a finite amount of processing resources to deal with
(this) overload of information. Performance on a task is positively related to the amount of processing resources that the person has available for task execution” (Schmitter-Edgecombe, 1996, p. 18). When the brain is injured, the individual may have less attentional resources available for tasks and as a result, experience deficits in several cognitive functions.

Tallon-Baudry (2012) links the role of attention to action, highlighting that attention must be directed towards what an individual is going to act on, requiring them to attend to the appropriate stimuli and to suppress distraction from irrelevant stimuli. He states that “the role of attention is to prioritize incoming sensory processing to enable optimized behavioural responses given the task at hand. The main neural mechanisms associated to attentional modulation of sensory processing are target amplification and distractor suppression.” (p. 3).

The various descriptions of attention above all include the components of the limitation of attentional resources, the process of directing attention to the target stimulus while suppressing irrelevant or competing stimuli, and vigilance. These components of attention can inform the development of new cognitive rehabilitation interventions.
### Table 2.1  Attention Type and Brain Area Involved

<table>
<thead>
<tr>
<th>Attention Type</th>
<th>Function of Attention Type</th>
<th>Brain area(s) involved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sensory selective attentional system</td>
<td>Orientation, engaging &amp; disengaging attention, object recognition</td>
<td>Parieto-temporo-occipital area</td>
</tr>
<tr>
<td>Arousal, sustained attention, vigilance</td>
<td>Mood regulation, motivation, salience of stimuli, readiness to respond</td>
<td>Midbrain reticular activating system, limbic structures</td>
</tr>
<tr>
<td>Anterior system for selection and control of responses</td>
<td>Intentional control, use of strategies for manipulating information, switching, inhibition</td>
<td>Frontal lobes, anterior cingulate gyrus, basal ganglia, thalamus</td>
</tr>
<tr>
<td>Alertness, sustained attention</td>
<td></td>
<td>Right hemisphere</td>
</tr>
<tr>
<td>Selective, focused attention</td>
<td></td>
<td>Left hemisphere</td>
</tr>
</tbody>
</table>


#### 2.1.c Attentional processing: theories

Peterson and Posner’s (2012) theory of attention describes three networks in the attentional system: alerting, orienting, and executive. The *alerting network* is involved in the maintenance of task vigilance and it lateralized to the right.
hemisphere. The *orienting network* prioritizes sensory input, selecting a brain modality or location. Parietal areas, frontal, and posterior areas are engaged in the orienting network.

Of interest is that although attention operates in sensory-specific modalities, these networks involved in orienting appear to overlap (Peterson & Posner, 2012). This may suggest that multi-modal intervention, such as music, could be effective in strengthening orienting, a stage of attention. This overlap of orienting networks may also support the transfer of benefit from one sensory modality to another.

The *executive network* is engaged in target detection, specifically the moment of target detection, and involves widely distributed connections from the midline cortex and the anterior cingulate cortex (ACC). The moment of target detection slows down detection of other targets or distraction, resulting in focused attention. Activation is noted in the ACC when there is conflict resulting from the need to suppress a dominant response to perform a subdominant response (Bush et al., 2000) and thus is believed to play a role in the regulation of cognition and emotion. The executive network is involved in the top-down control of signals to other brain regions. It has been proposed (Dosenbach et al. 2008) that the executive control is based on two separate networks: cingulo-opercular control network, engaged in task maintenance and the frontoparietal system, involved in task switching and initiation.
Peterson and Posner (2012) state that experience influences these attentional networks, lending support to the argument for the rehabilitation of cognitive functions, including attention. They state that "because parenting and other cultural factors interact with genes to influence behavior, it should be possible to develop specific training methods that can be used to influence underlying brain networks" (p. 85). They provide further support stating that “two forms of training methods have been used in the literature. One involves the practice of a particular attention network. Several such attention training studies have shown improved executive function and produced changes in attention-related brain areas (Klingberg, 2011, Rueda et al., 2005).” p. 85. The second training method noted was meditation.

2.1.d Working memory

Mesulam’s (2010) attentional matrix includes components of concentration span, vigilance, and resistance to interference. Michael & Mateer (2006) describe intact attention as “attending and holding information in mind”. These aspects of attention have been identified by others as working memory. Early studies with monkeys (Funahashi et al., 1989; Fuster, 1997) provided evidence of working memory, revealing that lateral prefrontal cortex (PFC) neurons remained active during a delay period in which they were required to maintain information in memory. Because of the attentional processes engaged during working memory tasks, targeting working memory should be a significant aspect of the rehabilitation of attention.
Working memory is described by Goldman-Rakic (1995) as the ability to hold a piece of information in mind for a short period of time and to update information moment to moment. Petrides (1994) identified the mid-dorsolateral region as the brain area where information can be held for monitoring and manipulation of stimuli, while the mid-ventrolateral region is engaged in the selection, comparison and judgement of stimuli.

Baddeley (2009) uses the term *working memory* to highlight the emphasis on function in addition to short-term storage. His hypothesis is that working memory is a limited capacity system providing temporary storage of information. His original model had two temporary storage components, one for speech and sound, the other for visual and/or spatial memory. He later revised his model (Baddeley, 2002) to include an episodic buffer whose primary function is integration of information, increasing storage capacity by integrating disparate parts into a whole. This reflects Miller’s (1956) concept of chunking of information for memory. It should be noted that motivic and phrasic patterns in musical structures involve the chunking of information, melodically, harmonically, and rhythmically, which may serve to provide scaffolding for memory in rehabilitation interventions.

Supported by evidence of the necessity of the verbal or phonological loop of working memory for new long-term phonological learning, Baddeley proposes that short-term or working memory tasks reflect both temporary storage and long-term memory. This potential link between short-term memory and long-term memory
success suggests that addressing attentional or short-term memory deficit in cognitive rehabilitation may, through improving long-term memory capacity, support improved new learning, a difficulty in ABI impeding or preventing rehabilitation success.

Corbetta and Shulman (2002) state that “the attentional set and working memory mechanisms overlap functionally” (p. 205). Therefore, cognitive rehabilitation interventions designed to engage working memory processes will also engage attentional process. Working memory tasks involve all aspects of attention theories proposed by Mesulam, including concentration, vigilance and resistance to interference; and by Michael and Mateer, including attending and holding information in mind. Working memory tasks’ ability to engage various components and stages of attention, plus its role in the creation of long-term memory, and thus new learning, indicate that cognitive rehabilitation tasks should place demands of working memory processes.

In addition to Baddeley’s phonological and visual-spatial memory, Smyth & Pendleton (1990) suggest a kinesthetic based system (i.e. gesture, dance). Music-based interventions have a unique potential to engage each of these stores of working memory: phonological, visual/spatial, and kinesthetic, either singly or in combination by involving sound, sight, and movement. By engaging various sensory modalities through music-based interventions, there is the potential of greater recruitment of attentional networks as a result of the increased scope of target
stimuli. This may be particularly significant when working with an individual who has experienced a brain injury as there may be deficits in one or more sensory modalities. By engaging various senses through a range of intervention designs, less impaired sensory modalities may become the initial source of attentional network engagement. As noted earlier, Peterson and Posner (2012) propose that orienting networks of various sensory-specific modalities appear to overlap. Therefore, engaging attention of an injured brain through one modality may serve to strengthen attention, in spite of deficits in another modality, or may over time, benefit the orienting processes of the more impaired modalities. Music-based interventions may significantly support the attentional arousal of an injured brain, and due to the potential for multi-modal designed interventions, they may also serve as an assessment tool for more impaired modalities.

2.1.e Attentional Control

While working memory tasks will engage the attentional networks of alerting, orienting, and executive, another aspect of attention needs to be considered when investigating attention rehabilitation. In order to rehabilitate attention, it is necessary to address the need for increased attentional or cognitive control. Attentional control is required to direct attention to the target stimulus and to override automatic responses. Miller (2000) defines cognitive control as the “mechanisms that override or augment reflexive and habitual reactions in order to orchestrate behaviour in accord with our intention” and he highlights that this cognitive control is “essential for what we recognize as intelligent behavior.” The
lack of attentional control experienced by many individuals with ABI is evident in a
deficit in goal-directed behavior. Dockree et al. (2004) states that:

“Attention deficits are among the most commonly observed deficits following
brain injury and damage to the frontal lobes of the brain particularly the
white matter connecting the frontal, parietal and striatal regions are, in part,
responsible for these deficits. It has been found that frontal lobe damage in
TBI patients results in a tendency to drift from intended goals and increases
the frequency of action-slips that were unintended. Moreover, self-reports
from traumatically brain injured patients revel that problems with attention
and concentration rate among the highest complaints of this patient group.”
(p. 403).

The question of the source of attentional control has been discussed in the
literature. Fuster (1997) states that the prefrontal cortex (PFC) “exerts its influence
through connective and reciprocal links with posterior cortical regions” and is
involved in working memory, the “selection and preparation of established motor
acts”, and inhabitation of interference. Stuss et al. (1995) develop this further,
describing the PFC’s control by recruiting relevant neural networks or schemas.

Baddeley (2012) proposes a central executive (CE) as the controller in working
memory. However, he stresses that the CE not be seen as “providing an explanation,
but rather a marker of issues requiring explanation” (p. 15). In developing his
theory regarding the CE, he states that attentional tasks place demands on the CE
and describes the functions it is engaged in: focusing attention, dividing attention
between two targets, switching tasks, and interfacing with long-term memory.

Norman and Shallice (1986) propose that attention can be controlled in two ways:
well-learned habits requiring little attentional control and by a Supervisory
Attentional System (SAS), that can “override situations not handled by habit-based processes”. The SAS becomes engaged when an individual needs to make a conscious decision regarding a response. A similar description of attentional control is proposed by Schmitter-Edgecombe (1996) who describes two forms of attention processes: automatic process, performed without conscious awareness, and effortful processes, requiring active attention and awareness. She states that:

“When automatic processing is unable to cope with the level of information input, as is typical in new situations, effortful processing is activated. Effortful processing requires a person’s active attention since external elements are competing for a capacity-limited resource. Effortful processes will therefore suffer a reduction in efficiency when carried out simultaneously with other attention-demanding operations, whereas automatic processes will not” (p. 19).

This reduction of efficiency in effortful processing and the inability to suppress distraction is commonly described as an outcome of ABI. Implicit, or automatic learning, is noted to be significantly easier than explicit learning for individuals with ABI (Schmitter-Edgecombe, 1996). This difficulty with explicit learning results in impairment for new learning which in turn may impede progress in overall rehabilitation efforts. Individuals with ABI not only function better with automatic responses, they also have difficulty overcoming these automatic responses and responding appropriately in new situations. Dockree et al. (2004) completed a study in which they noted that “TBI patients made significantly more errors than controls suggesting that they found it more difficult to combat the tendency to “drift” into a more automatic mode of responding”. They stated that the TBI patients’ errors were a result of a “transient drift in controlled processing”.
In developing cognitive rehabilitation interventions to address attention, an important consideration is to develop interventions that will stimulate and (re)develop top-down processing, enabling individuals with ABI to develop cognitive control through effortful processing opportunities and to overcome automatic responses.

As noted, two forms of attentional processes have been identified in the literature: automatic and effortful. In order to rehabilitate an injured brain in which the mechanisms of attention have been disrupted, the hypothesis for music-based rehabilitation interventions presented in this paper assumes that interventions should require a top-down response, or effortful processing, from the individual in order to develop attentional control. Attentional control is at the root of many other attentional deficits. By addressing this underlying mechanism of attention, it may be possible to improve other cognitive functions. Chen et al. (2011) state:

“If one cannot hold key information active in the mind or protect it from distracting information, then subsequent actions are less likely to be guided efficiently or effectively towards goal attainment. Targeting these specific cognitive abilities may therefore lead to improvements in functioning that generalize to broader domains of goal-directed functioning.” (p. 1542).

With the repeated experience of cognitive rehabilitation interventions, increased attentional control from top-down processing may then generalize to increased attentional control in new situations, improved new learning and goal-directed behavior or task-maintenance. It is important to use varied, including multi-sensory, approaches to interventions to lower the risk of improvement in one modality or task only rather than improvement in the broader scope of attentional processes.
Music based interventions, using varied presentations and complexities of melody, rhythm, and harmony in exercises that require specific responses by the clients to changing musical cues and including the possibility for multi-sensory stimulation, may be a unique rehabilitation tool for cognitive control.

2.1.f Top-down processing and goal-directed behaviour

When presented with stimuli, the brain will respond in one of two ways: top-down or bottom-up. Top-down cognitive processing involves the flow of information from higher levels to lower levels and is informed by previous experience. Bottom-up processes are in response to sensory stimuli “through perceptual analysis, towards a motor output, without involving feedback information flowing backwards from ‘higher’ to ‘lower’ centers” (Corbetta and Shulman, 2002, p.201). Miller (2000) describes top-down processing as “brain signals that convey knowledge derived from prior experience rather than sensory stimulation” (p. 59). Cognitive control is engaged during top-down processing. Miller (2000) states that “a key function of the neural circuitry mediating cognitive control is to extract the goal-relevant features of our experience for use in future circumstances” (p.59). Thus, goal directed behavior is a key component of cognitive control and must be included in the development of cognitive rehabilitation interventions.

The fact that goal-directed behavior is informed by previous learning suggests that it is “moldable” and able to be influenced. Miller (2000) supports this, stating that the neural mechanisms for cognitive control are “sculpted by experience”. As such,
it may be possible to sculpt or influence top-down processing ability through the repetitive experience of cognitive rehabilitation interventions. For rehabilitative purposes, a balance must be found between the repetition necessary for new learning with caution that the repetition does not result in the development of a single task-related skill rather than improvement in attentional control and the generalization of goal-directed behavior. To reduce this risk, a varied approach, with a gradual increase in task complexity, should be incorporated into the cognitive rehabilitation intervention. This range of tasks and levels of complexity will also serve to defend against the automatization of response and instead continue to stimulate effortful attentional processing.

2.1.g The role of the Prefrontal Cortex (PFC) in cognitive control

In order to ground cognitive rehabilitation in the mechanisms of attention, a closer examination of the role of the prefrontal cortex (PFC) in goal-directed behavior or cognitive control is needed. There are several theories regarding the role of the PFC in cognitive processes. Cohen et al. (1998) propose that the PFC is involved in the task of managing “information necessary to mediate an appropriate behavioural response”. Duncan et al. (1996) describe failure in goal-directed behavior as a result of PFC lesions.

The parietal and frontal cortices are involved in top-down or goal directed behavior (Anderson et al., 2002; Corbetta & Shulman, 2002; Bressler et al., 2008, Corbetta et al., 2008). The dorsolateral prefronal cortex is involved in control and performance
monitoring and the maintenance of sensory memory; the posterior parietal cortex and anterior intraparietal sulcus are key to the dorsal attentional network; and the inferior frontal region is involved in the ventral attentional network (Tallon-Baudry, 2012).

Miller (2000) proposes that the prefrontal cortex, overlapping and interconnected with “virtually all sensory neocortical and motor systems and a wide range of subcortical structures”, is central to the extraction of goal-relevant features of experience and informing new situations. He suggests that the “widespread projections” of the PFC back to the above noted systems allows the PFC to “exert a top-down influence on a wide range of brain processes”. D’Esposito & Postile (2002) describe the extensive involvement of the PFC in a range of cognitive processes stating that:

“one strong conclusion that can be drawn from (these data) is that lateral PFC activity cannot be ascribed to the function of a single, unitary cognitive operation...We have seen that human PFC is involved in several encoding and response-related processes as well as in the mnemonic and extramnemonic processes that can be engaged during the delay periods of working memory” (p. 17).

Miller (2000) also notes that prefrontal neurons have the ability to create networks that reflect associations between goal-relevant components of a task and proposes the role of dopamine to strengthen these connections. Fuster (1997) states that the PFC “is essential for the formulation and execution of novel plans or structures of behavior”. Because prefrontal networks are formed and activated during goal-directed tasks, it may be concluded that the PFC is important for learning and for
sustaining activity on a task. Maintaining goal-relevant information in memory, thus enabling one to persist towards goal-directed behavior, is working memory.

This supports the proposal, noted earlier in this paper, that cognitive rehabilitation interventions should include tasks which engage the processes of working memory, recruiting mechanisms involved in top-down processing and goal-directed behavior, resulting in improved attentional control.

In discussing how the PFC exerts cognitive control, Miller (2000) proposes a Biased Competition Model in which the PFC provides an excitatory signal, biasing brain signals in other brain areas towards task-relevant information. This in turn, suppresses responses of other neurons to irrelevant information. He states:

“In voluntary shifts of attention, a competitive advantage is conferred by excitatory signals (thought to originate in the PFC) that represent the “to be attended” stimulus. These excitatory signals enhance the activity of neurons in the visual cortex that process the stimulus and, by virtue of the mutual inhibition, suppress activity of neurons processing other stimuli. This idea of excitatory bias signals that resolve local competition can be extended from visual attention to cognitive control in general” (p. 62).

He further explains:

“Because task representations in the PFC include disparate information, the excitatory signals from this area could be involved in selecting particular sensory inputs (attention), memories (recall) or motor outputs (response selection). By simultaneously biasing processing in different brain systems towards a common ‘theme’ (the task), the PFC can select the neural pathways needed to perform the task” (p. 63).

The plasticity of the PFC towards neural biasing is evident in the experience of new learning and may suggest the potential for intentional stimulation of this top-down
processing through specifically designed learning experiences. As the process of goal-directed behavior is repeated and relevant networks consolidated, these networks become more efficient. This is demonstrated in imaging studies showing weaker activation during well-rehearsed tasks (Knight, 1984; Yamaguchi & Knight, 1991; Knight, 1997; Shadmehr & Holcomb, 1997) and is supported by Schmitter-Edgecombe (1996) who describes automatic and effortful processing on a continuum, with the potential for some tasks that were initially effortful to become automated.

The potential to stimulate a neuroplastic response in the PFC may be further supported by observations expressed by D'Esposito & Postile (2002) who state that “it is clear that any one region within the lateral PFC can be engaged by distinctly different cognitive operations in different contexts” (p.19). This may indicate the possibility to arouse a response in the PFC through an alternative stimulus when another is ineffective. Because music has several characteristics (melody, rhythm, harmony) and is a multi-modal stimulus, it may be uniquely effective in arousing the PFC.

Stimulating the neuroplasticity of the PFC through specifically designed new learning situations shaped according to the patient’s needs may potentially increase the injured brain’s ability for new learning in general. This ability for new learning may allow for the acquisition of new skills or behaviours following ABI which in turn, may evolve from effortful to automatic responses resulting in increased independence and functionality.
2.2. Potential Challenge to the Hypothesis of Music-based Cognitive Rehabilitation to Remediate Attention

Potential challenges to the hypothesis of the development of music-based cognitive rehabilitation interventions to remediate attentional processing are based on the debate within the field of cognitive rehabilitation regarding the efficacy of a remedial approach. The question regarding the efficacy of remedial cognitive rehabilitation has two components, the first is the validity of study results due to research design; the second is whether any improvement generalizes beyond task-specific improvements of rehab training exercises.

2.2.a Remedial approach: The question of research design

The Committee on Cognitive Rehabilitation Therapy for Traumatic Brain Injury in the National Academies Institute for Medicine (2011) highlights the lack of evidence for the efficacy of cognitive rehabilitation therapy (CRT) stating that:

“The committee identified 90 studies that met selection criteria. These studies signal there is benefit from some forms of CRT for TBI. However, the evidence for the therapeutic value of CRT is variable across domains and is currently insufficient overall to provide definitive guidance for the development of clinical best practice, particularly with respect to selecting the most effective treatment(s) for a particular patient...The committee found the insufficiency of the evidence was due to a number of identified limitations in the research designs” (p. 8).
Ceravolo (2006) states that:

“Deficits in attention and self-regulation are common complaints associated with a number of disorders across the lifespan. Many treatment programs have been developed with the intention of restoring or rehabilitating the impaired components of attention, with the number and variety of attention programs increasing rapidly. So far, irrespective of treatment population, the existing research does not provide sufficient evidence to reach any conclusions about the efficacy of programs designed to address attention deficits. There is need for more rigorous studies of available treatment programs across age levels and disorders, focusing on individual sources of variance, the nature of the research question, the choice of control or alternative treatment conditions and the theoretical framework of training efficacy” (p.51).

Van den Broik (1999) questions the efficacy of the remedial approach stating:

“...in memory disorders, (where) it has been argued that drill and exercise methods cannot be expected to enhance psychological functions in the same manner as muscle strength is re-established through exercise. While some have found that cognitive exercises bring about improvements in memory and attention which generalize to daily living, others have suggested that appropriately controlled investigations are relatively few in number and those that are available provide little encouragement for the restorative approach” (p. 258).

Remediation by direct training is also questioned by Park and Ingles (2001) who state that:

“Methods used to directly retrain attention produced only small, statistically insignificant improvements in performance in all general measures of cognitive function and in all specific measures of attention when improvement was determined using pre-post control for effect size estimates. Thus support for the hypothesis that direct retraining can restore or strengthen damaged attentional function was not found in the reviewed studies”(p. 205).

Park and Ingles (2001) completed a study regarding the efficacy of Attention Process Training (APT) and concluded that training resulted in “learning of specific
cognitive skills” but that it did not improve “damaged attention functions”. In response, Michael and Mateer (2006) state that the Park and Ingles’ review “inclusion criteria were overly broad, for example including studies which included participants with severe brain injury and would not be expected to significantly benefit from training. In addition, the types of programs and what was measured varied extensively between studies included in this review” (p. 61-62). They highlight studies that demonstrated the efficacy of APT (Sohlberg and Mateer, 2001; Sohlberg, 2005; Lincoln, Majid & Weyman, 2000; Cappa et al. 2003; Cicerone et al., 2005), although they acknowledge that although attention improved on tasks, there remains the question of generalization.

Mateer and Mapou (1996) reviewed several studies exploring the effects of attention training (Ben-Yishay et al., 1987; Diller et al., 1974; Wood & Fussey, 1987; Ethier et al., 1989; Gray & Robertson, 1989; Gray et al., 1992; Ponsford & Kinsella, 1988) and found mixed results. They state that “it is important to examine the experimental variables that might have led to different results (p. 10).

It should be also noted that the lack of evidence described is due to limitations in research designs and also that studies did not meet inclusion criteria for review. The question therefore can shift from the efficacy of cognitive rehabilitation to challenges (or flaws) in research design with this clinical population. Research complications arise from the heterogeneity of the ABI population in pre-morbid condition, injury type and location; whether data was collected during the acute or
post-acute stage of recovery; the lack of definitive definitions for cognitive rehabilitation and for attention; the range of potential goal areas within cognition; and results measures, whether they be “lab tests” or “real life situations”.

In addition to research design, another important question to consider is intervention design. Mateer and Mapou (1996) state that:

“most of the studies that have attempted to evaluate the efficacy of attention training have not been based on a theoretical framework of attention. Rather, they have utilized a variety of treatment tasks (often similar to tasks used in the assessment of attention) that appear to challenge patients but that do not necessarily fit within a larger conceptual model of attention.” (p. 9).

In examining the issues raised regarding research evidence for the efficacy of a remedial approach to cognitive rehabilitation, the response is not to dismiss the potential for cognitive rehabilitation success, but rather to highlight the need for further investigation, giving consideration to the issues raised.

2.2.b Remedial approach: The question of generalization

Gillian (2009) questions the transferability of a remedial approach stating that “most studies related to attention impairments focus on impairment-based measures...it is questionable if these interventions translate to meaningful improvement from the perspective of everyday function or quality of life” (p. 195).

He highlights the need for on-going research on this topic stating that:

“...interventions focused on improving the underlying attention deficit have been found to reduce impairments. Unfortunately, the ability to generalize these effects to more meaningful activities has limited research support and warrants further investigation related to the effects on activity limitations
and participation restrictions if they are to be included in intervention plans focused on improving performance in daily activities” (p. 197).

Gummow, Miller and Dustman (1983) raise the question of generalization of results stating that although study results may indicate improved performance on outcome measures, “it is not known whether behavioural changes were maintained over time or generalized to the home or ‘natural environment” (p. 265). Ceravolo (2006) states that:

“According to the literature, the ability of attentional process training to improve attentional functioning in post-acute phase following brain lesion has been demonstrated by some means. On the contrary, cognitive rehabilitation ability to generalize to untrained functional capacities or improve subjective perception of wellbeing has yet to be proven” (p. 50).

Park and Ingles (2001) address the question of generalization in their review stating that “our results suggest that the learning that occurs as a function of training is specific and does not tend to generalize or transfer to tasks that differ considerably from those used in training” (p. 207). They explain that they interrupted their results based on the conceptual framework of the “transfer appropriate processing hypothesis” which states that “performance on a particular task after training will improve to the extent that the processing operations required to carry out that task overlap with the processes engaged during training (Kolers & Roediger, 1984; Morris, Bransford & Franks, 1977). That is, performance will improve after training if the training task is similar to the targeted outcome measure” (p. 207). However, they point out that the hypothesis does not propose a method of training for a complex task and as a result, suggest breaking the task into small steps and shaping to the individual's ability, described as neuropsychological scaffolding.
Planning for generalization of the results of cognitive rehabilitation needs to be incorporated into the cognitive training (Stokes and Baer, 1977; Sohlberg and Raskin, 1996; Sohlberg and Mateer, 2001; Ponsford, 2008) with specific steps included to help facilitate the generalization. Sohlberg and Raskin (1996) propose five principles for generalization: 1) actively plan for and program generalization from the beginning of the treatment process 2) identify reinforcements in natural environment 3) program stimuli common to both training environments and real world 4) use sufficient examples when conducting therapy and 5) select methods for measuring generalization.

Generalization may take place at various levels. Gordon (1987) proposes three levels of generalization as: 1) gains are consistent on different training occasions 2) improvement is noted on similar tasks and 3) improvements transfer to functioning in activities of daily living. Recognizing that generalization could occur at different levels, when interpreting study results, one must consider what level generalization took place at, or not, and what measures were used to determine generalization of results. Another consideration is the time-line of the study. Because attention has been described hierarchically, perhaps studies with a shorter time-line did not allow for generalization to take place at more advanced levels. In addition, time-since-injury and level of impairment can influence the level and timing of generalization.

Key questions regarding the efficacy of the remedial approach to cognitive rehabilitation are primarily based on concerns related to study design and whether
or not generalization of results is seen in functions of daily life. As noted, there are several contributing factors to study results, and as such, one cannot discount the effectiveness of remediation of cognitive function based on research results alone. Generalization may have taken place at a lower level than that of improvement in life function. In addition, studies may not have employed effective measures or incorporated generalization into the intervention design. Thus, one cannot be deterred from a remedial approach, but rather, be informed as to the importance of planning for facilitation of generalization when designing training interventions and giving careful consideration to the appropriate measures to use to determine generalization.

2.3 Neuroplasticity of the Brain: A Case for Remediation

The brain’s ability to “change its own structure and functioning in response to activity and mental experience” has been defined as neuroplasticity (Doidge, 2015). Bach-y-Rita (1992) defines neuroplasticity as “the adaptive capacities of the central nervous system, its ability to modify its own structural organization and functioning. It permits an adaptive (or maladaptive) response to functional demand” (p. 194). Evidence of functional improvement following brain injury coupled with the development of imaging technology led to inquiry into the possibility of change within the brain (Bach-y-Rita, 2003; Rossini et al. 2003; Duffau, 2004; Desmurger et al., 2007). Plasticity of the brain was described as early as 1915 by Franz, Sheetz, and Wilson in their paper challenging the permanency of paralysis following stroke. Since that time, literature has demonstrated that the brain is not static, but rather, it
continues to change and modify itself in response to stimulation, in particular, learning. There has been a gradual shift from a “machine” view of the brain, in which a broken machine remains broken, to an understanding that the brain is able to undergo changes at various levels; from the view that the brain is “hardwired” to one in which the brain is plastic.

Neuroplastic change of the brain has been noted as a result of learning (Bach-y-Rita, 1992; Mateer & Kerns, 2000; Draganski et al., 2004; Lee et al., 2007; Altenmuller, 2009; Habib & Besson, 2009; Pantev, 2009; Pantev et al., 2009; Schlaug et al., 2009; Trainor et al., 2009) and also due to rehabilitation training for lost function in speech, motor, and cognition following brain injury (Taub, E., 2004; Saur, D. et al., 2006; Kelly et al., 2006). The brain’s neuroplastic response is possible at a number of levels, from synaptic to cortical and sub-cortical (Bach-y-Rita, 2003; Kolb & Gibb, 2002; Kelly et al., 2006, Duffau, H., 2009; Koziol & Budding, 2010, Raskin et al., 2011) and can be observed by changes in synaptic receptor plasticity, changes in activation levels, redistribution of neural networks, and cortical reorganization.

The goal in any rehabilitation efforts is to stimulate a neuroplastic response to adapt for damaged networks. As stated by Bach-y-Rita (1992): “When faced with the evidence that a particular type of brain injury ‘permanently’ eliminates some function, a brain plasticity-influenced approach is to ask: What can be done to reorganize the remainder of the brain to enable that function to be regained?”
Through numerous studies, certain principles for the stimulation of neuroplasticity have emerged. These include: 1) neuroplasticity is experience-driven. 2) Training must be intensive, with high repetition. 3) Training must increase in complexity, engaging learning or skill (not mindless repetition). 4) Training must be specific. 5) Neuroplasticity takes time.

While a large portion of the literature has demonstrated neuroplasticity and functional gains in speech and motor impairments following ABI, there is also literature supporting gains in cognitive rehabilitation (Gummow et al., 1983; Mateer and Mapou, 1996; Mateer et al., 1996; Van den Broek, 1999; Sohlberg, M.M. et al., 2000; Sturm, W. et al, 2004; Cicerone et al., 2006; Kelly et al, 2006; Kim et al, 2009; Engle and Kerns, 2011; O'Connell and Robertson, 2011; Rabipour & Raz, 2012). While numerous studies have demonstrated the efficacy of cognitive rehabilitation through functional changes, Kelly et al. (2006) and Chen et al. (2006) highlight the importance of using neuroimaging to evaluate and demonstrate a neuroplastic response to cognitive training, providing evidence of change, in both increases and decreases, in neural activation following cognitive rehabilitation. Both authors note the small number of neuroimaging studies.
2.4 Why Music-based Cognitive Rehabilitation Interventions?

Given the fact that evidence for neuroplasticity of the brain, including in the injured brain, is well supported in the literature and there is also increasing evidence for neuroplasticity in regard to cognitive function, it seems reasonable to pursue a remedial approach to cognitive rehabilitation. But why consider music-based cognitive rehabilitation interventions? Can music provide a unique stimulus for cognitive [re]training?

Moreno & Bidelman (2014) highlight the potential value of music as a stimulus stating that “music's impact on the brain is unique in that it offers distinct perceptual and cognitive benefits not observed with other forms of intense training or experience. Perhaps more significantly, music training is a rare activity that modifies a hierarchy of brain structures” (p.93).

The various components of music such as melody, rhythm, and harmony, arouse and engage different brain networks (Table 2.2). This scope of arousal may be particularly important when seeking to stimulate an injured brain. In addition, the increased cognitive control and attentional resources recruit by musicians as discussed below, suggest that music may be especially effective for the stimulation of attentional networks in cognitive rehabilitation.
### Table 2.2  Music Component and Brain Area Engaged

<table>
<thead>
<tr>
<th>Music Component</th>
<th>Brain Area Engaged</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pitch relation</td>
<td>Right auditory cortex, right anterior part of Heschl’s gyrus, posterior secondary cortex</td>
</tr>
<tr>
<td>Harmony</td>
<td>Inferior frontal areas (frontal operculum) bilaterally</td>
</tr>
<tr>
<td>Meter</td>
<td>Right side, anterior superior temporal gyrus</td>
</tr>
<tr>
<td>Rhythm</td>
<td>Left temporal lobe, basal ganglia</td>
</tr>
<tr>
<td>Working memory for pitch</td>
<td>Right auditory cortex, frontal cortical areas: dorsolateral and inferior frontal areas</td>
</tr>
<tr>
<td>Melody (memory of)</td>
<td>Left inferior temporal and frontal areas</td>
</tr>
<tr>
<td>Training (performing)</td>
<td>Motor cortex, cerebellum, corpus callosum, basal ganglia</td>
</tr>
<tr>
<td>Emotional qualities</td>
<td>Limbic and parlimbic areas, amygdala, hippocampus, cingulated cortex, orbitofrontal cortex</td>
</tr>
</tbody>
</table>

Adapted from Peretz & Zatorre, 2005; Zatorre et al., 2007; Sarkamo et al., 2013
The proposal for the potential value of music as a stimulus for cognitive rehabilitation was informed by evidence of music’s influence on the brain in regard to neuroplasticity, music’s influence on non-musical abilities, the musician’s enhanced working memory and cognitive control, the evidence for transfers of cognitive benefits from music training to nonmusical functions, and by anecdotal reports of clinical observations in the literature.

2.4.a **Neuroplasticity and the musician’s brain**

Music’s influence on the brain is evidenced in functional and anatomical differences between the brains of musicians and non-musicians (Bailey et al., 2014; Munte, Altenmuller, and Jancke, 2002; Habib and Besson, 2009; Hyde et al, 2009; Pantev, 2009; Pantev et al., 2009; Wan and Schlaug, 2010; Zimmerman & Lahav, 2012; Baily, Zatorre, and Penhune, 2014). Studies exploring these differences have been used to demonstrate the brain’s plasticity. This plasticity, to a large extent, is reflecting the plasticity of learning. However, these studies demonstrate music’s ability to stimulate change and also provide evidence of anatomical areas in which music has an influence, thus potentially informing the development of interventions that are music-based.

Anatomical distinctions in musicians include a larger corpus callosum [the fiber track underlying interhemispheric communication (Wan and Schlaug, 2010)], more grey matter in somatosensory, premotor, superior parietal, and inferior temporal areas of the cortex (Gasser and Schlaug, 2013), and more grey matter in areas
involved in higher order cognitive processing and auditory processing (James et al., 2013).

It is expected that music-related anatomical differences would be observed in brain areas such as sensorimotor and auditory areas. However, Hyde et al. (2009) observed that anatomical differences also extended to multimodal integration areas. They state that:

“while structural brain differences were expected in motor and auditory brain areas, unexpected significant brain deformation differences were also found in various frontal areas, the left posterior peri-cingulate, and a left middle occipital region. However, none of these unexpected deformation changes were correlated with motor or auditory test performance changes. These findings indicate that plasticity can occur in brain regions that control primary functions important for playing a musical instrument, and also in brain regions that might be responsible for the kind of multimodal sensorimotor integration likely to underlie instrumental learning. These results provide new evidence for training-induced structural brain plasticity in early childhood. These findings of structural plasticity in the young brain suggest that long-term intervention programs can facilitate neuroplasticity in children. Such an intervention could be of particular relevance to children with developmental disorders and to adults with neurologic diseases” (p. 185).

Others studies also demonstrate anatomical differences in musicians that extend beyond the expected auditory regions to non-auditory regions including the pre-central gyrus (Amunts et al., 1997), the anterior-medial part of the Heschl gyrus (Schneider et al., 2002), and parts of the cerebellum (Hutchison et al., 2003). The extent of neuroplastic response to music may imply potential for change in function and behavior, including aspects of cognition, and has not been thoroughly investigated.
2.4b Musician’s enhanced non-musical abilities

It would be expected that musicians would have enhanced music-related abilities as a result of training. However, functional differences between musicians and non-musicians include musician’s enhanced abilities in non-musical areas. Numerous studies have demonstrated enhanced abilities of musicians in a variety of areas including auditory perception (Strait et al, 2014), phonological awareness (Dege & Schwarzer, 2011), speech processing (Wong et al., 2007), listening skills (Munte et al., 2001), perceiving speech in noise (Parberry-Clark et al., 2008), and reading (Douglas & Willatts, 1994, Gardiner, Fox, Knowles & Jeffery, 1996). These studies demonstrating enhanced non-musical abilities following music training can support the hypothesis that music-based interventions have the potential to influence non-musical rehabilitation goals and that music-based interventions may support generalization of benefits to non-musical domains.

The research literature demonstrates that engagement in music results in differences in brain structure, both in music-relevant and non-music-relevant areas and in enhanced non-musical abilities, which suggests the rehabilitative potential for music for the injured brain. Of particular importance to the hypothesis of this paper is literature demonstrating music’s influence on cognition. Barrett et al. (2013) state that “a broad variety of study designs, which as a whole, support the notion that musical training can enhance neural, cognitive, and communication function” (p.2). Pallesen et al. (2010) provide further support stating that “evidence also indicates that musicians benefit from enhanced domain-general cognitive
processes, including enhanced mathematical, verbal, and non-verbal skills (Vaughn, 2000; Forgeard et al., 2008; Sluming et al., 2007) and non-musical enhancement of working memory in musicians has repeatedly been demonstrated” (p.1).

Several studies have demonstrated musician’s enhanced executive function resulting in a range of cognitive benefits (Hannon and Trainor, 2007; Bailystok and DePape, 2009; Strait et al, 2010; Moreno et al. 2011; Strait and Kraus, 2011). Other studies have demonstrated, when engaged in a difficult memory task, musicians’ recruitment of larger neural networks involved in cognitive control and sustained attention (Gaab and Schlaug, 2003; Pallesen et al, 2010).

Music’s association with enhanced cognitive abilities has been investigated by Schellenberg (2004, 2005, 2006, 2011; Schellenberg & Peretz, 2008). Schellenberg highlights the important question of music’s association versus music’s causation of cognitive abilities and concludes music’s association, stating that musical aptitude may be a “marker of general intelligence” (Schellenberg & Weiss, 2013) and that enhanced cognitive abilities of musicians reflect that individuals with higher IQ are more likely than those with lower IQ to participate in music training (Schellenberg, 2011). Although studies have positively associated music training to IQ (Schellenberg, 2004), Schellenberg (2011) concludes that these results “suggest that high-functioning children are more likely than other children to take music lessons and to perform well on a variety of tests of cognitive ability, and that music lessons exaggerate these individual differences slightly” (p. 534).
Studies concluding with a lack of causal effect of music on cognitive abilities may initially appear to weaken the validity of the hypothesis that music-based interventions, or music training, have the potential to contribute to cognitive rehabilitation. Studies investigating the role of genetics (Tan et al., 2004; Mosing et al., 2014) in musical training and outcomes might appear to suggest a reduced role of music itself. While acknowledging the value of these studies, in the context of cognitive rehabilitation, it is important to consider other factors. For example, many studies use standardized neuropsychological tests on healthy individuals. While these studies are important in establishing results in isolated aspects of cognition and are necessary to contribute to the body of knowledge regarding music’s influence on the brain, they do not necessarily effectively address or explore questions related to cognitive rehabilitation. When investigating the potential for music to stimulate cognitive processing in an injured brain, the question is not “can music make you smarter”, but rather, the focus is on a more preliminary question: “does music engage attention?” and if so, “can music engage attention in an injured brain?” What are the goals of cognitive rehabilitation and can music stimulate a response that is directed towards these goals?

2.4.c Music and cognition: musician’s attention and working memory

This hypothesis is particularly interested in music’s ability to engage attention and working memory as these are among the areas of cognition considered to be foundational to cognitive rehabilitation. Music’s influence on cognition and its potential use in cognitive rehabilitation is supported by the literature. The results
from a number of studies have provided evidence of enhanced attention and working memory following music training. Pallesen et al. (2010) note that “music competence may confer cognitive advantages that extend beyond processing of familiar sounds. Behavioural evidence indicates a general enhancement of both working memory and attention in musicians” (p.1). Bialystok and Depape’s (2009) study revealed improved attention and increased inhibition on a modified Stroop test following music training, while Moreno et al. (2011) found improved visual inhibition following one month of music training, in addition to improved IQ and functional changes at the cortical level. These studies indicate that music training does engage attention processing and can enhance it.

Studies also demonstrate the benefit of music training transfer to working memory function (Chan et al., 1998; Pallesen et al., 2010; Bugos et al., 2007) although there is variability in the nature of this transfer with study results indicating more benefit in either working or visual working memory. This variability of results may be due in part to the instrument used in training.

2.4.d *Music training and cognitive control*

The enhanced working memory and attention of musicians reflects increased cognitive control, associated with increased activity in the lateral PFC and parietal regions. The increased activity in the PFC during task-relevant adjustments is positively correlated with activity in the ACC engaged during response monitoring and error prediction. This ACC activity further supports cognitive control. Barrett et
al. (2013) note greater cognitive control and sustained attention in musicians, reflected in increased activation of greater neural networks involved with cognitive control. It is proposed that this increased cognitive control developed during music training may transfer to other cognitive domains (Pallesen et al., 2010; Barrett et al., 2013; Moreno & Bidelman, 2014).

Pallesen et al. (2010) state that music does influence attention and propose that musicians' enhancement in non-music cognitive activities is a result of increased attentional control and working memory demonstrated by increased recruitment of brain areas involved in top down processing, such as the parietal cortex, lateral PFC, and the ACC rather than enhanced processing only in auditory cortical areas. They predicted musicians' enhanced performance on two working memory tasks. Their study results revealed that, while both musicians and non-musicians rated task difficultly similarly, the musicians performed better due to allocating more resources as observed in greater activity in the ACC, which combined with bordering sections of the medial PFC, is involved in monitoring conflict and prediction of error. Musicians also demonstrated a higher magnitude of Blood Oxygenation Level Dependent (BOLD) brain responses as a result of working memory load increase. Their study concludes that:

"musicians are capable of recruiting more brain resources to sustain cognitive control during a working memory task with musical chords than are non-musicians, and in doing so are able to sustain a higher performance level despite the elevated cognitive demands. There were no strong indications in our results that the music-specific processes played a role in the superior performance of musicians, hence supporting previous evidence that cognitive control may be generally enhanced in musicians. Superior
cognitive control could represent a skill that is established during demanding musical training and transferred to other cognitive domains” p. 11.

Increased cognitive control of musicians is also noted by Moreno & Bidleman (2014) who suggested it as the main contributor to the range of neural and cognitive benefits reported in the literature.

Music based cognitive rehabilitation interventions may stimulate increased cognitive control due to the high level of self-monitoring and error detection required when engaged in music. An advantage to music activities is that the feedback response is immediate, providing immediate opportunity for monitoring, error detection, and correction.

Another contributing factor for enhanced attention and cognitive control of musicians may be the multi-modal nature of music stimuli. This multimodality of music may stimulate cognitive control though top-down processing of target selection and response, including inhibition of non-relevant aspects of the stimuli; increase arousal level, especially for an injured brain; and may support cross-modal or far(ther) transfer. Wan & Schlaug (2010) propose that music may lead to “poly-modal integration”, resulting in behavior change in other domains. Music’s multimodality influence may also support Moreno & Bidelman’s (2014) proposed continuum of transfer of cognitive gains following music training noted below.
The multimodal aspect of music processing is a consideration when developing cognitive rehabilitation interventions for the injured brain. Because arousal levels are lower, or specific modalities may be more impaired, the multimodal characteristics of music may serve as a stronger stimulus to engage attention and to potentially improve intermodal connections.

The first step in addressing cognitive deficits is to improve attention and working memory processes: functions of the PFC. Music's ability to engage the PFC and to stimulate the mechanisms involved in cognitive control and attention indicate its potential effectiveness to address injuries of the PFC. In order to remediate impaired cognitive processing, it is important to engage the PFC. Targeting the PFC processing for cognitive rehabilitation is support by Chen, Abrams, and D'Esposito (2006) who state that:

“A clear theoretical framework based on neural mechanisms underlying PFC function may assist in the development of more effective therapies. Cognitive rehabilitation treatments, including clinical trials, rarely consider these neural mechanisms. An additional emphasis on the neural mechanisms that mediate PFC functions may result in treatment prescriptions that differ from more traditional behavior therapy” (p. 108).

They further support targeting PFC functioning with the goal of rehabilitation by describing the potential neuroplastic responses of the PFC to rehabilitation efforts stating:

“Rehabilitation of PFC dysfunction through training may be considered a process of guiding mechanisms of plasticity for the “reintegration” of functional PFC networks. That is, mechanisms of plasticity following brain injuries include the possibilities of reorganization of available network components, or the generation of new network components. Mechanisms of plasticity at the cellular level that may support reorganization or
regeneration include alterations in metabolism, synaptogenesis, and synaptic pruning, including growth of new long-distance projections, and perhaps neurogenesis...Ultimately, for these neural changes to affect neurologic function, they must be translated into changes in the functioning of networks of neurons” (p.112).

They state that “training guides these neuronal changes”, leading to “functionally integrated networks and coherent behavior output” (p. 112).

2.5 Transfer of Cognitive Benefits of Music Training

Pallesen et al. (2010) state that by “allocating more resources.... the musicians were better able to uphold task performance than non-musicians” (p. 9) and suggest that cognitive benefits from music training transfer to other non-music cognitive tasks. This transfer of benefit, to both near and far cognitive processes has been investigated by Moreno & Bidelman (2014) who propose that neural and behavioural benefits observed in musicians may be a result “from an augmentation of these more general, and perhaps singular, top-down mechanisms” (p. 92). They support Pallesen et al. (2010) observations of greater brain recruitment and of benefit transfer stating that “larger brain networks tuned by musical exposure produced benefits that extend well beyond the scope of music to influence high-level cognitive functions of language, intelligence, attention, and memory” (p.94).

In investigating neural plasticity and cognitive benefit from music training, Moreno & Bidelman (2014) reviewed longitudinal training studies, concluding that “music (but not visual arts training) positively enhances not only auditory processing relevant to speech and language but also impacts the visual modality and executive
functions, ie. Higher-order mechanisms which regulate, control, and manage important cognitive processes like working memory, attention, and planning” (p. 86). Literature supports the improved cognitive processing as a result of music training. Moreno et al. (2011) state that: “our findings demonstrate a causal relationship between music training and improvements in language and executive functioning, supporting the possibility of broad transfer between high-level cognitive activities” (p. 1431). This transfer and improvement in high cognition may be a result of music engaging shared neural resources with other cognitive tasks.

In examining the near-far transfer of sensory and cognitive benefits of music training to higher cognitive processes, Moreno & Bidelman (2014) propose a orthogonal model with a continuum along a transfer dimension and a processing level. The transfer dimension represents the continuum from near transfer, that is, transfer of benefits to untrained activities related to music, to far transfer, which includes transfer of benefit to activities unrelated to music. The processing dimension includes both sensory processing reflecting “benefits to basic perceptual feature extraction” and cognitive processing, representing benefit to higher cognition.

Using their model, Moreno & Bidelman (2014) propose that benefits initially directly associated to music, such as neural encoding of musically relevant sound, over time with repeated exposure, gradually begin to benefit the sensory processing of non-musical domains, for example, enhanced auditory encoding of speech. This in turn, eventually can benefit higher order cognition such as enhanced perception
of phonological characteristics of speech. This model may explain the continuum of near-far transfer of benefit of music training to non-musical activities including higher cognitive processing.

The continuum along sensory to cognitive processes that is presented in Moreno & Bidelman’s model can serve to support music-based interventions as a first step in engaging attention, through senses, and potentially transferring benefit to higher cognitive processing or leading to rehabilitation of aspects of cognitive processing. Music is a strong sensory stimulus, and as noted by Munte et al. (2002), it is “highly complex and structural in several dimensions” and therefore could be used as a first step in stimulating and enhancing higher cognitive processes by engaging attention at the sensory level. It is important to remember that this may take significant time in comparison to healthy study participants.

Moreno & Bidelman (2014) note that the amount of far transfer may be dependent on the individual’s cognitive capacity. When considering the use of music-based cognitive rehabilitation interventions with the goal of far-transfer, the individual receiving the treatment will have a reduced cognitive capacity due to their brain injury. The level of far transfer may be reduced due to the initial reduction in cognitive capacity. Research can investigate which candidates, based on their level, type, and location of brain injury, are most likely to benefit from the intervention. However, because of the heterogeneity of the ABI population, the question may not
be only who can benefit from music-based interventions, but also, how much time might it take.

Because of music's influence on cognition, its potential for use as a rehabilitation intervention has been proposed by several studies. Wan & Schlaug (2010) state that “because the human brain can be shaped by musical experience, one promising application of a music-making program is in the treatment of neurological and developmental disorders” (p. 574). In addition, they highlight music's arousal of the limbic system, thus potentially enhancing motivation to engage in demanding rehabilitation tasks. Habib and Bennon (2009) study concludes that “the possibility of using music as a therapeutic tool for children struggling with learning difficulties opens fascinating avenues at the intersection of neuroscience, musicology, and pedagogy” (p. 283) while Barrett et al.’s (2013) study results support cognitive gains following music training with elderly participants leading the authors to conclude that “music training may thus serve as a powerful cognitive rehabilitation technique in older adults” (p. 8).

2.6 Music-based Cognitive Rehabilitation

2.6.a The interventions

Based on the theories and models of attention, in developing music-based cognitive rehabilitation, this hypothesis assumes the following criteria for the development and application of interventions:
1. The intervention is designed to stimulate top-down processing, engaging the PFC.
   a. Detection and response to a target stimulus is used to increase attentional processing and engage cognitive control.
   b. Goal-directed behavior
   c. Effortful processing

2. The intervention will place demands on working memory.

3. The intervention is designed to target a specific aspect of cognition, informed by the models of attention described by Sohlberg and Mateer (2001). These include focused, sustained, selective, alternating, and divided attention.

4. Interventions will be administered following the hierarchy of attention and cognition, beginning at the level appropriate for the client.

5. The interventions throughout treatment period will be shaped, gradually increasing in complexity and will include novelty to continue to engage attention and stimulate attentional and memory processing at an increasingly higher level (Kelly, Foxe, Garven, 2006; Sohlberg & Mateer, 2001). This in turn may also serve to support generalization.

6. The interventions will be varied, highlighting melody, rhythm, or harmony or focusing on different senses such as sight, auditory, and movement in order to train attention and to prevent the acquisition of a “trained task” only within a specific activity type.
7. Interventions will be administered with consideration to intensity and duration of treatment, recognizing that neuroplastic change is sculpted by experience.

2.7 Neurologic Music Therapy

There are currently several standardized music-based cognitive rehabilitation interventions developed by Neurologic Music Therapy (NMT) which are grounded in neuroscience. NMT was a catalyst in shifting the focus of music therapy towards a science-based model. NMT is defined as “the therapeutic application of music to cognitive, sensory, and motor dysfunctions due to neurologic disease of the human nervous system. NMT is based on the neuroscience model of music perception and production, and the influence of music on functional changes in nonmusical brain and behavior functions” (Thaut, 2005, p. 126). NMT has 20 standardized interventions which have been developed based on the Rational Scientific Mediating Model (RSMM). The RSMM includes four steps: 1. Music response models 2. Parallel non-music response models 3. Mediating models 4. Clinical research models (Thaut et al., 2014, p. 4). Research findings from RSMM can be translated into clinical applications with the Transformational Design Model TDM. The TDM includes six steps: 1. Assessment of patient 2. Development of goals 3. Design of non-musical, functional exercise and stimuli 4. Translation of step 3 into music-based functional exercise 5. Reassessment 6. Transfer of learning to activities of daily living (ADLs). (Thaut, 2014, p. 62).
NMT interventions include nine that have been designed to address cognitive goals. These include: Musical Sensory Orientation Training (MSOT), Musical Attention Control Training (MACT), Musical Neglect Training (MNT), Auditory Perception Training (APT), Musical Psychosocial Training and Counseling (MPC), Musical Executive Function Training (MEFT), Musical Mnemonics Training (MMT), Musical Echoic Memory Training (MEM), and Associative Mood and Memory Training (AMMT). Thaut (2010) states that “the role of music in cognitive rehabilitation has been the last domain to come into full focus in neurologic music therapy”. This recent focus within NMT will result in important contributions to the ongoing investigation into, and the development of, music-based cognitive rehabilitation. The NMT intervention MACT is the tool of investigation in this study regarding the efficacy of music-based interventions to arouse and engage attention of an injured brain.
Chapter 3
Methodology

3 Methodology

3.1. Sample Size

This study was completed by fifteen participants: 8 in the control (7 M-1 F) and 7 in the experimental condition (6 M – 1 F). Initially 21 participants gave informed consent to join the study. Following the first treatment session, two upcoming participants were withdrawn from the study at the discretion of the recruitment site due to the potential of behavioural concerns as a result of possible frustration related to the treatment tasks. Three participants failed to attend their pre-test session and one participant did not attend their post-test session and therefore were disqualified from the study. Participants did not know which group they had been assigned to, whether APT or MACT, until immediately after the pre-testing. Therefore, group assignment did not influence attending the pre-testing or involvement in the study. Participants who did not complete the study failed to do so as a result of their cognitive impairment: behavioural concerns due to potential level of frustration dealing with cognitive tasks or forgetting to attend scheduled data collection session.
3.2 Participants

3.2.a Eligibility Criteria

Study participants met the following inclusion criteria:

1. adult (age 18+)

2. ABI rated as moderate or severe according to Glasgow Coma Scale, NIH scale, or physician's report

3. Identified as having a cognitive impairment with no known pre-existing (pre-injury) cognitive deficits

4. Be able to complete the pre- and post- tests independently.

The study did not specify specific brain lesions sites as inclusion or exclusion criteria.

3.2.b Exclusion Criteria:

1. hearing impairment or central auditory processing disorder. Participants self-identified that they did not have a diagnosed hearing impairment.

2. depression
3.2.c Personal Information

The following information was required of each participant:

1. Glasgow Coma Score or NIH rating as applicable

2. Injury description / lesion site

3. Time since injury

4. Information regarding participant’s cognitive abilities pre-and post-injury.

5. Information regarding musical background

6. Information regarding any other treatments currently being received

All personal information was encrypted.

Participant profiles are described in Table 3.1 and Table 3.2
<table>
<thead>
<tr>
<th>Participant No.</th>
<th>Gender</th>
<th>Age</th>
<th>Level of Education</th>
<th>Primary Language</th>
<th>Employment at Time of Injury</th>
<th>Injury Type</th>
<th>Glasgow Coma Scale</th>
<th>Time Since Injury (years)</th>
<th>Lesion Site(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>57</td>
<td>High School</td>
<td>English</td>
<td>Truck Driver</td>
<td>Stroke</td>
<td>N/A</td>
<td>9</td>
<td>Broca’s Area &amp; prefrontal lobe</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>72</td>
<td>University</td>
<td>English</td>
<td>Retired College Professor</td>
<td>Brain Tumor</td>
<td>N/A</td>
<td>6</td>
<td>Right side craniotomy involving super lateral region (parietal lobe)</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>59</td>
<td>College</td>
<td>English</td>
<td>Architectural Landscaper</td>
<td>Aneurysm-Stroke</td>
<td>N/A</td>
<td>14</td>
<td>N/A</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>56</td>
<td>College</td>
<td>English</td>
<td>Telephone Linesman</td>
<td>Stroke</td>
<td>N/A</td>
<td>7</td>
<td>Prefrontal lobe &amp; occipital lobe</td>
</tr>
<tr>
<td>5</td>
<td>M</td>
<td>59</td>
<td>High School</td>
<td>French</td>
<td>Moving Company</td>
<td>Aneurysm</td>
<td>N/A</td>
<td>20</td>
<td>Right side</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>35</td>
<td>High School</td>
<td>English</td>
<td>Was in high school at time of accident</td>
<td>TBI-MVA</td>
<td>N/A</td>
<td>21</td>
<td>Right frontal lobe</td>
</tr>
<tr>
<td>7</td>
<td>M</td>
<td>57</td>
<td>College</td>
<td>English</td>
<td>Electrician</td>
<td>TBI-fall</td>
<td>N/A</td>
<td>5</td>
<td>Subdural hematoma involving entire left hemisphere</td>
</tr>
<tr>
<td>8</td>
<td>M</td>
<td>48</td>
<td>High School</td>
<td>French</td>
<td>Canadian Radio Television Communication (CRTC)</td>
<td>TBI-MVA</td>
<td>N/A</td>
<td>10</td>
<td>Left hemisphere, multiple contusions &amp; hemorrhages, depressed skull, diffuse swelling</td>
</tr>
</tbody>
</table>

MVA = Motor vehicle accident  
TBI = Traumatic Brain Injury
**Table 3.2 Participant Profiles: Participants 9-15 MACT Group**

<table>
<thead>
<tr>
<th>Participant No.</th>
<th>Gender</th>
<th>Age</th>
<th>Level of Education</th>
<th>Primary Language</th>
<th>Employment at Time of Injury</th>
<th>Injury Type</th>
<th>Glasgow Coma Scale</th>
<th>Time Since Injury (years)</th>
<th>Lesion Site(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
<td>M</td>
<td>54</td>
<td>University</td>
<td>English</td>
<td>Restaurant Baker</td>
<td>TBI-Motorcycle Accident</td>
<td>3/15</td>
<td>13</td>
<td>Left &amp; right frontal lobe</td>
</tr>
<tr>
<td>10</td>
<td>M</td>
<td>30</td>
<td>High School</td>
<td>English</td>
<td>Transport Truck Driver</td>
<td>TBI-4 wheeler Accident</td>
<td>N/A</td>
<td>4</td>
<td>Left &amp; right temporal lobe</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>64</td>
<td>College</td>
<td>English</td>
<td>Owned &amp; operated Antique Shop</td>
<td>TBI-MVA</td>
<td>N/A</td>
<td>24</td>
<td>Prefrontal lobe</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>56</td>
<td>College</td>
<td>English</td>
<td>Was in college</td>
<td>TBI-MVA (x2 in 1 year)</td>
<td>15</td>
<td>2</td>
<td>Post-concussion Syndrome</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>55</td>
<td>College</td>
<td>Russian</td>
<td>Dental Hygienist</td>
<td>Stroke</td>
<td>N/A</td>
<td>7</td>
<td>Right frontal, parietal &amp; occipital regions</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>46</td>
<td>High School</td>
<td>English</td>
<td>Advertising Sales coordinator/Display Sales Representative for weekly community newspaper</td>
<td>TBI-4 Wheeler Accident</td>
<td>4/15</td>
<td>8</td>
<td>Left frontal lobe and temporal lobes, subarachnoid hemorrhage overlaying bilateral cerebral hemispheres, diffuse brain edema, suspected diffuse axonal injury,</td>
</tr>
<tr>
<td>15</td>
<td>M</td>
<td>58</td>
<td>College</td>
<td>English</td>
<td>Government Worker</td>
<td>TBI-Assault</td>
<td>2/15</td>
<td>5</td>
<td>Left occipital lobe, medial temporal lobe, hippocampus, mid-brain/central pons and right hippocampus and thalamus</td>
</tr>
</tbody>
</table>

**MVA** = Motor vehicle accident  
**TBI** = Traumatic Brain Injury
3.3 Recruitment

Participants were recruited through an adult ABI day program, Vista Centre, in Ottawa, Ontario. The facility was provided with an information letter describing the study and a Letter of Administrative Consent to obtain permission to use that facility as a recruitment site. Upon receipt of the signed Letter of Administrative Consent, a Participant Letter of Information was provided to the site which staff distributed to clients within their services who met the inclusion criteria.

Names and contact information of potential participants, those who had indicated interest in participation in the study following reading the Participant Information Letter, were provided to the primary investigator. The investigator followed up by contacting the interested individuals, further explaining the study and providing them the opportunity to ask any questions. Following this discussion, if the individual confirmed a desire to participate in the study, they were required to sign a Letter of Consent. If a legally appointed POA had been assigned to the participant, the POA’s signature was be accepted.

None of the participants were Neurologic Music Therapy clients of the primary investigator. None of the participants were currently receiving any other therapies.
3.4 Study Design

The data collection period was three consecutive weeks. Week one included the pre-testing, immediately followed by the first treatment session. Week two included the second treatment session. Week three included the third treatment session, immediately followed by post-tests. A short data collection time allowed for the study to start with a smaller dosage to identify the point of earliest possible efficacy of the treatment. This in turn could provide the logical basis for stepwise lengthening of treatment until positive responses are found. A second reason for a short data collection is to reduce participant dropout from the study.

Participants were randomly assigned to the control group or the experimental group. Randomization was achieved through an unpredictable allocation sequence with names of participants contained in sealed, opaque envelopes to maintain concealed allocation. Randomization was completed by two individuals external to the study. One individual placed each name in an individual opaque envelope and sealed it. The second individual randomized the envelopes into the two treatment groups. It was not possible to blind the participants to the treatment group they were randomized to.

3.4.a Control Group: Attention Process Training

Attention Process Training (APT): APT is a standardized non-music neuropsychological treatment for auditory attention developed by Sohlberg and
Mateer (2001). APT is a direct attention training approach based on the principles of neuroplasticity. Structured drills are designed to target specific aspects of attention with the goal of activating and stimulating these attention types and strengthening their neural circuitry (Solhberg and Mateer, APT-3 Manual p. 13).

3.4.b Experimental Group: Music Attention Control Training

Music Attention Control Training (MACT): MACT is a standardized treatment within Neurologic Music Therapy (Thaut & Gardiner, 2014). MACT provides “structured active or receptive musical exercises involving pre-composed performance or improvisation in which musical elements cue different musical responses to practice attention functions” (Thaut, 2005, p.196).

3.5 Treatment

Participants in the control group and the experiment group received three individual 45-minute attention treatment sessions held on three consecutive weeks. During the 45-minute session, 35 minutes involved active engagement in attention training exercises. The remaining time consisted of time to provide instructions for the task, to choose a musical instrument if applicable, and for feedback from the participant following each task regarding their level of effort and motivation for the task. No participant in either the control group or the experimental group had a
level of motor impairment that would impede their participation in the study.

Although the experimental group participated in a treatment that involved a live therapist during the tasks and the control group treatment was based on a video recorded therapist and computer tasks, the experimental group did not receive any additional coaching, prompting, or feedback from the live therapist. Care was taken to ensure consistency in and between both treatment groups in regards to the facilitation of the sessions and the tasks of the treatment. Consistency of treatment within groups was ensured as treatment tasks for both the MACT group and the APT group were prepared in advance of the sessions and adjustments were not made during any session to accommodate an individual’s level of cognitive impairment or difficulties during the task. Participants in both groups received further explanation or clarification of tasks as required.

3.6 Treatment Descriptions

The tasks in both the control group and the experimental group focused on sustained attention, selective attention, and executive control or flexibility. Sustained attention refers to one’s ability to sustain their attention during a continuous or repetitive task. Selective attention enables one to respond to a target while suppressing distraction. Executive control or flexibility includes components of alternating attention, the cognitive flexibility that allows an individual to shift
their attention focus between targets or tasks. Demands on working memory, holding an item in memory or manipulating information, were held to a minimum.

3.6.a Control Group Treatment: APT

Each participant in the control group participated in three 45-minute individual attention treatment sessions using the computerized-version (APT-3) of the APT program developed by Sohlberg and Mateer (2001). A computer with the APT program was prepared in a quiet room, separated from the day program area. The participant sat at the computer with the primary investigator sitting beside them to clarify instructions of task if needed and to ensure the computer mouse required for responses was always accessible to the participant.

Tasks targeting auditory sustained, selective, and cognitive control were selected from the APT task options and a computer program of these tasks was prepared. A different program was prepared for each session, with tasks progressively slightly more difficult in each session. Each participant in the control group completed identical programs.

Sustained and selective attention tasks were three minutes long. All tasks were set at a slow speed with tasks items presented at the rate of one per second. Examples of sustained attention tasks include listening for one or two targets presented in a three-minute sequence of similar items. Upon identifying targets, the participant pressed the computer mouse to register their response. Targets included alphabet
letters, numbers, animal sounds, and sound effects. Additional sustained attention tasks included listening for numbers in ascending or descending order. Selective attention tasks were similar to sustained attention tasks, but with the addition of auditory or visual distractors. For example, the participant may be listening for a target item while at the same time hearing “white noise” or seeing various geometric shapes or spirals moving randomly around the computer screen. Cognitive control or flexibility tasks required the participant to remember number or word sequences and to verbally state the number or word sequence in a different order, engaging working memory. For example, a sentence might be required to be repeated with words in reverse order. In the case of this study, the numbers or words were briefly viewed on the computer screen while the video-therapist said them, after which the visual representation of the numbers or words was removed.

Directions for each task were explained by the therapist on the screen. However, the primary investigator provided further explanation or clarification as required prior to the beginning of the task.

As part of the APT program design, following each task, the participant was asked to rate their level of effort on a Likert scale of 0-10, from “super easy” to “crazy hard”. They were also asked to rate their motivation on a Likert scale of 0-10, from “I gave up” to “I was in the zone”. Participants gave careful consideration to these scales. In rating effort required, most identified “I had to think” (Likert point 5-7) for the majority of the tasks. In rating motivation, most rated themselves as “I was pretty focused” (Likert points 5-7) for the majority of tasks.
3.6.b Experimental Group Treatment: MACT

The music-based intervention, MACT, was facilitated in the same room as the APT, separate from the day program activities at the site. The MACT tasks were facilitated by the primary investigator, an accredited music therapist, qualified as a Neurologic Music Therapy fellow. MACT tasks were designed to engage auditory sustained, selective, or cognitive control. A specific set of tasks were prepared for each of the three treatment sessions. In each consecutive session, the tasks slightly increased in level of difficulty. All participants participated in the same tasks. The identical musical target for a specific task was used for all participants.

MACT tasks were designed to resemble the non-music APT tasks as closely as possible. For example, during a sustained attention task in the APT treatment, the participant was required to listen for a specific number in a numeric sequence and the behavioural response was to press the computer mouse to response to the target. During a sustained attention task in the MACT treatment, the participant was required to listen for a target rhythm pattern embedded within an improvised melody. The target rhythm required a specific behavioural response from the participant such as, to stop playing on their own instrument and resuming play when they heard the target sounds again.

A variety of pitched and non-pitched instruments were available for use in the MACT treatment. The group of instruments was set aside so as not to create a distraction during the tasks, with three instruments appropriate for the next task set out before the participant to choose from.
Pitched percussion instruments included a xylophone, a glockenspiel, a slit drum and set of tone-blocks. Non-pitched percussion included a buffalo drum, a variety of shakers, a tambourine, and claves. The percussive instruments provided opportunity for a larger range of dynamics when required during a MACT task. The pitched instruments allowed for a range of pitch variation as required during a MACT task. Melodic instruments also provided increased opportunity for musical creativity by the participant, which in turn may also have increased attentional focus.

Both pre-composed music and improvised music were used during the treatment. Using both pre-composed and improvised music provided opportunity to use music that was familiar and that which was unfamiliar. Each of these presentations of music could potentially affect the participant in different ways. For some, a pre-composed song that was familiar became predictable and the individual felt they were able to more effectively shift their attention from it and focus on the musical target of the task. For others, the pre-composed familiar song became a distraction as they were “drawn into the song” and had to invest increased effort to focus on the musical target. Improvised music also had different effects on different individuals. For some, the unpredictability of improvised music was a distraction as they were drawn to track and try to predict the musical direction of the unfolding music. For others, the unpredictability of the improvised music made the music less of a distraction and they felt they were better able to turn their attention to the target. Thus, both forms of music were used. The same pre-composed music was used on the same tasks for each participant. Improvised music was also used for the same
tasks with each participant.

Sustained attention tasks were 3 minutes long as in the APT program used by the non-music group. Sustained attention tasks involved the primary investigator playing on one instrument and the participant playing at the same time on a second instrument, chosen from those offered. Each sustained task required the participant to listen to the researcher's playing and following as close as possible with their own playing. Examples of sustained attention tasks include the researcher playing on an instrument and the participant accompanying the researcher on a second instrument and being required to match changes in tempo, pitch, or dynamic level that the researcher introduced in their playing. The task might include tracking one change element such as match the tempo of the researcher, or may include two elements such as match the tempo changes and dynamic changes of the researcher.

A second example of a sustained attention task was the researcher improvising a song while the participant accompanies on a second instrument. The participant is required to listen for a target rhythm embedded in the improvisation at random intervals. When the participant identifies the target rhythm, they are to stop playing their instrument while the researcher continues playing. Once the researcher acknowledges, with a head nod, the ceased playing of the participant in response to the target, the participant rejoins the improvisation. In a second version, the participant was required to stop playing their instrument upon hearing the target and to listen for the target as a cue to re-enter the improvised music. A third example of a sustained attention task is accompanying the researcher's playing and switching to a pre-determined second instrument when they identify a target
rhythm or pitch. In all sustained attention tasks, the music targets were introduced at random intervals by the researcher throughout the intervention.

Selective tasks were three minutes long. As in the APT program, when the participant was required to respond to a specific target within a sequence of similar information, the information was presented in one-second intervals. For example, when the participant was required to respond to a specific chord from a presentation of various chords, the chords were presented one second apart. Selective attention tasks required the participant to focus their attention while suppressing distraction. For some tasks, the distraction was the large array of musical events within the music itself. For example, the participant listened for a specific chord of distinct harmonic characteristics from a sequence of different chords. Upon identifying the target chord, the participant was required to give a specific behavioral response, such as strike an instrument. Other selective attention tasks were similar to sustained attention tasks but with the addition of an auditory distraction external to the music. The external auditory distraction was provided by playing a recording of the researcher reading a text. To ensure distraction potential, the volume of the text-reading recording was set to match the volume of the electronic piano being played by the researcher during the task. The improvisation played by the researcher contained a musical target to listen for and respond to while simultaneously hearing the recording of the text reading.

Cognitive control or flexibility tasks engaged alternating attention and required the participant to follow and respond, on their own instrument, to the musical cues
from two different sources that alternated unpredictably throughout the task. One source of musical cue was provided live by the researcher, the second source was provided through a recording that was activated via remote control at random times throughout the task. For example, the researcher would play a rhythm pattern on the keyboard. The participant was required to match the rhythm pattern on their own instrument and play it simultaneously with the researcher. Unexpectedly, the researcher would cease playing the keyboard and at the same time the recording with a distinctly different rhythmic pattern would be played and the participant was required to now match the rhythm pattern of the recording. This task required the participant to alternate their attention between two sources of information and to respond to each. To keep the alternating requirement unpredictable, the participant was positioned so that the researcher and instrument, and the recording device, were out-of-view. In addition, the playing time of the researcher and recording were of varied lengths and alternated unpredictably.

Following each task, the participant was given two Likert Scales matching the scales used during the APT treatment group. The first scale was used by the participants to rate the level of effort required to complete the task, ranging from “super easy” to “crazy hard”. The second scale was used to measure their motivation, from “I gave up” to “I was in the zone”. For the majority of the tasks, participants indicated the level of effort required as “I had to think” (Likert Scale 4-7) and motivation was most often ranked as “pretty focused” (Likert Scale 4-7). This indicates that both the APT and MACT groups identified similar levels of effort required to complete the tasks of their treatment sessions. The mean level of effort indicated by the APT
group was 4.87. The mean level of effort indicated by the MACT group was 5.01.

### 3.7 Pre-Post Testing

On the first day of treatment, immediately prior to the attention training session, all participants received three standardized neuropsychological tests to measure attention. All tests were administered by a research assistant trained in the test administration and blinded to the participant’s group assignment. Pre-and post-tests included Trail Making Test A and B, Digit Symbol, and Brown Peterson Test.

After completion of the intervention period participants were re-tested on the same three neuropsychological tests. The results of these tests were scored by a blinded assessor for statistical analysis.

#### 3.7.a Trail Making Test

The Trail Making Test (TMT) is a measure of attention, speed, and cognitive flexibility. There are two separate tests: Trail Making A (see Appendix 1) and Trail Making B (see Appendix 2). Trail Making A requires the individual, using a pencil, to connect letters in proper order that are presented randomly on the page. Trail Making B requires the individual to alternatingly connect letters and numbers in proper order that are presented randomly on the page. Scoring is based on the time to complete the task. A practice test, a shorter version of the test, is completed prior
to each of the Trail A and Trail B tests to ensure the individual understands the test procedure.

Correlating moderately well ($r = .31-6$), Trail A and B measure slightly different functions (Heilbronner et al., 1991; Pineda & Merchan, 2003). Trail A is sensitive to attention maintenance. Due to the shifting of attention between letters and numbers, the increased required line length, and the increase of items within a 3 cm distance, Trail B places greater cognitive demands on visual search, cognitive flexibility, and motor speed (Stauss et al., 2006).

TMT is a standardized neuropsychological test (Barr, 2003, Lucas et al., 2005; Mitrushina et al., 2005; Steinberg et al., 2005; Tombaugh, 2004) that ranks as the top instrument to measure attention and fourth in use for measuring executive functioning (Rabin et al., 2005).

### 3.7.b Digit Symbol Test

The Digit Symbol test is a subtest of the Symbol Digit Modalities Test (Smith, 1991). The Digit Symbol test (see Appendix 3) has been used to test divided attention (Ponsford & Kinsella, 1992). It also requires visual scanning, perceptual speed, motor speed and memory (Laux & Lane, 1985; Lezak, 1995). The version of the Digit Symbol Test used in this study included measurement of incidental learning (Uchiyama et al., 1994).

The participant is required to check a symbol key where a symbol is identified with
a specific number and then in the following chart, insert the correct symbol to the corresponding number. The numbers in the graph are presented in non-sequential order. To measure incidental learning, a second chart, without a symbol key, containing 18 blocks in presented to the participant. They are required to fill in as many symbols as they can remember to match the corresponding numbers. Thirdly, the participant is provided a blank piece of paper on which they write any symbols they remember, regardless of associated number. The Scoring for this study was done by identifying the location on the graph at two minutes, by the number of correct symbols recalled in incidental learning, and by the number of correct symbols remember in free-recall, not associated with a number.

The Digit Symbol is a standardized neuropsychological test mostly used to assess divided attention, visual scanning, and motor speed (Bowler et al., 1992; Emmerson et al., 1990; Gilmore et al., 1983; Joy et al., 2004, Hinton-Bayre et al., 1997, 1999; Yeudall et al., 1986). An example of the Digit Symbol can be found in the appendices.

3.7.c Brown-Peterson Task

The Brown-Peterson Task (Peterson & Peterson, 1958) measures working memory, the ability to maintain information no longer available through sensory input and to maintain it during distraction. Lower performance is seen with individuals with memory, attention, or executive function deficits (Strauss et al., 2006). The version used in this study was Auditory Consonant Trigrams (Stuss et al., 1987, 1988, 1989)
In this test, the participant was required to remember three letters after various length delays doing mental math. The delays were 9, 18, and 36 seconds. Mental math was calculated aloud by the participant to serve as a distractor. Scoring is based on the number of correct letters remembered following the delay.

The Brown-Peterson Task is a standardized neuropsychological assessment mostly used to measure working memory (Bherer et al., 2001; Boone et al., 1998; Floden et al., 2000; Kopelman & Stanhope, 1997; Stuss et al., 1987).

3.8 Statistical Analysis

Attentional improvement was measured by comparing pre- and post-test results of three standardized neuropsychological attention assessment measures: Trail Making A and B, Digit Symbol, and the Brown Peterson Test. Paired-sample t-tests were used for each test to compare pre- and post-test means within each treatment group. Additionally, repeated measures ANOVA was used to analyze Trail A and B data for between group differences. For all tests, mean difference time between pre- and posttest were analyzed by two-sample t-tests. For mean time differences in Trail B an additional follow-up nonparametric Mann Whitney test was applied. Statistical analysis was performed by a professional statistician who was blinded to the participants and to the groups, using RStudio Statistical Software (Version 0.99.903).
4 Results

4.1 Trail Making A and B

The mean time in seconds was determined for the Trail A and Trail B Tests (Table 4.1). Paired-sample t-test results for Trail A Test did not reveal any statistically significant changes for either the APT group or the MACT group. However, both groups showed reduced times post-test, indicating that both treatments may have improved attention. The MACT group trended towards a lower post-test time than the APT group in Trail Test A, although this difference was not statistically significant \(p=0.10\).

Using Paired t-tests, the MACT group had a statistically significant lower post-test time in comparison to the pre-test time for Trail B Test (pre-test mean: 157.33 seconds, post-test mean: 137.17 seconds, \(p = 0.04\)). A repeated ANOVA analysis revealed marginally significant results \(p=0.051\). Results for Trail B test for the APT group revealed no significant change in pre-and post-test times. However, there was some evidence of a poorer performance by the APT group on post-test times for Trail B Test (pre-test mean 140.00 seconds, post-test mean 160.00 seconds, \(p =0.22\)).
Table 4.1 Trail A and B Pre-Post Test Times for APT and MACT: t-Tests

<table>
<thead>
<tr>
<th>Test</th>
<th>APT Group</th>
<th>MACT Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test</td>
<td>Post-test</td>
</tr>
<tr>
<td></td>
<td>mean (SD)</td>
<td>mean (SD)</td>
</tr>
<tr>
<td>Test A</td>
<td>73.88</td>
<td>55.25</td>
</tr>
<tr>
<td></td>
<td>(78.38)</td>
<td>(31.69)</td>
</tr>
<tr>
<td>Test B</td>
<td>140.00</td>
<td>160.00</td>
</tr>
<tr>
<td></td>
<td>(100.07)</td>
<td>(91.34)</td>
</tr>
</tbody>
</table>

*p<0.05 – statistically significant
SD = standard deviation
Excluded patient 15 for trail B comparisons

Table 4.2. Trail A Pre-Post Test Times for APT and MACT: ANOVA
Measure: Measure_1 Tests of Within-Subject Contrasts

<table>
<thead>
<tr>
<th>Source</th>
<th>Test</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>Linear</td>
<td>0.231</td>
<td>1</td>
<td>0.231</td>
<td>1.205</td>
<td>0.292</td>
</tr>
<tr>
<td>Test* Group</td>
<td>Linear</td>
<td>0.091</td>
<td>1</td>
<td>0.091</td>
<td>0.473</td>
<td>0.504</td>
</tr>
<tr>
<td>Error (test)</td>
<td>Linear</td>
<td>2.494</td>
<td>13</td>
<td>0.192</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 4.3 Trail B Pre-Post Test Times for APT and MACT: ANOVA
Measure: Measure_1 Tests of Within-Subject Contrasts

<table>
<thead>
<tr>
<th>Source</th>
<th>Test</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Test</td>
<td>Linear</td>
<td>0.48</td>
<td>1</td>
<td>0.048</td>
<td>.000</td>
<td>.993</td>
</tr>
<tr>
<td>Test* Group</td>
<td>Linear</td>
<td>2765.762</td>
<td>1</td>
<td>2765.762</td>
<td>4.684</td>
<td>.051</td>
</tr>
<tr>
<td>Error (test)</td>
<td>Linear</td>
<td>7085.417</td>
<td>12</td>
<td>590.451</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A two-sample t-test was used to compare the difference in mean time between the APT group and the MACT group (Table 4.3). No statistically significant differences were seen for Trail A Test (APT group mean: -18.62, MACT group mean: -6.57, \( p = .54 \)), or Trail B Test (APT group mean: 20.00, MACT group mean: -20.17, \( p = 0.05 \)). Levine’s test for equality of variance was non-significant, therefore the t-tests used the assumption of equal variance.

Table 4.4  Trail A and B Comparison of Post-test Mean Time of APT and MACT: t-Test

<table>
<thead>
<tr>
<th>Test</th>
<th>Mean (SD)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>APT Group</td>
<td>MACT Group</td>
</tr>
<tr>
<td>Test A</td>
<td>-18.62 (49.86)</td>
<td>-6.57 (9.07)</td>
</tr>
<tr>
<td>Test B</td>
<td>20.00 (42.25)</td>
<td>-20.17 (18.30)</td>
</tr>
</tbody>
</table>

*p<0.05 – statistically significant

SD = standard deviation

Excluded patient 15 and for Trail B comparisons

However, non-parametric test indicated significance for the mean time difference between pre-and post-test between APT and MACT groups (Mann Whitney, \( p = 0.029 \)). (Table 4.4)
While repeated measures ANOVA did not support significance findings from individual t-tests for Trail B, the close values for ANOVA ($p = 0.051$) and the t-test for time difference between pre-and post-test between groups (parametric $p = 0.05$, non-parametric $p = 0.029$) may suggest partial evidence or a trend towards specific benefits of the MACT intervention over APT. Therefore Null Hypothesis 1 has to be accepted whereas Null Hypothesis 2 can be partially rejected.
4.1.a. Individual participant data

Inspection of individual participant data scores for pre- versus posttest show a higher consistency in posttest improvements for MACT. After MACT 5 participants improved while one decreased performance. In the APT a much higher degree of variability was present. One participant improved, two stayed the same, and five decreased to various degrees.
Figure 4.2. APT Trail B Pre-Post Test Times (in seconds)

Figure 4.3. MACT Trail B Pre-Post Test Times (in seconds)
4.1.b. **Comparison of study participants and normative data**

The pre-and post-times are compared with results of normal or neurologically stable adults (Dikmen et al., 1999) in Table 4.5. This comparison reveals that the study participants required almost double the time of norms to complete the tasks.

**Table 4.6  Trail A and B: Comparison of Study Participants Results with Normative Data**

<table>
<thead>
<tr>
<th>TEST</th>
<th>APT Group</th>
<th>MACT GROUP</th>
<th>Normative Data</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test mean (SD)</td>
<td>Post-test mean (SD)</td>
<td>Pre-test mean (SD)</td>
</tr>
<tr>
<td>Trail A</td>
<td>73.88 (78.38)</td>
<td>55.25 (31.69)</td>
<td>52.86 (26.84)</td>
</tr>
<tr>
<td>Trail B</td>
<td>140.00 (100.07)</td>
<td>160.00 (91.34)</td>
<td>157.33 (75.33)</td>
</tr>
</tbody>
</table>

4.2 **Digit Symbol**

A paired t-test was used to compare pre-test and post-test mean times in seconds (Table 4.6). No statistically significant differences were noted comparing pre- and post- test results of the Digit Symbol Test, Incidental Learning, or Free Recall for either the APT group or the MACT Group. Examination of the results did not reveal a consistent trend in either group.
Table 4.7  Digit Symbol: APT and MACT Pre-Post Test Results

<table>
<thead>
<tr>
<th>Test</th>
<th>APT Group</th>
<th>MACT Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre-test mean (SD)</td>
<td>Post-test mean (SD)</td>
</tr>
<tr>
<td>Digit Symbol Time</td>
<td>286.25 (187.68)</td>
<td>285.38 (163.12)</td>
</tr>
<tr>
<td>Digit Symbol Location 2 mins</td>
<td>65.50 (14.61)</td>
<td>65.38 (13.90)</td>
</tr>
<tr>
<td>Incidental Learning</td>
<td>2.88 (3.48)</td>
<td>3.00 (3.30)</td>
</tr>
<tr>
<td>Free Recall</td>
<td>4.38 (2.50)</td>
<td>4.88 (3.14)</td>
</tr>
</tbody>
</table>

*p<0.05 – statistically significant

Excluded patient 15 for all comparisons

A two-sample t-test was used to compare the mean results of the APT group and the MACT group (Table 4.7). No significant differences in means were found between the groups for all of the tests.
Table 4.8  Digit Symbol: Comparison of Post-test mean for APT and MACT

<table>
<thead>
<tr>
<th>Test</th>
<th>APT Group</th>
<th>MACT Group</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit Symbol Time</td>
<td>-0.88 (64.75)</td>
<td>3.00 (21.48)</td>
<td>0.89</td>
</tr>
<tr>
<td>Digit Symbol Location at 2 mins</td>
<td>-0.13 (8.58)</td>
<td>2.33 (5.43)</td>
<td>0.55</td>
</tr>
<tr>
<td>Incidental Learning</td>
<td>0.13 (1.46)</td>
<td>0.67 (1.51)</td>
<td>0.51</td>
</tr>
<tr>
<td>Free Recall</td>
<td>0.50 (1.60)</td>
<td>1.00 (1.41)</td>
<td>0.56</td>
</tr>
</tbody>
</table>

*p<0.05 – statistically significant

Excluded patient 15 for all comparisons

4.2.a Comparison of study participants and normative data

The Digit Span is a subtest of Symbol Digit Modalities Test (SDMT). Table 4.8 compares the results of study participants with SDMT norms (Uchiyama et al., 1994) for men which includes high education and low/high IQ, aged 40-49 and greater than age 50. Comparisons with normative data reveal that study participants required four times longer to complete the task indicating the level of cognitive impairment and difficulty to complete this task.

Table 4.9  Digit Symbol: Comparison of Study Participants’ Results with Normative Data

<table>
<thead>
<tr>
<th>Test</th>
<th>APT Pre-test</th>
<th>MACT Pre-test</th>
<th>Norms age 40-49</th>
<th>Norms age &gt;50</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit Span</td>
<td>286.24 (187.68)</td>
<td>213.33 (41.62)</td>
<td>52.96 (9.26)</td>
<td>50.14 (8.18)</td>
</tr>
<tr>
<td>Incidental Learning</td>
<td>2.88 (3.48)</td>
<td>3.33 (2.34)</td>
<td>5.53 (2.47)</td>
<td>4.86 (2.42)</td>
</tr>
</tbody>
</table>
4.3 Brown-Peterson Task

A paired t-test was used to compare pre-test and post-test mean for each delay set for the APT group and the MACT group. No statistically significant results were seen for the APT group or the MACT group in total correct item recall (Table 4.9).

Table 4.10 Brown-Peterson: Pre-post-Test Results of APT and MACT

<table>
<thead>
<tr>
<th>Test: Brown-Peterson</th>
<th>APT Group</th>
<th>MACT Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td>Total Correct</td>
<td>29.00</td>
<td>30.38</td>
</tr>
<tr>
<td></td>
<td>(15.67)</td>
<td>(18.38)</td>
</tr>
</tbody>
</table>

*p<0.05 – statistically significant

Excluded patient 15 for all comparisons except 0 delay

A two-sample t-test was used to compare the mean difference between the two groups (Table 4.10). There was no evidence that the music group or non-music group varied in terms of mean differences. While not statistically significant (p=0.50), the MACT group showed an overall higher total number of recall from pre-test to post-test (mean: 4.00) in comparison to the APT group (mean: 1.38).
Table 4.11 Brown-Peterson: Comparison of Post-test Mean of APT and MACT

<table>
<thead>
<tr>
<th>Test: Brown-Peterson</th>
<th>Mean (SD)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>APT Group</td>
<td>MACT Group</td>
</tr>
<tr>
<td>Total Correct</td>
<td>1.38 (5.15)</td>
<td>4.00 (8.83)</td>
</tr>
</tbody>
</table>

*p<0.05 – statistically significant
Excluded patient 15 for all comparisons except 0 delay

4.3.a Comparison of study participants with normative data
Table 4.11 compares the study participants’ results with normative data indicating that as the delay interval increased, participant’s performance was at approximately 50% of norms.

Table 4.12 Brown-Peterson: Comparison of Study Participants’ Results with Normative Data

<table>
<thead>
<tr>
<th>Test: Brown-Peterson Task (Pre-test results)</th>
<th>APT Group</th>
<th>MACT Group</th>
<th>Norms Age 30-49</th>
<th>Norms Age 50-69</th>
</tr>
</thead>
<tbody>
<tr>
<td>9- second delay</td>
<td>8.13 (4.76)</td>
<td>4.67 (4.08)</td>
<td>12.0 (2.5)</td>
<td>11.5 (2.3)</td>
</tr>
<tr>
<td>18-second delay</td>
<td>4.00 (4.41)</td>
<td>5.50 (3.73)</td>
<td>10.5 (3.1)</td>
<td>10.2 (2.5)</td>
</tr>
<tr>
<td>36-second delay</td>
<td>4.63 (3.93)</td>
<td>3.33 (2.25)</td>
<td>9.9 (3.0)</td>
<td>8.7 (2.9)</td>
</tr>
</tbody>
</table>
Chapter 5
Discussion

5 Discussion

5.1. Primary Goal: Can music-based cognitive rehabilitation interventions be effective for remediation of cognitive impairment following an acquired brain injury?

To investigate this research question, pre-and post-test results within and between a non-music based (APT) and a music-based (MACT) cognitive rehabilitation treatment were compared. In summary, no significant differences between the two interventions were found on Trail A Test, Digit Symbol, or the Brown-Peterson Task. T-test results for Trail B Test revealed a statistically significant lower post-test time for the MACT group \((p = 0.04)\) when using a paired t-test while results for the APT Group on the same test revealed no significant change \((p = 0.22)\) although a poorer performance was observed on post-test time. However, a repeated measures ANOVA for Group x Time did not support significance for Trail B Test \((p = 0.051)\). Two sample t-tests for comparison of mean time difference pre- vs post-test between APT and MACT showed no significance \((p=0.05)\) but a follow-up nonparametric Mann Whitney test showed significance in favor of MACT over APT \((p = 0.29)\). The close values for ANOVA and the two-sample t-test and significance in the nonparametric analysis may suggest partial evidence or a potential trend for the benefit of MACT intervention. While statistical analysis indicated no evidence for differences between APT and MACT, further evaluations of the data and clinical and
theoretical considerations of the results will be discussed in the following, including demographic comparisons between the group and impact of the treatment conditions on specific brain lesions diagnostics.

5.1.a Trail Making Tests

Trail A Test revealed no significant change in pre- and post- test times for either the APT or the MACT groups. On Trail B Test, although not statistically significant, the MACT had lower post- test times (pre-test mean: 157.33 seconds, post-test mean: 137.17 seconds, \( p = 0.04 \)). This is in contrast to the APT group which performed more poorly on post-tests (pre-test mean: 140.00 seconds, post-test mean: 143.00 seconds, \( p = .91 \)). Within the APT group 5 participants performed worse, 2 participants remained the same, and only 1 participant improved on the post-test. However, in the MACT group 1 participant performed worse and 5 improved. The results of the APT group reveal the typical fluctuations and inconsistency in ABI performance (Figure 4.1) while the MACT results indicate that the MACT treatment induced more stability in performance across subjects (Figure 4.2).

It is noteworthy that the MACT group improved their performance on Trail B. While both Trail A and B Tests measure attention, speed, and mental flexibility, Trail B places more cognitive demands on the individual and reflects executive control due to the shifting of attention between letters and numbers and the increased visual interference due to an increase of items in 3-cm space from 11 to 28 (Strauss et al., 2006). Thus, in addition to attention, Trail B has been used to measure
cognitive flexibility or executive functioning. The improved performance of MACT group on Trail B Test indicates improvement on the task that placed demands on both sustained attention and executive functioning.

The APT group’s increase in time on Trail B post-test in contrast to the MACT group’s decrease in Trail B post-test time was an unexpected result. This increase in time for the APT Group may be a result of cognitive fatigue following the treatment session which become more evident on the Trail B due to the increased level of cognitive demands for that task. The question then becomes, why did the MACT group not also increase their time due to cognitive fatigue following a treatment session or at the least, simply maintain their pre-test mean? One possible explanation may be that because the MACT tasks included targets of rhythm, melody, and harmony, the MACT group experienced an increased attentional engagement during treatment. Each of these musical components engage different brain sites: melody (memory of) engages the left inferior temporal and frontal areas, rhythm engages the left temporal lobe and the basal ganglia, and harmony engages the inferior frontal areas (frontal operculum) bilaterally (see Table 2.1). As a result, the MACT group may have received a neutrally more distributed attentional stimulus. This may have aroused and engaged attentional processing to a degree that the MACT group was able to sustain their attention and process the Trail B task more effectively and efficiently. In addition to enhanced sustained attention, the increased distribution of attentional engagement during the MACT session may have contributed to the improvements noted on the measures that included executive
functioning: Trail B and the Brown-Peterson Task. However, the Brown-Peterson Task improvement was not statistically significant as noted.

In addition to the wide distribution of attentional stimulus of the music used MACT interventions, another consideration for the effectiveness of MACT is the role of rhythm. Due to the nature of music, the majority of the MACT tasks included the component of rhythm, even if melody or harmony was the response target. Therefore, the neurological responses to rhythm may have served to engage the alerting and attentional processes in an on-going manner due to the constantly changing rhythmic aspects of the music throughout the treatment session, potentially leading to a stronger sustained attentional engagement. This stronger attentional arousal throughout each treatment session may have served to support the maintenance of effortful processing, resulting in increased cognitive control. An increase in cognitive control would be reflected in measures that included executive functioning such as Trail B Test. Another possible impact of rhythm on attention, as described earlier, is that the rhythmic patterns may drive attention by “interacting with attention oscillations via coupling mechanisms” (Thaut, 2005, p. 74).

Trail A Test did not reveal any statistically significant changes for either the APT group or the MACT group. However, both groups had reduced times posts tests. Within the APT group, 4 participants increased their post-test time while 4 decreased their post-test time. Within the MACT group, 1 participant increased their post-test time, 2 remained the same, and 4 participants decreased their time.
Although not statistically significant \((p = 0.10)\), the MACT trended towards a lower post-test time.

Since further examination of the Trail B test suggests benefit for MACT treatment for attentional processing, one might question why Trail A test results did not also reveal a stronger difference between APT and MACT post-test times. One explanation could be that upon further examination of the data, an outlier was noted in the APT group. Participant 4 made an inexplicable marked decrease in time (pre-test: 227 seconds, post-test: 111 seconds). This large decrease in time may have skewed the data results for the APT group. A second explanation might be that, although statistically insignificant, both groups had a lower post-test time suggesting the benefit of both APT and MACT treatments. However, on Trail B test, with the inclusion of executive functioning and cognitive flexibility demands, the distinction of the benefit of MACT on attentional processing may have become more observable.

Because the MACT group improved performance on Trail B while the APT performed more poorly, it is necessary to examine the randomization process to determine if one group was distinctly different at any level from the other. Important contributors to pre-post-test results can be: severity of ABI, lesion site(s), and time since injury. Although the ABI clinical population in inherently heterogenic, the experimental group and the control group in this study were reasonably equal. All participants had an ABI rated as moderate or severe. While the
lesion site(s) varied within each group as is typical in ABI, there was some consistency between the groups in that the APT group had 3 individuals with PFC injury while the MACT had 4 individuals with PFC injury. Time-since-injury was also comparable. The mean time-since-injury for the APT group was 11.5 years while the mean time-since-injury for the MACT group was 9.5 years. All participants were in the post-acute stage of their injury, thus it is reasonable to expect that no individual gave their group a particular advantage due to their stage of recovery. For both groups, the most common self-assessment following each task was “I had to think”, indicating that both groups found the tasks equally challenging. Although participants were placed in the experimental or control group through random assignment and the ABI clinical population has unavoidable heterogeneity, the profile of the two groups in this study was reasonably similar so that one group did not appear to have a significant advantage or disadvantage over the other (Figure 5.1).
5.1. b Digit Symbol Test

The Digit Symbol Test has been used as a test of divided attention (Ponsford & Kinsella, 1992). A two sample –test found no significant difference between the groups on any components of the Digit Symbol Tests suggesting that neither the Attention Training Program nor the Music Attention Control Training had impact on divided attention. There are two possible contributing factors to this lack of change for either group: the level of difficulty of this task for the participants due to their level of cognitive impairment and the memory component of the test.
Feedback from several participants in both the APT Group and the MACT Group following treatment tasks targeting divided attention indicated that this area of attention was particularly challenging. Comparison of study participants and norms (Table 4.6) test times revealed that the study participants required four times more time to complete the Digit Symbol test. With this level of cognitive impairment, a longer treatment period might be needed in order to see in change in post-test results. A future study with a longer data collection time may gain different results on the Digit Symbol test. The nonsignificant results are also in line with findings by Thaut et al. (2009) suggesting that longer intervention dosages may be necessary.

Another important consideration is that the Digit Symbol Test includes a significant memory component. APT and MACT tasks in this study did not address memory and this would have contributed to the lack of results on this measure.

5.1.c Brown-Peterson Task

The Brown-Peterson Task (Auditory Consonant Trigram) is used as a measure for working memory, and also addresses attention, divided attention, and executive functioning. A two-sample t-test was used to compare the mean difference between the two groups (Table 4.8). There was no evidence that the APT or MACT group varied in terms of mean differences. Although the Brown-Peterson Task is used to measure attention, it is also used to measure working memory, the major component of this test. Working memory tasks were used for a small percentage of
time (12%) in both the APT and MACT treatments and this may have contributed to the lack of significant results on this measure.

A second consideration regarding the overall lack of results is the difference between the Brown-Peterson Task and the attention training tasks of the APT and MACT treatments in regards to the cognitive load of the distraction used. The distraction during the Brown-Peterson task is the requirement to audibly do mental math calculations during the delay interval. The extra cognitive demands of the mental math calculations during testing may have resulted in an increased cognitive load in comparison to the treatment tasks, resulting in no overall improvements in either groups post-test.

In comparing pre-and post-tests, the MACT group (mean of 4 more letters) had a higher total recall of correct letters in the post-test than the APT group (mean of 1 more letter). While not statistically significantly different, these results may be clinically relevant due to the trend of the MACT group towards improvement.

5.1.d Other considerations

Standardized neuropsychological tests used as post-tests to measure changes in attention after three weeks of treatment did not capture the improvements observed over the three sessions. Individuals in both the APT and MACT group demonstrated improvement on different tasks within treatment. For example, in session one Participant No. 11 (MACT) could not complete the alternating attention
task and ended the task pre-maturely. In the second session, he was able to complete one of the two alternating attention tasks. He did not attempt the second alternating attention task due to difficulty. However, in the third session, he successfully completed both alternating attention tasks and stated “it is getting easier”. In session one, Participant No. 15 (MACT) did not complete either the alternating attention tasks, withdrawing after a few moments for the first task. In session two he stopped at two minutes, stating “this is not relating” and did not attempt the second task. However, in session three he successfully completed both alternating attention tasks with a good performance on each. Any possible improvement of Participant 15’s performance could not be captured in post-testing as he refused to complete post-tests shortly after post-testing began. Although the tasks varied slightly, and gradually increased in level of difficulty over the three treatment sessions, Participant No.’s 10, 11, 13, 14 (MACT) all spontaneously stated during session 3 that “it is getting easier”. Participants in the APT group also demonstrated improvement on some tasks during the course of treatment. Because these observations were not part of a formal assessment, for both groups, it might be challenging to differentiate between improvement in cognitive functioning and improvement in self-confidence. Because the tasks varied and slightly increased in difficulty over the three treatment sessions, it is reasonable to expect that the improvements observed were not only task specific improvements due to practice. Although these observations do not affect the results of this study, they do suggest that future studies with a longer data collection period may show an accumulative benefit of treatment and stronger study results.
5.2  MACT is Grounded in Theories of Attention

Attention is foundational to other cognitive functions and therefore should be a primary focus in cognitive rehabilitation following ABI. The theories of attention can guide the development and implementation of cognitive rehabilitation interventions. It is important that cognitive rehabilitation interventions be grounded in theories of attention to ensure the most informed and effective strategies for rehabilitation. In investigating the effectiveness of MACT to address cognitive impairment, one must examine MACT in light of theories of attention. Using the unique stimuli of musical elements to arouse and engage attention, MACT interventions are grounded in the science of theories of attention and are designed to specifically target various components of attention for cognitive rehabilitation. MACT tasks are goal directed and engage the PFC through top-down, effortful processing which can led to an increase in cognitive control and improved attention, memory, and executive function.

5.2.a MACT and attentional networks

Literature describes attention as a multidimensional construct with various contributing components and types. Peterson and Posner’s (2012) theory of attention describes three networks: alerting (task maintenance), orienting (prioritizes sensory input), and executive (target selection). Similarly, Mesulam (2010) describes the various components of attention as the “attentional matrix” which includes target selection, vigilance, attention span, and resistance to distraction. Sohlberg and Mateer (2001) describe attention in terms of different
forms of attention: focused, sustained, selective, and divided. Depending on lesion site and other factors, an individual may demonstrate more impairment in one area of attention than another. Peterson and Posner (2012) and Sohlberg and Mateer (2001) highlight that experience can influence attention networks and state that targeting deficit in specific attention networks or types during treatment can aid in rehabilitating that specific area of impairment and the functional difficulties.

In the literature, the various aspects of attention are often divided, however it is important to acknowledge the functional interconnectedness of attention networks. Cohen (1993), Mesulam (2010), and Schmitter-Edgecombe (1996) highlight the interconnectedness of the various components of attentional processing. This interconnectedness is also acknowledged by Baddeley (2009) who states that working memory tasks involve all aspects of attention theories including concentration, vigilance, and resistance to inference. Baddeley (2012) suggests that attentional tasks that engage focused attention or divided attention place demands on the central executive, the proposed controller of working memory. In cognitive rehabilitation treatment, in addition to targeting specific attention types, tasks that involve working memory should also be included due to the engagement of various underlying attentional processes. There is evidence for the effectiveness of interventions that engage working memory to remediate attention difficulties in patients (Cicerone, 2002).
MACT tasks were carefully designed to engage the various attentional networks proposed in Peterson and Posner’s attentional theory and Mesulam’s attentional matrix ensuring that MACT tasks are addressing the underlying mechanisms of attention. In addition, focused and divided attention types were specifically targeted in the MACT tasks, which according to Baddeley (2012), would also support the engagement of working memory, thereby engaging various components of attention and cognitive control. The specific targeting of attention components during MACT tasks enables MACT to drive attentional processing and increase the opportunity for a neuroplastic response and improved attentional functioning.

MACT tasks targeted specific components of attention and were goal directed demonstrating that MACT interventions are grounded in attention theories and informed by science. In addition to this informed development of MACT interventions, the fact that they are music-based interventions further strengthens the use of MACT for cognitive rehabilitation as the various components of music provide a range of stimuli type and brain recruitment sites which may be especially important when attempting to engage attentional processing in an injured brain.

5.2.b **MACT and attentional control**

In addition to engaging attentional networks, cognitive rehabilitation should also seek to increase cognitive control. The lack of cognitive control is evident in a deficit in goal-directed behavior and rates among the highest complaints of this (ABI) patient group (Dockree, 2004). This complaint was reflected in feedback from the
study participants who self-identified the effort required to sustain their attention on a task. During the first treatment session, Participant No. 11 explained that he gets “distracted by thoughts in his head”. While observing that the researcher had auditory distractions recorded on a device for use during one of the MACT tasks, Participant No. 13 commented “you carry distractions around on your device, I carry them around in my head”. During the second treatment session, APT participant No. 2 stated “now that I know my mind is wandering, I am trying harder to focus”. Interestingly, during the first MACT treatment session, Participant No. 11 stated “my mind starts to wander, but the music keeps pulling me back”, highlighting the attentional engagement of the music components. An increase in cognitive control should be a goal of attention training.

Effortful processing, in contrast to automatic processing, serves to increase cognitive control. Participants in both the APT and MACT group indicated that the treatment tasks required effortful processing by, the majority of the time, rating their effort required as “I needed to think” on the effort scale following each task. Thus, it is confirmed that MACT interventions did place demands of cognitive control. To drive the process of effortful processing, tasks should require top-down responses. MACT tasks, with the varied presentations of stimuli, provided a range of targets to attend to and required goal-directed behavior in response. The varied presentations and complexities of musical elements of melody, rhythm, and harmony used as stimuli may make music-based attention tasks uniquely effective in driving attentional processing and increasing cognitive control of the injured
brain. Because of the variation in presentation, the interventions allow for improved attentional processing and reduce the risk of simply improving on a task-related skill.

MACT tasks are goal directed and stimulus driven, engaging attention as described by Corbetta and Shulman (2002), providing a clear perceptual input and placing demands on attentional resources over a period of time and to respond to the target with a specific behavior. The goal-directed nature of MACT tasks engage the PFC and drive top-down processing which can serve to increase cognitive control, a significant contributor to improved attention and cognitive functioning. The results of the Trail B test which is regarded as a valid measure of executive function may indicate a positive trend towards increased cognitive control.

Further examination of the data revealed that three of the four most improved MACT results on Trail B were from participants who had experienced a prefrontal cortex injury. The fourth MACT participant with a PFC injury also improved, but to a lesser degree. The improvement of MACT participants who had experienced PFC injury is significant as a primary goal of cognitive rehabilitation is to use interventions that will engage the PFC, increasing cognitive control and improving attention. The importance of re-integration of PFC networks following ABI is highlighted by Chen et al. (2006) who states this should be a primary consideration in cognitive rehabilitation. The improvement of performance of participants with a PFC injury is particularly important, providing evidence that MACT successfully
engaged the PFC and that, although not statistically significant, benefit was observed following treatment. PFC injury results in a tendency to drift from intended goals (Dockree et al. 2004) and impacts the ability to complete goal-directed behavior. Baddeley (2012) states that functions of the central controller enables one to focus attention and to switch attention or divide attention between two tasks. Dosenbach et al. (2008) also state that executive control involves two networks, maintenance of attention and switching of attention. The above literature supports the results of MACT group on Trail B suggesting that MACT treatment targeted the PFC, improved attentional processing and cognitive control, and was evidenced on a measure of executive function or cognitive flexibility while the results of the APT group may suggest a lack of attentional control on this measure. The APT group also included three individuals with PFC injures with similar time- since- injury (APT: 7, 9, 21 years; MACT 7, 8, 24 years). Both the APT and MACT group included individuals with PFC injury, similar severity levels, and similar time-since-injury. However, only the individuals in the MACT group demonstrated benefit from treatment (Figure 5.2).
5.2.c *MACT and executive functioning*

Executive functioning is involved in planning, monitoring, activating, switching, and inhibition (Cicerone et al., 2006) and is mediated by working memory (Miller & Cohen, 2001). Haskins (2012) describes executive functioning as “integrative cognitive processes that determine goal-directed and purposeful behavior”, such as make plans or solve problems, and that executive functions are “superordinate to more basic cognitive processes such as memory and attention”. Cicerone et al. (2006) state that mechanisms of attention, including sustained attention, inhibition of irrelevant information, and monitoring information fall
within the scope of executive functioning. With repeated practice, motor or sensory
tasks result in expanded cortical representations. However, with repeated practice
on higher cognitive tasks, there is an increase in efficiency of the underlying
networks supporting the tasks and changes within the connectivity between them
(Kelly et al., 2006). Because attention is an underlying cognitive process to executive
function, improvement in attentional mechanisms may lead to improvement in
executive functioning. MACT participants’ trend of improvement on Trail B Test,
which ranks fourth as an instrument used to measure executive functioning (Stauss
et al., 2006), demonstrates the attentional engagement of MACT tasks, which in turn
resulted in improvements on an executive functioning measure. These results are
supported by Thaut and et al. (2009) who also found improved executive
functioning following Neurologic Music Therapy sessions specifically targeting
executive functioning training. Other studies have also demonstrated gains in
executive functioning that were also reflected in attentional areas (Klingberg, 2011;
Rueda et al., 2005). Cicerone et al. (2006) highlight that “only a small number of
studies have examined the efficacy of rehabilitation interventions that target
specific aspects of executive functioning”. Thaut et al. (2009) is the only study to
specifically investigate the benefit of music-based interventions on executive
functioning. Thaut et al. (2009) and this current study provide promising
preliminary results regarding the efficacy of music-based interventions to improve
executive functioning in the injured brain.
While the MACT group showed gains in attention, demonstrated by improvement on the Trail B test, neither group showed gains on the Digit Symbol Test which also measures divided attention. This may be due to the fact that the Digit Symbol also included the aspect of memory which may have contributed to increased difficulty and a lack of improvement on the post-test. Comparison to norms, the participants required four times longer to complete the test, reflecting the level of difficulty. This may also be a contributing factor to the lack of consistency by either participant group in the pre- and post-test results. A longer treatment period may show different results.

In the current study, gains seen in executive functioning on the Trail B Test may reflect the effectiveness of MACT in targeting the attentional networks underlying executive functioning. Future studies might further investigate the effectiveness of MACT specifically on executive functioning.

5.3 Limitations of this study

There are several limitations to this study that should be noted when considering the generalizability of the results:

1. **Sample-size.** This study had 15 participants. A larger sample size is needed to increase statistical power or the results and to provide a more precise estimate of the benefit of music-based cognitive rehabilitation interventions.

2. **Time-line.** This study collected data through pre- and post-testing over a 3-week period to investigate the effect of repeated treatment over a short
period. This allowed for identification of a time point of earliest possible
efficacy of treatment, providing the logical basis for stepwise lengthening of
treatment until positive responses are found. In addition, a three-week
separation of the pre- and post-tests was intended to reduce a practice effect
on post-tests and also helped to reduce participant drop-out as longer study
periods often lead to severe attrition of subjects in clinical studies.

Although, this study's design used a three-week data collection period
for the reasons outlined above, this time period may have been too short to
gain significant results due to the severity of brain injury and cognitive
impairment of the participants. A longer data collection period could allow
for observation of an accumulative effect of APT or MACT treatment on
attentional arousal and engagement and may provide different results.

3. **Individual cognitive deficit.** The inclusion criteria for the study participants
included having a cognitive impairment following an ABI rated as moderate
or severe. However, specific forms of attention deficit were not identified in
the inclusion criteria. The individuality of the attention deficits and the
degree of deficit in the various attention types of the participants may have
impacted the results.

4. **The role of cognitive fatigue.** Most participants commented on the effort
required to complete the MACT and APT tasks. This is to be expected due to
the identified cognitive impairment. However, cognitive fatigue was not
factored into results.
5. **Heterogeneity of participants.** Due to the complexity and diversity of brain injury, there is an avoidable heterogeneity of participants in a study involving the ABI clinical population.

   The heterogeneity of the sample group for this study included factors that could be potential confounds. These include the range of time-since-injury, the age span of the participants, and the diversity of lesion sites.

5.4 **Secondary Goal: To Contribute to the Literature of Music-based Cognitive Rehabilitation**

The second purpose of this study was to contribute to the body of literature of music-based interventions in cognitive rehabilitation and to link science to the rationale for, and design of, music-based cognitive rehabilitation.

There is strong literature support for the use of music-based interventions for the rehabilitation of motor (Altenmuller, E.G., et al. 2009; de Dreu, M.J. et al., 2012; Hurt Thaut et al., 1997, 2010; Thaut et al., 1997; Thaut et al., 2007) and speech impairments (Schlaug E.G. et al. 2009; Wilson, 2006; Zipse et al., 2012) following ABI. Although the music cognition literature supports the hypothesis of music-based cognitive rehabilitation, there is sparse literature providing evidence for its efficacy. In particular, there are very few randomized control trials.
Brant et al. (2010) completed a systematic review regarding the use of music therapy as a rehabilitation tool following ABI. This review concluded that the Neurologic Music Therapy intervention, Rhythmic Auditory Stimulus (RAS), may be beneficial for improving gait regulation for individuals following stroke. Brant et al. (2010) stated that more research was needed to determine the effects of music therapy on other rehabilitation goal areas. This review did not provide any evidence for music-based cognitive rehabilitation.

Magee et al. (2017) completed an updated systematic review regarding the efficacy of music-based rehabilitation following ABI. This updated review added 22 new studies and identified only two studies investigating music therapy for cognitive goals of attention and memory, as well as emotional needs (Sarkamo, 2008; Pool, 2012). Magee et al. (2017) concluded that there was evidence for the efficacy of music interventions for gait, timing of upper extremity function, communication, and quality of life goals following stroke. They stated the need for more high quality RCTs for all ABI rehabilitation goal areas before clinical recommendations could be made.

An additional search of literature regarding music therapy and cognitive rehabilitation produced four further studies since 2010 (Bower et al., 2014; Gardiner et al., 2015; Pfeiffer et al., 2015; Sarkamo & Soto, 2012). Early studies completed by Wit et al. (1994) and Knox & Jutai (1999) remain as some of the few studies exclusively investigating music's influence on attention.
This study can contribute to a gap in the literature regarding the use of music-based interventions for cognitive rehabilitation through the results found. In addition, this study provides discussion of relevant literature in support of music-based cognition. This study also highlights the efficacy specifically of MACT, a standardized Neurologic Music Therapy intervention. Although the literature regarding music therapy and cognitive rehabilitation is limited, the literature specifically investigating the influence on attention is even more sparse. This is a significant gap in the literature because of attention’s foundational role in cognitive functioning. In order to explore the question of music in cognitive rehabilitation, it is imperative to explore the question of music in the rehabilitation of attention. A contributing factor to this gap may be the complexity of attention itself and the interconnectedness of the various components of attention. Another challenge is the heterogeneity of the ABI population and the scope of cognitive deficits.

This paper investigated the influence of music on attention, both through a discussion of supporting literature and through the research project. Further research is needed, larger samples and longer data collection periods with more statistical power, to better support the hypothesis of music-based cognitive rehabilitation.
5.5 Clinical Applications

5.5.a Effectiveness of MACT

MACT is grounded in the theories of attention. This study’s results provided partial evidence at least of a trend for the efficacy of MACT to arouse and engage attention. In particular, successful attentional engagement was shown on measures that included executive functioning (Trail B). In all other measures both APT and MACT produced similar results in attention training. There is a need for further research evidence, however clinicians can be confident that MACT is a valid and effective treatment tool for targeting attention deficit.

5.5.b Recommendations for clinicians

In implementing MACT in clinical settings, the following recommendations are made: the clinician should have an understanding of attention and be informed of various attention types and deficits, develop their treatment according to APT guidelines of hierarchy in order to ensure on-going benefit, and use a broad range of music types in their treatment, ensuring the inclusion of both improvised and familiar music. It is imperative that the neurologic music therapist keeps in mind that the goal of MACT is to drive attentional processing with the goal of remediation.

1. Understanding of attention

It is important for Neurologic Music Therapists to have a clear understanding of the various types of attention and to have a basic understanding of attention’s contribution to executive functioning and memory in order to make informed
clinical decisions regarding assessment, the establishment of goals, and the design and implementation of the MACT tasks for the cognitive rehabilitation of their clients. Having an understanding of attention will prevent the neurologic music therapist from creating cognitive goals that are too general and as a result, less effective, as they may not target the specific deficit and needs of the client.

2. Hierarchy of difficulty

Neurologic Music Therapists should be careful to follow a hierarchy of difficulty, following the APT protocol, to ensure an on-going attentional arousal throughout the course of treatment by continuing to make demands on effortful processing and to support the potential for an increase in attentional control. Due to the variety of possible presentations within music and its components, neurologic music therapists have a unique and broad range of resources to use in their clinical work in cognitive rehabilitation. Within such a broad range of resources, the neurologic music therapist must take care to thoughtfully sequence treatment so that early treatment tasks are designed to be at a level of difficulty appropriate to the client’s level of ability during the initial assessment period. Over the course of treatment, as improvement is noted with consistency, the neurologic music therapist should modify the tasks accordingly, gradually increasing the level of difficulty. This gradual increase in task difficulty will ensure on-going cognitive engagement and effortful processing in target areas and as a result, support potential cognitive gains from treatment and the transfer of these gains to non-musical contexts. Effortful processing is necessary for increased cognitive control, a foundational component of cognitive rehabilitation.
In addition to carefully following a hierarchy of task difficulty during treatment, it is also important that the neurologic music therapist follow MACT protocol while incorporating a variety of musical targets or cues in the MACT tasks. For example, when working on sustained attention, one task might use a rhythmic pattern as a cue, while another sustained attention task might use a change in pitch as a cue. Music provides a rich variety of potential cues for the neurologic music therapist to draw upon. It is important that the neurologic music therapist uses this variety of cues when designing their treatment in order to avoid a task-specific improvement, that is, the client developed their skill of rhythm discrimination rather than experiencing a range of attentional tasks that drive overall attention processing.

3. Use of improvised and pre-composed music

Neurologic music therapists should include a balance of familiar and improvised music as each place unique demands of the clients’ attentional processing. Depending on the individual, familiar music may “draw them into the music” distracting them from the treatment task or in contrast, may be familiar and therefore easy to ignore. Improvised music may be novel and “attention-grabbing” or unfamiliar and disregarded. Using a variety of target types, melody, rhythm, and harmony, embedded in both familiar or improvised music extends the intervention options available to the therapist and can contribute to the development of an individualized hierarchy of task difficulty for the client as required for on-going effortful cognitive processing and cognitive benefit.
4. Length of session

When doing clinical work with individuals who are living with the effects of cognitive impairment, it is important to carefully consider the length of the treatment session and the pacing of the interventions. Although frequency and intensity of treatment are important factors for rehabilitation, the clinician must remember that cognitive fatigue is common for the individual with cognitive impairment. The clinician may need to consider shorter sessions initially and plan rest breaks during treatment.

5. Supporting generalization of gains in treatment

Although this study focused on remediation of attentional processing, the importance of metacognitive strategies to support generalization should not be overlooked. Neurologic Music Therapists should be encouraged to dialogue with neuropsychologists and other related professionals on the health-care team of their clients to encourage and support generalization of attentional gains in NMT sessions.

Literature indicates that planning for generalization will support generalization to take place (Stokes and Baer, 1977; Sohlberg and Raskin, 1996; Ponsford, 2008). Based on this literature, at a stage of treatment the therapist would begin to fade the music stimulus and start to introduce non-musical tasks from ADL’s that require the cognitive areas targeted with the interventions. However, literature’s evidence of music’s cognitive benefits and the transfer to other cognitive domains may allow for this cognitive rehabilitation model to exclude a specific, non-musical plan for
generalization. Pilot case-studies by this author also support that the model is effective without non-musical steps for generalization as cognitive benefits for clients, first observed within a musical context, in time did generalize and were observed in ADL’s. Furthermore, functional standardized test scores pre- and post music-based interventions should also be a good indicator of successful generalization.

Neurologic music therapists can support the generalization of cognitive gains in NMT sessions by increasing the client’s awareness of strategies used in the session such as increased effort to attend or by highlighting the results of failure to attend or suppress distraction, for example. By highlighting the need to attend, the client can be educated about strategies that will increase their potential for cognitive rehabilitation and on how to aid in the generalization of attentional gains. Following treatment session two, Participant 12 (MACT) commented: “this helped me to know where my struggles are. I got my (cognitive) tests back from the doctor, but now what do I do?” During treatment Participant 5 (APT) said: “I am really focused, I want to do this (improve attention). I’m really concentrating.” This awareness of the need to concentrate can lead to improved functional performance. Following a sustained attention task in which he was listening for the number two in a sequence of random numbers, Participant 2 (APT) stated that he “assumed the number was going to be 2, if not, he let it pass. He insightfully commented that: “I can adapt my behavior to improve my performance”. Interestingly, he was the only APT group participant to improve on the Trail B post-test.
By carefully assessing the client’s cognitive deficit and recording progress, the neurologic music therapist can educate the client about their improving attentional abilities and support the generalization of these gains. Meta-cognitive training is an important contributor to successful generalization. The decision on how to approach generalization would be dependent on the patient’s level of insight and whether or not they have resource support to aid generalization. Contributing factors to how long it might take for generalization to occur, or if it can occur, include severity of injury, lesion sites, time since injury, and frequency and intensity of treatment.

5.5.c Other clinical considerations

Because of the heterogeneity of the ABI population and the complexity of cognitive impairment, there are several factors to consider when determining who might best benefit from the proposed cognitive rehabilitation interventions. These include:

1. Level of cognitive impairment: mild, moderate, or severe
2. Time since injury: acute or post-acute stage.
3. Components of cognition most impaired.
4. Auditory processing.
5. Level of awareness.
6. Level of motivation

The results of this study provide encouraging evidence that MACT may be beneficial for individuals who have experienced an ABI rated as moderate or severe. In
addition, results were not limited to individuals with a lower time-since-injury. Therefore, when giving consideration to who might benefit from MACT, neurologic music therapists are encouraged to consider individuals in the post-acute stage, including those with more severe injuries. However, as in all rehabilitation, assessment results and the individuality of the circumstances will determine the potential effectiveness of an intervention.

5.6 Other Observations: Comments from Participants

Although not contributing to the research question nor to the formal results of this study, feedback and comments from the participants provided valuable information regarding the experience of living with cognitive impairment following ABI and of the need for psychological support. Information gained from participants’ “informal data” can inform the development of future research questions, study design, and highlights the need for ongoing research into cognitive rehabilitation following ABI. It can also inform clinical practice and the implementation of cognitive rehabilitation.

It was observed that all participants described concern about their cognitive impairment, often explaining the specifics, such as “I have trouble to concentrate and remember”, and apologizing for any potential cognitive errors they might make. Participant 13 (MACT) stated with regret: "I know I am slow" while Participant 14 (MACT) quoted documentation that “due to cognitive difficulties and the impact they have on ability to work at a fast and efficient pace, I am not deemed
competitively employable”. The impact of this awareness of cognitive deficits was noted in other comments. Participant 2 (APT) stated “I do fine until I being to doubt myself” while Participant 14 (MACT) stated “I keep questioning myself”. Participant 4 (APT) explained: “the gears are not clicking in, I don’t trust myself, even with things I used to know well”. Participant 11 (MACT) described feelings of frustration and being overwhelmed during cognitively demanding tasks. Participant 9 (MACT) explained how he “goes blank” when there is distraction in a room, not knowing “what I am supposed to do”. Both Participant 9 (MACT) and Participant 4 (APT) inquired as to why “confused” was not listed on the Likert Effort Scale following treatment tasks. They both stated that they felt confused at times during the tasks and wished that there was the option to indicate this.

Following the final session, Participant 4 (APT) asked to briefly explain to the primary investigator “what I am going through” in a desire to highlight the struggles of cognitive impairment. He stated that “after my stroke I lost my independence, my self- esteem, and my worth”. He explained that he remained at home for the first four years following his stroke and “did nothing and got worse”, only leaving his home in the evening “so I didn’t see people”. He described the fear that long-term memories were fading away, becoming harder to access, and that he was making the effort not to “bring up memories in case I am losing them. I will only have the shell of a memory”. He concluded with: “I know who I was and what I used to do. Now it takes longer to do anything. I am not sure of myself anymore. Am I doing anything right?”
Spontaneous comments from a number of participants in this study highlighted the importance of psychological support during cognitive rehabilitation. Sohlberg and Mateer (2001) state that attentional deficit may be a result of the brain damage itself, a psychoemotional response where the individual cannot effectively process information due to being overwhelmed with grief, or a combination of both factors (p.148). Following the trauma and life-changing event of a brain injury, the individual may have a loss of identity and experience significant losses in various areas of their life resulting in a low self-esteem and confidence. This in turn, can have an impact on cognitive function. Sohlberg and Mateer (2001) highlight the importance of recognizing the “interaction between neurological dysfunction and psychoemotional difficulties” when developing a cognitive remediation program (p.148).

5.7 Recommendations for Future Studies

Several recommendations for future studies arose during the course of this investigation:

1. **Larger sample size. Longer period of data collection.**

   It is important that future studies use a larger sample size to provide a more precise estimate of the benefit of music-based cognitive interventions. A larger sample would reduce random error and increase statistical power, thereby more accurately detecting the difference between music and non-music attention training and any benefit of treatment. In addition, a longer
duration for the study period may find results of larger changes pre-and post-test due to a possible accumulative benefit of treatment.

2. **Sequential study.**

This study investigated music-based cognitive rehabilitation interventions effect on attentional processing. This is due to attention’s foundational role in other cognitive functioning. It is important to investigate the treatment effects on the treatment mechanism prior to further to investigation of its effect in broader contexts. This study contributed to the initial level of inquiry: “do music-based attention tasks effectively arouse and engage attention?”. A future sequential study could investigate the benefit of music-based attention tasks on increasingly more complex cognitive domains.

3. **Participant inclusion criteria: specific lesion site.**

This study did not include lesion site in inclusion criteria. Future studies might investigate the influence of music on attention with participants with a specific lesion site, in particular the prefrontal cortex.

4. **Influence of single music component on attention.**

Future studies might investigate and compare the influence of single music components, melody, rhythm, and harmony, on attention. It would also be interesting to investigate the influence of single music components with participants include in the study based on lesion site to see if the injured brain responds to the stimuli as music cognition literature might predict according to the lesioned brain area. This may lead to an exploration of a
neuroplastic response developed through the treatment of music-based
cognitive rehabilitation.

5. *Influence of music components on single attention type.*

This study investigated the influence of music on attention using MACT and
used melody, rhythm, and harmony as targets in attention tasks. The MACT
treatment addressed sustained, selective, and divided attention. Future
studies might investigate the influence of these components, either singly or
combined, on a single attention type.

Because executive functioning engages several aspects of attention, a future
study may use executive function measures as pre-and post- treatment
assessment of attention and overall cognitive gains following music-based
cognitive rehabilitation. The executive function measures should be
standardized neuropsychological measures. However, it would be interesting
to also measure any executive functioning gains in a functional, real-life
setting.

6. *Joint-study with NMT and music cognition.* Future studies that may investigate
either of the proceeding two research questions could be strengthen by a
joint-investigation by a neurologic music therapist and a music cognition
scientist.
7. **Use of brain imaging.**

As literature support for the effectiveness of music-based attention tasks continues to grow, future studies should include brain imaging data to indicate the degree of engagement and the brain networks involved and to inform the clinical application of interventions.

8. **Participant survey.**

It is recommended that future studies include a participant feedback survey. This feedback can provide insights when interpreting data results and provide opportunity to gain information not specifically set out in data collection goals. Although quantifiable results are important to studies, other valuable information may be captured in a participant survey or through documentation of participant feedback or comments.

Because of the number of participants in this study who expressed concern about, or apologized for, their attention deficit, it may be interesting for a future study to include a participant survey regarding self-confidence and how this might be affected during the course of treatment. A second question could be “how might self-confidence affect test results?”

### 5.7.a Future studies: other considerations

Other considerations when developing or investigating a music-based model for cognitive rehabilitation include:

1) Time line of data collection or evidence of benefit for client
2) Tests and measures.

**Time-line for data collection.** There are two aspects to this question: first, the actual time line from beginning to end of data collection, and secondly, the stage of learning or attentional behavior at the time of results measures.

Most studies investigating music and cognition have included healthy participants without cognitive impairment. This has permitted a data collection time-line that is relatively short, compared to what would be needed in gaining results with an individual with an injured brain and cognitive impairment. Because of the heterogeneity of the ABI population and the interconnectedness of cognition, and thus, of cognitive impairment, it might be difficult determine a realistic time line needed for data collection and validation of study results. Although it is recognized that a longer data collection time line will be required, it may be challenging to engage participants for an extended period of time for research purposes. Parallel to this issue is the fact that in rehabilitation treatment, evidence for benefit, in particular far-transfer, will take time. This may be a concern for participants, but more so for funders.

Secondly, in regards to the time-line of data collection, measures need to be interpreted according to the possible stage of skill acquisition or learning rather than only on change from baseline measures or not; or on generalization or not. Decreases or increases in neural activity can correspond to short or long term
training. Different aspects of cognitive processing may be dominating, depending on what stage of training the neural activity is being assessed. For example, the greater neural recruitment observed in Pallesen et al.’s (2010) study was attributed to long-term training of the musicians. Therefore, when testing this hypothesis, minimal neural activity, or activity of limited processes may reflect the stage of training rather than reduced effectiveness of the intervention. In addition, increased efficiency of networks may reduce activity levels. As a result, the time-line for data collection needs careful consideration to the stage of skill acquisition; as does awareness of the possible time required for cognitive improvement in clinical settings.

**Tests and measures.** The third area to consider when developing and testing music attention task’s influence on attention is that of measures and assessment. There are several factors to consider when determining what to test and how to measure results. A number of standardized neuropsychological tests for attention use time required for test completion as a primary measure. However, there may be an increase in attentional arousal or accuracy that might not be reflected in test time alone. Through treatment the individual may have developed the ability to more effectively suppress distraction or attend to a target for an increased amount of time, yet may have a slowed processing time or initial delayed response. In addition, individuals living with the effects of ABI may also have a level of motor impairment which could interfere with task responses, potentially causing a slowed
response although the cognitive processing itself may have improved. In these cases, a timed pen-and-paper test may not accurately improved cognitive functioning.

Many standardized assessments are intended to differentiate between gross cerebral pathology or none but do not reflect brain systems (Cicerone et al., 2006). demonstrating the role of brain imaging in future studies. Studies that include measures other than time-required- for- test or use brain imaging may provide greater insights into changes in attentional processing of the study participants.

There is an increased emphasis in research on ecologically valid or real world functional outcomes and measures of participation and quality of life although this has not been reflected in most cognitive rehabilitation studies (Cicerone, 2008). In addition to standardized neuropsychological tests, future studies might consider including ecologically valid, quality-of-life measures, or functional rating scales to reflect changes that might not be evident on standard pencil-and-paper measures.

5.7.b Research in Other Disciplines

In addition to the recommendations for future studies investigating the benefit of music-based cognitive rehabilitation, it should be highlighted that there is a need for on-going research in the field of cognitive rehabilitation. Research in Psychology and Rehabilitation Science research can continue to provide important information regarding cognition and the injured brain’s response to cognitive training, informing the development of treatment interventions. In particular, it is important to have
on-going research into the plasticity of the PFC. As in music-based cognitive rehabilitation, the body of literature regarding PFC plasticity is sparse. As this literature base continues to emerge, it can inform future research questions and guide the implementation of cognitive rehabilitation, in particular rehabilitation targeting the various components of attention, including related functions of memory and executive function.

5.8 Conclusion

Music is recognized as significant neural stimulus, arousing multiple brain areas (see Table 2.1), engaging networks in both hemispheres. Music engages attentional processes, provides cognitive benefits in working memory and cognitive control (Barrett et al. 2013), and results in greater recruitment of brain areas involved in top-down processing (Gaab and Schlaug, 2003; Pallesen et al, 2010). The cognitive benefits of music training suggest the potential for music-based tasks to benefit cognition, and in particular, to improve cognitive functioning in the injured brain. The potential efficacy of music-based interventions to remediate cognitive impairment has been discussed by examining supporting literature regarding: music's stimulus of a neuroplastic response, both anatomical and functional; enhanced non-musical abilities of musicians; increased attentional control and working memory of musicians; and the transfer of gains from music training to non-musical domains. As a result, the rationale for music-based cognitive rehabilitation interventions is well supported in the literature.
The range of music components - rhythm, melody, harmony, not only arouse different brain sites (Peretz & Zatorre, 2005), but also provide a range of potential target features to extract in an intervention, driving top-down processing and goal-directed behavior. This results in engagement of the PFC, supporting the strengthening of attentional networks and improving cognitive control. The range of music components also allows for music-based interventions to be varied in presentation and complexity, thereby providing opportunity for the repetition required to stimulate a neuroplastic response and support new learning (Koziol & Budding, 2009) while avoiding boredom in the therapeutic process. The variation of intervention design and complexity also incorporates the hierarchy of attentional processes and maintains novelty in the therapeutic process, supporting effortful responses as is required to continue to engage attentional processing and prevent an automatic, learned response to the task. The multimodal aspect of music may allow for greater orientation arousal of an injured brain, increasing the potential for attention rehabilitation. Because music engages the limbic system (Koelsch, 2005), it may increase motivation, supporting individuals with ABI to engage in the therapeutic process for an extended period of time, as required for rehabilitation.

In addition to discussing literature that supports the hypothesis for music-based cognitive rehabilitation, this study investigated the benefit of music-based cognitive rehabilitation interventions in a randomized control study with individuals who have experienced an ABI rated as moderate or severe and have been identified as having a cognitive impairment as a result of their injury. The close value of ANOVA
(p = 0.051) for MACT group’s Trail B post-test time and the significance of nonparametric test (Mann Whitney, p = 0.029) for time difference between APT and MACT groups’ Trail B post-test times provide marginal statistical support for evidence of benefit of MACT, a standardized Neurologic Music Therapy music-based cognitive rehabilitation intervention, over APT as another well established non-music based auditory technique. Further examination of the results of Trail B revealed that the MACT group had a more stabilized response to treatment with the majority of participants demonstrating an improved performance post-test, in contrast to the APT group which performed more poorly and had more inconsistency in performance on the post-test. In addition, three participants with PFC injury in the MACT group improved on Trail B post-test while three individuals in the APT with similar lesions site (PFC), injury severity, and time-since-injury did not improve following treatment. Taken together, evidence supports the benefit of MACT and the results warrant further investigation into the benefit of music-based cognitive rehabilitation.

Because of the role of the PFC in cognitive control and attentional processing, cognitive rehabilitation interventions should place demands on the PFC through goal directed tasks that required top-down processing. Results of MACT group participants on Trail B suggest that MACT interventions successfully engaged PFC functioning. This was demonstrated not only in the examination of results of individuals who had experienced a PFC injury, but also by the specific test where notable results were observed: Trail B, a test measuring both attention and
executive functioning. The improvement of the MACT group on an executive function measure indicates increased cognitive control and mental flexibility and provides evidence of music-based tasks engaging underlying attentional networks and higher cognitive processes of executive function, demonstrating the effectiveness of music-based attention tasks to target PFC functioning. It has been proposed that the increased cognitive control developed in a music-training context may transfer to non-music domains (Pallesen et al., 2010; Barrett et al., 2013; Moreno & Bidelman, 2014), making it realistic to propose that attentional gains observed in music-based cognitive rehabilitation treatment sessions could transfer to general increased attentional control.

Results of Trail A, Digit Symbol, and Brown-Peterson task did not reveal any significant changes or differences for either the APT or the MACT group. A possible factor for this lack of results may be the short data collection period. Because of the level of performance of the participants in comparison to norms, the participants may have required longer treatment in order for any benefit to be observed. In addition, the Digit Symbol and Brown-Peterson Task included a memory component which was not a primary focus in the APT and MACT interventions. A longer treatment period and more treatment time committed to working memory tasks may gain different results.

The results of this study provide only marginal statistical evidence for the benefit of music-based cognitive attention interventions in one test. However, further
examination of the results provides encouraging evidence that using components of music to target the remediation of the underlying mechanisms of attention may be able to improve attentional processing and increase cognitive control for the injured brain. While the majority of the MACT participants improved on Trail B, MACT interventions, in contrast to APT interventions, may have had a particular benefit for individuals with a PFC injury. Time-since-injury did not impact the benefit of MACT, supporting the addition of MACT to rehabilitation treatment in the post-acute stage, including several years post-injury. It is also important to note that the participants in this study had ABI rated as moderate or severe. These factors can guide clinicians in the implementation of MACT and encourage individuals with ABI that they may continue to strive towards gains in their cognitive rehabilitation goals, even following the ideal “window of opportunity” in the first two years post-injury. However, it is imperative that clinicians give careful consideration to all individual factors of their client’s brain injury and status when determining the potential effectiveness and the implementation of MACT as noted above in other clinical considerations.

Due to the small sample size, this study does not have statistical power. In addition, results of two of the neuropsychological tests failed to show statistically significant results demonstrating the effectiveness of music-based cognitive interventions. Further research with larger sample size is needed, and the use of standardized treatments in this study allows for exact replication in future studies.
This study is one of the first studies to investigate NMT for rehabilitation of cognitive functions and will extend the small body of literature on cognitive rehabilitation following ABI. The results of this study indicate that MACT is grounded in attention theories and provide preliminary evidence of the influence of music-based attention treatment tasks on attentional processing and the potential benefit of music-based cognitive rehabilitation to remediate attention deficit. Music-based cognitive rehabilitation may be a unique and powerful attentional stimulus, applicable to a range of attention types and levels of impairment. Music-based cognitive rehabilitation may be a significant contributor to an individual’s journey of cognitive rehabilitation; supporting an increase in attention, cognitive control, memory, and executive functioning, thereby supporting them to gain an increase in functional independence, reduced family and care-giver stress, and to experience an improved quality of life following an ABI.
Appendix 1

TRAIL MAKING A
Appendix 2

Trail Making B
Appendix 3

Digit Symbol
Appendix 4

Brown-Peterson Task
(Auditory Consonant Trigram)

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<th>Delay (s)</th>
<th>Response</th>
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18" delay _______
36" delay _______
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[http://dx.doi.org/10.1016/j.heares.2014.01.002](http://dx.doi.org/10.1016/j.heares.2014.01.002).


