THESIS

THE EFFECT OF TEMPO AND REGISTER MODULATION ON SUSTAINED AND SELECTIVE AUDITORY ATTENTION IN A MUSICAL TARGET DETECTION TASK

Submitted by

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WE HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER OUR SUPERVISION BY CHRISTINE K. STEVENS ENTITLED THE EFFECT OF TEMPO AND REGISTER MODULATION ON SUSTAINED AND SELECTIVE AUDITORY ATTENTION IN A MUSICAL TARGET DETECTION TASK BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF MASTER OF MUSIC.

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ABSTRACT OF THESIS

THE EFFECT OF TEMPO AND REGISTER MODULATION ON SUSTAINED AND SELECTIVE AUDITORY ATTENTION IN A MUSICAL TARGET DETECTION TASK

This study investigated performance on a musical target detection task under four conditions in which the tempo was either fast (120 bpm) or slow (80 bpm), and the target was either in the upper register or lower register (1 octave lower). A target detection task was utilized to examine sustained and selective auditory attention. Performance measures included number of correct targets detected, number of commission errors, and response time in milliseconds. Jones' (1992) theory of rhythmic attending predicts that an entrainment effect occurs at the referent level (musical measure) of attending to the musical stimulus. Sloboda's (1985) hypothesis of attention and music predicts that performance in the upper register conditions should be superior to the lower register conditions. These predictions were examined through a target detection task, modeled upon similar visual attention studies. The author composed music which embedded a three note target regularly occurring at an interpresentation interval (IPI) of four measures. The target occurred a total of twenty four times in each condition. Nineteen non-musician subjects from the Social Work undergraduate classes participated in the experiment. All subjects heard the four conditions with the tempo conditions counter-balanced. The higher register conditions always preceded the lower register conditions due to anticipated higher level of difficulty for lower register or more hidden target conditions. Results indicated no significant effects of tempo or register when performance was analyzed by condition, an indication of selective attention. The use of time segmentation of performance data was then analyzed to examined sustained attention. Again, there was no significant effect of tempo and register modulation upon performance over time. This result indicates that subjects were able to sustain their attention. Indeed, a visual analysis of the results of target accuracy revealed that subjects sustained a generally high level of performance (68%) across all conditions. Responses to an open-ended question regarding what strategy subjects used were analyzed qualitatively. An ANOVA demonstrated that strategy did demonstrate a significant effect on response time ($p = .049$). A *post-hoc* analysis indicated that subjects who used the anticipation/timing strategy were significantly faster in their responses than those who used the repetition strategy ($p = .016$). These results support the primacy of timing within auditory attentional processing (Marks & Crowder, 1997, Jones, 1992). Furthermore, a cognitive timing mechanism is discussed. Music facilitated attending and attentional distraction models in clinical music therapy are discussed.

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CHAPTER ONE: INTRODUCTION

Purpose

This study investigated the effect of temporal elongation and register changes on selective and sustained auditory attention in normal non-musician subjects. Temporal elongation was defined as extending a given music stimulus through reducing the tempo. In a spatial sense, this may be considered the horizontal axis of a music stimulus. In order to further investigate the effect of music on attention, this study additionally compared task performance under a condition where the target was in the upper register or lower register, creating a hidden and more complex condition. A target detection paradigm was used in which auditory attention was necessary to select a re-occurring three note target embedded in a musical piece. Within this task, varied temporal conditions and the varied register of target presentation conditions were utilized to investigate effects on task performance as a measure of selective and sustained auditory attention.

Need

Current research in music therapy often focuses on clinical effectiveness without establishing a theoretically based and empirically supported model for clinical music therapy interventions. Cognitive applications of music therapy are practiced but not well researched or documented in the music therapy literature. Attention is discussed in the music therapy literature in relation to pain rehabilitation (Wolfe, 1978, Malone, 1996) and in terms of the effect of music on memory and attention (Morton, Kershner, & Siegel, 1990). Additionally, Geringer and Madsen (1995) examined differences between focus of attention to various musical elements between musicians and non-musicians. Research on attention in music education has demonstrated that individual and group Suzuki violin lessons improved children's' attention scores on a 15 minute visual-motor task created by the author (Scott, 1992).

Despite the lack of empirical research in the music therapy literature, researchers from other fields have demonstrated an interest in studying music cognition. Information gained from these investigators may potentially inform the practice of music therapists. However, these theories must be tested with clinical populations to determine their merit in music therapy practice. Although music therapists treat individuals with attention disorders and other cognitive disabilities, many music therapy techniques rely upon anecdotal observations that music attracts attention. Accordingly, music may be useful in distracting clients from pain, obsessive thoughts, and other symptomotology. A musical distraction model may have considerable value in music therapy clinical practice. Similarly, a music facilitated attending model may contribute to practice knowledge for the treatment of individuals with attention disorders.

This research seeks to clarify inherent relationships between selective and sustained attention and different musical stimuli including changes in tempo and register. Results will assist in establishing a better understanding of the mechanisms in auditory attention which can be made use of in music therapy applications. Results will also contribute to a knowledge of auditory attentional processing.

Theoretical Background

In order to establish a theoretical basis for the therapeutic use of music within cognitive-based interventions, it is essential to address four sequential steps of scientific inquiry. First, the inherent elements of music which elicit attention must be understood. Secondly, cognitive and neuropsychological theories of attention must be explored to understand the mechanisms involved in attentional processing. A third step consists of considering how rhythmic and melodic elements in music may effect attention performance. This involves research which tests a model of attentional processing with normal subjects. Finally, testing clinical populations assists in establishing a theoretically based music therapy model for working with individuals with cognitive impairments.

In terms of the first step, Berlyne (1971) asserts that music holds attention because of its temporal nature. Music unfolds over time and therefore contains inherent motivational properties. How specific elements arouse attention has been investigated in terms of dynamics (Huron, 1992), as well as pitch and melody (Sloboda, 1985).

Understanding how music elicits attention can be further illuminated through an examination of the cognitive and neuropsychology perspectives of the mechanisms of attentional processing. LaBerge (1995) writing from a neuropsychological position, stated, "what seems to help the sustaining of selective attention is in the stimulus itself. No one can possibly attend continuously to an object that does not change" (p. 36). Within the attention literature, it has been noted that attention is dually determined by the stimulus attributes and the observer's cognitive abilities, limitations, and motivation. It is generally agreed that different types of attention activate corresponding brain areas. Halperin (1986) localized the core structure of attention in the locus coeruleus in the brain stem, particularly because of its noradrenergic function. Mirsky (1986) argued that the basal ganglia, limbic system, and the prefrontal cortex contribute to the neural system of attentional processing. LaBerge (1995) also supported the notion of the limbic system's involvement in visual attention. He also proposed that vigilant attention, which occurs over an extended time period, may involve norepinephrine. Brain activation in this case probably includes the right frontal lobe as well as the parietal lobes. Cohen (1993) asserted that the temporal lobes contain neural systems involved in the timing and sequencing of attentional information. The author described the temporal lobes as contributing to temporal continuity, while the parietal lobes contribute to spatial aspects of stimulus processing. Cohen (1993) also agreed that the limbic system is involved in attentional processing, probably in the area of motivation, specifically in the medial temporal lobes.

Models within the cognitive psychology field have historically used an information processing paradigm where attention is conceptualized as a filter mechanism through which non-significant information is eliminated (Klein, 1996). Indeed, attention is a critical entry process for stimulus information to enter the cognitive system.

In terms of the third step, a model of attentional processing which incorporates the notion of rhythmicity is the rhythmic attending model presented by Jones (1992). Her and her colleagues' research demonstrates that auditory attention to music can be directed by manipulating temporal elements (Jones, 1992, Jones, Boltz & Kidd, 1982, Kidd, Boltz, & Jones, 1984, Boltz, 1991). Jones asserted that a rhythm generator at the referent level of music facilitates an entrainment effect of attention. The referent level is a temporal character existing between detail-oriented and future oriented attending. In musical terminology, the referent level would be a measure, the detail-oriented each beat, and the future-oriented a phrase. Whereas information processing theories of attentional processing have examined the function of attention in filtering out information and making a selection amongst the many stimuli presented, Jones (1986, 1992) has focused on how subjects time their attention.

Entrainment has been used as a model for synchronizing internal systems such as gait with an external time cue (Thaut, 1992). Entrainment is a process by which two oscillators synchronize, generally the weaker following the stronger. Because the rhythm in music provides structure through the accents of the downbeats, a referent level of attention is created. This study seeks to investigate attentional entrainment as a model for sustaining auditory attention and improving selective attention in an auditory task. According to Jones' theory of rhythmic attending, if a musical stimulus is elongated, the referent level would be greater as well. How subjects will perform over time with a changing tempo condition is not clearly predicted by Jones and is worthy of investigation.

CHAPTER TWO: LITERATURE REVIEW

"What seems to help the sustaining of selective attention is in the stimulus itself. No one can possibly attend continuously to an object that does not change."
(LaBerge, 1995, p.36).

Attentional processing

Attention plays a foremost role in many cognitive processes, including short term memory, storage, recall, and other aspects of the information processing chain. The importance of attentional processing has inspired various attempts to define attention. The early psychology theorist William James believed attention was synonymous with interest and effort. He identified two types of attention: sensorial and intellectual (Lyon & Krasnegor, 1996). Later, cognitive psychologists operationalized attention in terms of the information processing paradigm, with attention encompassing three stages; encoding, central processing, and response organization/ motor output (Sergeant, 1996). Attention was viewed as a limited resource, a proposition which was supported by poor performance on dual-task tests of divided attention (Jones, 1986). More recently, neuropsychologists and neurophysiologists have defined attention in terms of activation of brain areas via neural networks associated with different functions of attentional processing (Cohen, 1993, LaBerge, 1995, Mirsky, 1996). All disciplines seem to agree that attention is difficult to isolate, particularly from memory and executive functioning, and that it involves a number of cognitive tasks with a complex corresponding system of neural mechanisms.

Due to the abundance of information presented to the brain, attention often functions to reduce the number of elements to which we may attend. Both visual and auditory attention provide sensory avenues through which information enters the perceptual system. Attentional choices are determined by the internal states of the subject, such as cognitive limitations of attention, personal preference, and motivation, as well as properties of the stimulus itself

(LaBerge, 1995). Furthermore, these choices may vary depending upon the type of attentional processing being expressed. Cognitive psychology literature cites four different attentional processes; sustained, selective, divided, and focused attention (Lyon & Krasnegor, 1996). LaBerge (1995), writing from a cognitive-neuroscience perspective, consolidates these into three manifestations of attention; selective, preparatory and maintenance, all of which may be sustained. He emphasizes four considerations of attention; its goals, expression(s) in brain pathways, mechanism(s), and sources of control. The general goals of attention according to LaBerge (1995) are to produce accurate and speeded perceptual judgments and actions, and to sustain processing of a mental activity. An enduring debate regarding sources of control for different attentional manifestations has addressed whether modulation of attention occurs through an enhancement of the target, disenhancement of the surround, or a combination of both. (Klein, 1996, LaBerge, 1995)

Information processing models: Historical perspective of attention theories

Attention research began to take a more prominent role in the 1950s with Donald Broadbent's experimental studies using the information processing paradigm (Klein, 1996). Prior to this time, attention was neglected by mainstream psychology. Broadbent's (1958) theory of attentional processing focused on the limited capacity model which necessitated selection of stimuli. His model was demonstrated through a physical construction of tubes representing information channels with "flaps" at the end representing the selection or filtering process. However, the earlier filter model of attention did not explain results of experiments where subjects reported information from an unattended channel (Sloboda, 1985). Theorists later developed the notion of attentional energy which was also seen as a limited resource (Jones, 1986). Interference tests of same or different modality, i.e. visual task with auditory distractor, demonstrated that sensory modality had an effect on task performance, supporting the idea of modality specific resource pools (Wolfe, 1997, Klein, 1996, Sloboda, 1985). A seminal study used the Sperling partial report procedure to establish a time estimation of endurance of an image in brief auditory storage (Darwin, Turvey, & Crowder, 1972). The auditory brief storage was calculated at approximately 2 seconds, compared to the visual brief storage which was calculated at 250 msec. This may be a logical consequence of the temporal quality of sound, causing less availability for rehearsal strategies. Visual stimuli, on the other hand, can be renewed as often as necessary by simply looking at the stimulus. The exact calculation may not be as significant as recognizing that the limited time does not prevent perception, memory, and even problem-solving functions to occur (LaBerge, 1995).

A shift in conceptualizing attention arrived with Posner and Snyder's theory of controlled versus automatic attending (Sergeant, 1996). Attentional processing may be expressed in an automatic, fast, effortless processing mode when stimuli is processed consistently over many trials, or in a controlled, slow, capacity-limited, effortful processing model to deal with novel or inconsistent information (Schneider, Dumais, & Shiffrin, 1984). This remains a helpful distinction in terms of attentional demands of tasks.

Using the resource capacity model as a spring-board, Kahnemann developed the cognitive energy perspective (Sergeant, 1986). He introduced the importance of effort, defined as the energy needed to meet the demands of the task. This theory postulated three energetic pools; arousal, activation, and effort. Similar to the notions of separate resource allocations for different modalities, Kahnemann's (1973) theory posited that allocations of attentional resources varied by task. According to Kahneman (1973), arousal is defined as a phase response, producing a time-locked effect to a stimulus. This is the first time a temporal aspect of attention is introduced to a cognitive processing model. On a neurological level, it is believed to involve the mesencephalon and reticular formation. Signal intensity and novelty most influence arousal during the encoding stage. Activation involves the basal ganglia and corpus striatum. Activation is involved in the motor expression and is effected by preparation, time-of-day, and time-on-task. Effort occurs in the hippocampus and is influenced by cognitive load. Measurements of effort in attentional processing originally used pupil dilation, but currently include decelerated heart rate, respiratory sinus arrhythmia, and event-related desynchronization, ERD (Sergeant, 1996). Effort may also serve to excite or inhibit the other two pools. This creates a management function necessary in attentional processing, making this a top-down approach. In localizing specific attentional functions, the cognitive energy theory as detailed by Kahnemann and Sanders has been more compatible with neuropsychological thinking of attention. Drug studies have supported the different energy pools in the finding that barbiturates have more effect on the encoding stage and amphetamines on the motor organization aspect of attention.

More current theories from the information processing paradigm include the additive factor model, AFM, first outlined by Sternberg (Sergeant, 1986). This theory describes a taxonomy of task variables within each aspect of attention; encoding, central processing, and response organization. Task variables are then tested to examine interference effects, indicating that they access the same cognitive pools of attention.

Neuropsychological models

Neurological localization of attentional processing has been of interest to neuropsychologists. Given the executive functions of attentional processing, it is logical to expect a certain degree of anterior, frontal activation. However, it is interesting that many neuropsychological models have investigated the role of the limbic system and other lower brain areas in attentional processing (Cohen, 1993, LaBerge, 1995). Mirsky (1986) presented a neurological model of attention, where phylogenetically older brain structures are believed to serve important functions. He identified the basal ganglia and gray matter in the reptilian brain, the limbic system, and the prefrontal cortex as contributing to the neural system of attentional processing. Halperin (1986) localized the core structure of attention in the locus coeruleus (LC) in the brain stem, particularly because of its noradrenergic functions. The rate of neural discharge is believed to correlate with the degree of attention. For example, low level noradrenergic discharge from the LC results in poor vigilance or sustained attention, whereas high discharge enhances signal-to-noise ratios for target cells. Supportive evidence is derived from examining the effect of medications which increase attention in children, which also affect the noradrenergic metabolism. Developmentally, the locus coeruleus develops by the time of birth, and newborns have demonstrated attentional orienting responses. Halperin (1986) also identifies other cortical structures particularly in visual attention; posterial parietal, pulvinar nucleus, thalamus, superior colliculus and frontal cortex, cingulate gyrus, and hippocampus.

Cohen (1993) reviewed the process of auditory processing which contributes to auditory attention. The author identified the following neural pathway; inner ear, cochlea which determines frequency recognition, the subcortical sensory pathway including the inferior and superior colliculus and the olivary nuclei, the lateral geniculate nucleus of the thalamus, and finally the primary auditory cortex, areas 41 and 42 of Brodman's system which project to higher cortical systems. Other authors also include the medial geniculate nucleus of the thalamus which receives projections from the inferior colliculus (Poritsky, 1992). Cohen (1993) believed that the temporal lobes have a primary role in timing. The author stated, "contained in the temporal lobes are neural systems that are important for the timing and sequencing of information" (p.172). Cohen (1993) also supported the role of the limbic system primarily in motivational demands of attentional processing.

Research investigating young subjects with attention deficit-hyperactivity disorder (ADHD) indicated that methylphenidate (MPH) normalized slowness and performance deterioration in a continuous performance task (Van der Meere et. al, 1995). These results support the hypothesis of low activation of MPH in ADHD individuals.

Developmental studies help to indicate brain functioning with respect to different types of attention. In early childhood, an infant's attention is driven by the stimuli. Four month olds demonstrate clear preferences for stimuli with contrasts of light/dark, a moderate number of edges, and moving. As early as 4 months old, novelty becomes important in sustaining attention.

By age 4, the child can scan the environment and by age 5 or 6 an internally driven attentional preference system develops. Vigilance accuracy changes are greatest between the ages of 6 and 7. The capacity for focused attention is fully developed by age 7, whereas sustained attention continues to develop through adolescence. The motor output aspect of attention develops primarily in middle childhood (Halperin, 1986).

Selective attention

Schneider, Dumais, & Shiffrin (1984) defined selective attention as "the organism selectively attends to some stimuli, or aspects of stimuli, in preference to others" (p.3). Auditory selective attention is often observed behaviorally through an individual moving closer to the stimulus to hear it better (Takahashi, 1997). Many metaphors of mechanisms of selective attention have arisen from cognitive psychology which differ according to their view of either enhancing target or disenhancing surround. Metaphors which support the modulation of attention through enhancement of target include; spotlight, zoom lens, resource allocation, and gain. Metaphors which function through an inhibition of the surround include; filter, gate and channel. The third possibility, which assumes a combination of both enhancing the target and inhibiting the surround has not yet inspired a metaphor. Another formerly popular metaphor of the mechanism of selective attention was the bottleneck theory. According to this model, the bottleneck represents the capacity limitation causing subjects to make preferential choices for certain stimuli that then pass through the bottleneck more easily than non-preferred stimuli.

Selection has been shown to vary according to perceptual load or difficulty. Paquet & Craig (1997) demonstrated performance changes in a task using varying levels of perceptual difficulty. They also examined attentional cueing where the target was made more distinctive through dramatic differences compared to non-target stimuli in the surrounding area. Target distinctiveness was shown to decrease the perceptual load and facilitate improved selective attention. Another area examined in their research was the notion of automaticity. It appears that selective attentional control is determined not only by the individual but also by the stimulus to the degree that it automatically captures attention. Specific elements of the stimulus which cause automatic selection have been studied (Paquet & Craig, 1997). In the visual modality, an example of automatic selection is the STROOP test (Mateer & Mapou, 1996). Subjects are shown the word blue written in red ink. They are asked to report in what color the word is written as soon as they can. Most subjects say the word "blue" because reading the word is more automatic than processing the color. In the auditory modality, another example of automatic selection is the "cocktail party" phenomenon (Moray, 1959, Wood & Cowan, 1995). Subjects were found to automatically attend to a source where they heard their names and continue attending to that source for a short time afterward (Wood & Cowan, 1995). At a cocktail party, people may be talking to one specific individual, but hear their name across the room. This phenomenon demonstrates an automatic auditory shift of attention. Studies of automatic selection reveal the role of the stimulus is determining attentional control.

According to LaBerge (1995), selective attention may be thought of as a process which responds to questions about the stimulus, including what, where, and which on within milliseconds. He summarizes six findings pertaining to properties of the stimuli which effect selective attention, primarily by means of visual selective attention research using search tasks (LaBerge, 1995). These include; stimulus boundaries, variable size and variable intensity of the attended area, attending to one connected area at a time, the movement or shift of the attended area, and the duration of attention. Pertaining to duration, the author asserts that a subject requires approximately 100 milliseconds to selectively sample information from objects in a visual display. Duration can be sustained however, through one's interest in the stimulus. Although these findings apply primarily to visual selective attention, analogous functions in auditory attention can be proposed and investigated.

LaBerge (1995) identified a model of selective attention which combines cognitive, neuropsychology, and neuroscience research. Unfortunately, his model emphasizes the visual modality where indeed more research has been performed compared to auditory attentional research. According to the author, the expression of selective attention occurs through neural boosting in terms of amplitude. The integration of information of what, where, and which one occurs in the anterior superior temporal area. In terms of controls of the expression and mechanism of selective attention, the author asserts that the object attributes play an important role in sustaining selective attention.

Sustained attention

Sustained attention defined as ability to attend continuously to a given task, was first illuminated through vigilance studies (Sergent, 1996). Certain types of vocational positions which required continuous attentional performance, such as night watch-men, demonstrated fatigue over time which effected job performance. Rumbaugh & Washburn (1996) defined vigilance as "ability to maintain focused attention across time" (p.207). During target detection tasks over time, subjects must "detect the target stimulus and ignore the aperiodic presentation of nontarget stimuli" (Rumbaugh & Washburn, 1996, p.207).

Tomporowski & Tinsley (1996) demonstrated that sustained attention is effected by memory demand and motivation. In a study comparing young and old subjects, Tomporowski & Tinsley (1996) found support for the theory that overall levels of sustained attention are lower in older than younger individuals. This difference was more pronounced as the processing demands of vigilance tests were increased by varying event rate. The question of motivation is interesting as well, because some theories predict that increases in task difficulty are intrinsically more motivating for subjects to perform. This creates an interesting paradox because increased task demands may decrease attentional performance, yet they may also increase motivation which may compensate for degradation in attention. The study showed that external motivation in the form of money, produced better performance of sustained attention. The authors used a measure of sustained attention which examined overall levels of target detection and decline of target detection over time.

Sustained attention is one of the primary attentional mechanisms which is impaired in attention deficit hyperactivity disorder (ADHD) (Barkley, 1997). The author stated, "for over 20 years, ADHD has been viewed as comprising three primary symptoms, these being poor sustained attention, impulsiveness, and hyperactivity" (p.65). Current thinking on ADHD holds that impulsiveness and hyperactivity are combined as one main symptom. Other attentional disorders, including those caused by traumatic brain injury (TBI) involve poor sustained attention as well (Mateer & Mapou, 1996). Neuropsychological tests of sustained attention include the Seashore Rhythm Test and the Continuous Performance X and AX tests (Mateer & Mapou, 1996).

The separation between sustained and selective attention has been debated by supporters of the information processing paradigm. Halperin (1996) stated that "the two components are not discernible because the ability to sustain attention is usually measured by decrements in performance over time, which at least in part involves selective attention" (p.127). The author cited research using a visual search task in which sustained attention was measured as an increase in response times as a function of time on task, and selective attention was measured as an increase in response times to target as a function of number of distractors. Other theories of attention have attempted to outline the unique types of attentional processing. One such model, developed by Shum defines "sustained selective processing" as "requires ability to select and manipulate particular stimulus and response features while ignoring others" (Mateer & Mapou, 1996, p.5). Others, such as Sohlberg & Mateer attempts to separate sustained and selective attention. They define sustained attention as the "ability to maintain consistent behavioral response during continuous and repetitive activity. Incorporates concept of vigilance and, at perhaps a higher level, the concepts of mental control or working memory. (Mateer & Mapou, 1996, p.6).

From a neuroscience perspective, selective attention can be sustained or unsustained

(LaBerge, 1995). Mirsky's (1996) neuropsychology perspective identifies the specific neural structures involved in sustaining attention as the reticular formation, midline, and the reticular thalamic nuclei. LaBerge (1995) believed that alertness is influenced by norepinephrine which increases the signal to noise ratio and activates the right frontal lobe as well as the parietal lobes during sustained vigilance.

Music cognition

Within the field of music cognition, attention to music may also be considered a primary initial step in the music perception processing chain. The aesthetic theorist, Berlyne (1971) believed that music had a unique connection with attention through music's effect of maintaining a listener's attention as it unfolds over time. From an arousal perspective, Berlyne (1971) viewed music's temporal quality as unique within the category of aesthetic stimuli. Investigators from a variety of disciplines have been interested in how music arouses a listener's attention. Experiments designed to illuminate differences in attentional processing caused by level of musicianship, as well as specific musical elements; including dynamics, melody, and rhythm have been performed to date.

Geringer and Madsen (1995) found a difference in attention to musical elements based on level of musicianship when listening to classical music. Although not stated as such by these authors, their study may be understood as an investigation of selective attention. They found a difference between musician and non-musician listening patterns, using a criteria for musicianship of two years or more of private music lessons and/or ensemble playing experience. Of the five elements included; rhythm, dynamics, timbre, melody, and "everything", results showed that musicians rated timbre higher than non-musicians, whereas non-musicians more highly rated dynamics and melody. These investigators also found that musicians were more able to identify specific elements. Both groups had higher preference ratings when melody was perceived as salient, and both groups rated rhythm equally low. According to this study, musicians seem to perceive musical stimuli differently than non-musicians.

Huron (1992) discussed the differential effect of musical intensity (dynamics) on passive attention, with increases causing a more robust effect, particularly at a gradual pace, and decreases being much less effective unless sudden and dramatic. He proposed that many classical composers used this model of dynamic manipulation for the purpose of sustaining a listener's passive attention through a ramp archetype of intensity building. The author defined the "ramp archetype" (Huron, 1992) as a pattern of gradual intensity building, followed by an immediate drop of intensity, such that the next ramp can be reconstructed. A similar effect was found in vocal music with more attention allocated to vocal additions of vocal parts than deletions.

Melodic pattern recognition tasks with competing melodic lines have been used to study the relationship between attention and pitch. Sloboda (1985) reports that underlying harmonic structure facilitates attending to simultaneous melodic events. Error detection tasks demonstrated subjects greater ability to detect errors an octave apart compared to intervals of a 4th. Indeed, research on the vertical axis of musical space indicates that harmonic coherence is more important than space between notes. Overall, research in the area of pitch has produced the following attentional principles; 1. Attention is pulled to the melody in the highest pitch range. 2. Melody lines can be differentiated by manipulations of dynamics, timbre, and movement contrasts. 3. Attention is pulled by a change of quality or texture in the focal line; including novelty or additional lines creating an orienting response. 4. Attentional conservation is achieved by avoiding changes in competing parts encouraging sustained attention to the same melodic lines (Sloboda, 1985).

<u>Rhythmic attending</u>

The connection between rhythm and attention is evident in the Seashore rhythm test, still utilized in the Halstead-Reitan neuropsychological battery today as an indicator of auditory attention (Mateer & Mapou, 1996). However, rhythm has not received the interest nor amount of research as other musical elements in terms of examining attentional principles. Despite this research atmosphere, Mari Reiss-Jones and her colleagues have been investigating a rhythmic model of attending for the past ten years.

Jones (1986) criticized attention theories from the information processing paradigm which have defined time as processing time, or time required to encode a stimulus. Indeed, response time has been a valuable measurement in attention research. “Time” in Jones’s theory of rhythmic attending pertains to the dynamic aspects of attending, including the interplay of the person’s attention and the stimulus timing. She asserted that while cognitive psychology research trends have identified how subjects select to what they will attention, questions of how subjects determine attentional timing to a stimulus have not been addressed. In targeting attention, a subject may demonstrate the following rhythmic errors; anticipation-ahead of stimulus, late-miss stimulus, or synchronized attending-in phase. Attentional timing is influenced by temporal predictability. Spatio-temporal occurrences in the environment can shape attentional timing as can the needs of the subject. The author asserted that “synchronous attending determines perceptual learning” (Jones, 1986, p.22). Research on spoken language lends support to this theory. Prosodic information including accents and intonation have been shown to prepare listeners for timing of attentional focusing. Indeed, as LaBerge (1995) stated, the retard of a musical piece serves to assist the audience in timing their applause, which usually begins in unison. It may be easier to predict when an important stimulus will occur, than what it will be, particularly in the event of novelty. Temporal and melodic invariants appear to be abstracted from the presented stimulus to be used when encoding similar stimuli. Empirical research in both visual and auditory modalities supported Jones’s theory of rhythmic attending. Skelly, Hahn, & Jones (1983) found an interaction of temporal context and temporal deviation on a visual time judgment task. The task involved viewing a circular array of eight unfolding radial lines, either at a pace of every 200 milliseconds (isochronous rhythm context), or at a varied presentation rate. Subjects errors were consistent with predictions that an entrainment effect occurred in the isochronous rhythm condition to the 200 millisecond level (referent level), whereas in the varied rhythm condition, subjects demonstrated a larger referent rhythm.

Jones, Boltz, & Kidd (1982) investigated effects of melody and tempo on attention. Their hypothesis was that temporal context directs selective attention towards or away from various melodic positions. Short rule-generated melodies consisting of nine tone patterns arranged in three groups of 3 pitches and a maximum of 12 beats were composed. This study was a revision from a previous experiment because the melodies were found to be too complex for adequate subject performance. Four different rhythmic patterns with variances in accents were utilized, and melodic alterations were based on varying gestalt principles. They found that rhythmic context directed listener's attention to specific serial position errors. Furthermore, temporal predictability enhanced pitch error detections and was a facilitating factor to selective attention processes. Subjects also performed best when higher-order gestalt violations were detected. Jones (1992) expanded her theory of rhythmic attending by proposing that the listener's attention entrains at a referent temporal level of music through a cognitive "rhythm generator". The referent time level exists between detail-oriented and future-oriented attending, thus providing a temporal anchor. Detail-oriented or analytic attending is focused and exists for a short duration. An example may be if a listener directs their attention to each beat or individual pitch within a melody. Future-oriented attending, considered preparatory attention by LaBerge (1995), is more global and exists in large time periods. In musical terminology, this may be a melodic phrase or a movement of a piece. The referent-level of attending to music consists of the measure. In extension of this temporal theory, the author proposed that the size of the serial integration region (SIR) is relative to the level of temporal attending. Therefore, in analytic attending the serial integration region is low, perhaps within one serial position. The SIR expands as the temporal attention level shifts from analytic to referent and finally to future-oriented where the largest SRI occurs. The degree to which musical elements are integrated into an ongoing pattern is determined by the temporal level of attending. In support of this theory, the author and research team found temporal expectancy errors occurring at the referent level of the endings of four measure folk melodies when the preceding referent level measure was either elongated or reduced. Interestingly, the variations in rhythmic extension or reduction occurred one measure before the tempo expectancy errors, demonstrating that attentional entrainment may occur relatively quickly and automatically based on the preceding rhythmic phrase. In support of this theory, Shaffer (1993) in his writing on musical performance and attention discussed the referent points, or "attraction points" in music. He stated that because the tempo typically fluctuates in music expressiveness, an internal timekeeper must exist which "is a kind of programmable clock that can modulate its pulse rate under instruction from the motor program. Its demonstrable ability to return very accurately to a particular tempo shows that this clock has stable referents. If we think of the clock as a neural oscillator, then the referents can be seen as attractor points of the oscillatory system, and the rubato excursions, of speeding up and slowing down, as perturbations away from an attractor" (Shaffer, 1993, p.139).

Indeed, the auditory modality has been shown to be more temporally acute as compared to visual attention. Marks & Crowder (1997) demonstrated support for an auditory temporal acuity hypothesis. This hypothesis stated that "the temporal discriminability of auditory events is greater than that of visual events" (p.166). An auditory modality advantage for temporal distinctions explains evidence for modality specific differences of in terms of recall (Murdock, 1967). When subjects are given a list to remember, they demonstrate memory for the first and last items, referred to as recency and primacy effects (Murdock, 1960). Marks & Crowder (1997) demonstrated that "aurally presented word lists were more sensitive to temporal schedules of presentation" (p.164) as compared to visual presentations using a continual-distractor paradigm.

Boltz (1991) studied time estimation errors based on rhythmic and melodic modulations. Results indicated that different dynamic attending modes; detail, referent, and future, did effect subjects perceptions of length of music, known as the filled interval effect.

Clinical applications

Research in the field of neuropsychology has shown that attention is a highly remediable brain process, even in cases of diffuse and severe brain injury effecting memory (Mateer & Mapou, 1996). Cognitive rehabilitation strategies often assist effected individuals in improving attentional functioning. A multitude of strategies exist for improving attention in cases of ADHD, clinical depression, pain management and other disorders effecting attention. Rehabilitation of attention has fallen into three main categories; compensatory approaches, environmental modifications, and direct interventions. This last category, direct interventions, is aimed at restoring cognitive capacity (Mateer & Mapou, 1996). Music may apply to all three categories of attention rehabilitation. Music may also play a unique role in sustaining selective attention, thus creating a carrier wave and mediating response for individuals with cognitive impairments. Furthermore, one limitation of attention rehabilitation has been the question of generalizability. Studies have demonstrated that although TBI patients performance improved on cognitive tests of attention, they reported continued high levels of problems functioning in the real world (Mateer & Mapou, 1996). This finding has driven an interest in rehabilitation exercises which are more applicabe. Because music listening exercises aimed at improving attention can be learning in the rehabilitation environment and transferred to the real world, music may indeed have a role in cognitive rehabilitative applications.

Eccleston (1995) discussed evidence that chronic pain patients may be shifting attention between the pain stimulus and distractors to achieve psychoanalgesia. Previous research demonstrated that subjects experiencing high intensity pain perform poorly on cognitive tasks, while performance of subjects with low level pain is unaffected. The author concludes that pain is always perceived on a conscious level, and thus cannot be automated like many other perceptual processes. Because pain perception is always a controlled process, cognitive interference tasks must be highly demanding of central attentional resources. Furthermore, the task must not lend itself to automatization and should be varied and complex. McCracken (1997) supported an attention theory of pain management in a study which examined pain vigilance in subjects with chronic low back pain. Subjects reporting preoccupation with pain reported more pain intensity, emotional distress, psycho-social disability, and had higher pain-related health care utilization. Results of this study support the central role of attention in pain. Music distraction may facilitate a reduction in pain through causing attention shifting from pain to music stimulus, thus causing psychoanalgesia.

A distraction model seemed to underlie a study by Malone (1996) which examined the effects of live music on pain reduction in pediatric patients. A music therapist provided live music during a variety of painful medical procedures; intravenous starts, venipunctures, injections, and heel sticks. The music was utilized to distract the children from anxiety, fear, and pain as a consequence of the procedures. Results demonstrated a differential effect of live music pre and post needle phases demonstrating more success than during the need insertion. This study confirms theories of pain distractibility, that music has limited effectiveness when individuals are experiencing high intensity pain. However, lower levels of pain may be minimized through music as distraction.

Morton, Kershner & Siegel (1990) presented empirical support for the use of music with individuals with problems related to memory and attention. The authors theorized that music utilized prior to an attention task could prime and possibly focus attention through arousal mechanisms in the brain. Because the researchers were interested in examining hemispheric lateralization, the attention task utilized was a dichotic listening test involving free report, directed left ear, and directed right ear. Results supported a bilateral arousal hypothesis, in that overall performance on the free recall task increased. These results were interpreted by the authors as evidence for an overall cerebral arousal, facilitated by the right hemisphere, in response to the music prior to the tasks. Cerebral arousal may facilitate sustained attention.

Teasdale et al. (1995) proposed a model called Attentional Control Training (ACT) with depressed individuals, aimed at preventing relapse. This approach integrates cognitive therapy and attention training. The authors proposed that by "redeploying the resources necessary for the maintenance of that configuration (depressive schema) to the processing of other, non-depressogenic information" (p.30), the individual prevents a reoccurrence of depression. This is similar to a distraction model, however, the attentional resources must be fully engaged elsewhere in order to be disengaged in focusing on the depression. Although the authors do not specifically address music, it is a possible stimulus which may create non-depressogenic schemas through active listening utilizing attentional resources.

CHAPTER THREE: HYPOTHESES

This study investigated performance on an auditory target detection task under four stimulus conditions. Slow versus fast tempo of the music stimulus, and upper register versus lower register target were utilized to examine performance effects. In order to analyze the data statistically, the following null hypotheses were tested:

1. For the main effect of temporal condition, there will be no significant difference between task performance in the slow and fast tempo conditions.

2. For the main effect of register of target, there will be no significant difference between task performance in the upper and lower register conditions.

3. There will be no significant interaction between tempo and register of target.

In addition, responses to debriefing questions concerning strategies utilized were also correlated with task performance to examine differential effects of strategy utilized. The following null hypothesis was considered:

1. There will be no significant difference in task performance by strategy.

CHAPTER FOUR: METHODOLOGY

Subjects

Subjects were recruited from the current undergraduate students in the Department of Social Work. All potential subjects were asked to respond to demographic questions including gender, age, current GPA, and history of musical experience (see Appendix 1). Criteria for exclusion due to musical knowledge was based upon prior research (Geringer & Madsen, 1995) and included a minimum of two years of musical training or playing in the past five years. Twenty subjects completed the music listening experiment and nineteen valid cases were analyzed. One subject was eliminated due to no responses being recorded under any of the conditions. Subject ages ranged from 18 to 47 (M = 24, sd = 7.9). Of the 18 females and 1 male, fifteen subjects were majoring in social work and four were majoring in another field, but were currently enrolled in an undergraduate social work course. The mean grade point average was 3.1, ranging from 1.2 to 4.0, (sd =.595). The mean years of musical experience was 1.9, (sd. = 2.15) ranging from 0 to 6 years. No subject reported musical experience of more than two years in the last five years.

Following the experiment, subjects were asked to complete the following open-ended debriefing questions; 1. On a scale of 1-10, with 1 being low and 10 being high, how difficult was this task? 2. Did you use any particular strategies? 3. Did you think that all four musical pieces were equal in length? 4. Were you able to sustain your attention during the task, or did you notice your attention wavering at a particular point?

Materials

A total of 4 musical test sequences were produced using an Ensonic keyboard and Vision computer program which allowed for manipulation of MIDI data. Dynamics were controlled by using a standard keyboard attack velocity of 66. All conditions were heard by subjects through stereo headphones at a medium volume level. The auditory target included a three note melodic (A, C, Bb) and rhythmic motif played on a synthesized piano sound.

One composition created by the author served as the basis for MIDI manipulation producing the other three conditions. The composition followed an ABCABC form with 16 measures within each section. Music test stimuli were in 4/4 meter with a target presentation every 4 measures. The target consistently occurred on the first beat of the third measure with an interpresentation interval (IPI) of 4 measures. Varied harmonic changes in the musical progression served as auditory distractors. Melodies which utilized the rhythmic shape of the target, but substituted different notes were specifically created to act as distractors. The target appeared at regular time intervals with the exception of target 10, which inadvertently was recorded at the beginning of the phrase. Each condition was preceded by two presentations of the target in the register of the subsequent target condition. The upper register conditions presented the target within one register above middle C (higher register condition), and lower register conditions transposed the target down one octave (lower register condition). In producing the lower register condition, no other changes occurred from the original music stimulus except the octave of the target. During one such transposition of target 11, a rhythmic change in the target occurred such that this target was eliminated, leaving a total of 24 targets in each condition. Temporal conditions included a fast tempo of 120 beats per minute, and a slow tempo rate of 80 beats per minute, calculated by using a 40% tempo reduction coefficient. Total time of musical stimulus in the slow tempo condition was 4.87 minutes, with one beat equal to .8 seconds. In the fast tempo condition, the length of the musical stimulus was 3.21 minutes with one beat equal to .5 seconds. The tempo of the target remained consistent with the tempo of the musical piece.

Design

A repeated measurements design was used with a counter-balanced presentation within the upper and lower register stimulus conditions and across all tempo conditions producing the following four orders of presentation:

Presentation 1:slow/upper, fast/upper, slow/lower, fast/lower

Presentation 2: fast/upper, slow/upper, fast/lower, slow/lower

Presentation 3: slow/upper, fast/upper, fast/lower, slow/lower

Presentation 4: fast/upper, slow/upper, slow/lower, fast/lower

Tables 1 and 2 illustrate the independent and dependent variables respectively.

Table 1: Independent variables under study

Factor	Tempo	Register	Time Segment
Levels	1. Slow 2. Fast	1. Upper 2. Lower	1. Beginning 2. Middle 3. End

Table 2: Dependent variables under study

Dependent Variables **Selective Attention**	**Sustained Attention**	**Strategy**
Sum of correct responses by condition	Sum of correct responses by time segment	Strategy utilized by subject
Sum of commission errors by condition		
Mean response time by condition	Mean responses time by time segment	

Accuracy of responses measured by number correct, commission errors and quickness of response time were the main indicators of selective attention. The range of response correctness was calculated from the onset of the first note of the target to 1 second post the onset of the third note in the fast condition and 1.5 seconds post onset of the third note in the slow condition. Keyboard presses between the onset of the first and third notes of the target were calculated as negative numbers in real time prior to the onset of the third note. Audio data analysis was performed using Sound Designer II, produced by Digidesign. This program is utilized in the audio tape analysis of court evidence to determine authenticity. All keyboard presses falling outside the region of correctness were considered commission errors. Accuracy measurements were segmented by three time regions; beginning, middle, end, to create indicators of sustained attention. These time segments created balanced conditions in terms of musical form; beginning; AB, middle; CA, end; BC.

Strategy utilized was determined through subject self-report to the second debriefing question, "Did you use any particular strategies?". Subjects were not provided with a list of strategies from which to choose. The question was meant to be open-ended and information generating. Responses were analyzed qualitatively.

Data Analysis

Data was analyzed using SPSS 7.5 for Windows. Group comparisons were examined using factorial analyses of variance (ANOVA). Correlations of subject demographics with dependent variables were examined with Pearson correlation coefficient. A least significant difference test of multiple comparison (LSD) was used as a *post hoc* measure.

Procedure

Potential subjects completed a demographic interview and those meeting criteria for non-musician proceeded with the experiment after signing an informed consent form (Appendix 2).

Each subject was read the same experiment instructions by the author (Appendix 3). Four musical test conditions were presented to each subject for a total time of approximately 20 minutes. Subjects were instructed to strike a note on the keyboard immediately each time they heard the musical target. The subject's keyboard press was recorded on a Fostex X-15 Multi-tracker four-track recorder to provide audio data for analysis. Debriefing questions followed completed task performance.

CHAPTER FIVE: RESULTS

Subject Data

A Pearson Correlation Coefficient showed no significant correlation between correct responses and GPA ($r = .040$, $p = .870$). Descriptive statistics were calculated to summarize subject responses to debriefing questions. The mean score of perceived level of task difficulty on a Likert scale of 1-10, higher indicating increasing difficulty, was 5.0 (sd = 2.4), ranging from 1 to 9.5. Fifty three percent of subjects reported equality of length of the four conditions, and forty seven percent recognized the differences in length. Thirty seven percent of subjects reported that their attention wavered at the end of the whole experiment, 11% reported attention wavering in the beginning of each condition, 11% at the middle of each condition, and 11% at the end of each condition. Eleven percent reported their attention wavering more in the slow conditions and 11% reported sustained attention.

Subjects reports of strategies used were analyzed qualitatively and categorized by content. Strategy responses are displayed in Table 3.

Table 3: Subject reported strategies utilized.

Subject	Response	Category
1	None	No strategy
2	None	No strategy
3	Recognized the song. Memorized the first one.	Anticipation/Timing
4	By the fourth one I knew when to expect it (target).	Anticipation/Timing
5	I knew it was the same song. I improved over time.	Anticipation/Timing
6	Repeated it (target) over in my head.	Recognition
7	Kept on saying the little tune (target) in my head.	Recognition
8	Got better over time. Learned when to expect it (target).	Anticipation/Timing
9	Repeat target in my head.	Recognition
10	Learned the rhythm. Knew when it (target) would come.	Anticipation/Timing
11	None, just concentrated.	No strategy
12	None	No strategy
13	Listened for the first two notes, but that didn't work so I learned to wait.	Anticipation/Timing
14	I recognized the pattern.	Anticipation/Timing
15	Tried to hear where it was in the song to predict it.	Anticipation/Timing
16	Improved at the end. Started off listening to the high end stuff.	Recognition
17	Last two were easier because I closed my eyes, didn't concentrate on the whole song, just listened for the target.	Recognition
18	Tried to concentrate on it (target), concentrated too hard, had to find a balance.	Recognition
19	At first I listened to the whole piece. Then I reduced the listening area to the lower part so the third and fourth ones were easier. I tuned out the melody.	Recognition

The resulting three categories of responses were defined as follows; 1. anticipation/timing strategy-focus on timing and the interpresentation interval (IPI) of target occurrence within the song, may indicate referent or future-oriented attending, 2. recognition strategy-recognizing the target by shape and specific notes, may indicate detail-oriented attending, 3. no strategy-included simple concentration or no strategy reported. 42% (eight subjects) were categorized as using anticipation/timing strategy, 36.8% as utilizing the recognition strategy, and 21% as utilizing no strategy. Strategy was further analyzed in terms of performance and is discussed later.

Order Effect

A one way ANOVA was performed to analyze the effect of the order of the presentation of experimental conditions. If an order effect was found, there may be evidence of a practice effect in which subjects improved their performance by learning over time. Results of the ANOVA using number of correct responses by presentation indicated no significant difference ($F = 1.389$, $p = .253$). The means ranged from 13.95 to 18.53 correct responses and are presented in Table 4.

Table 4: Mean correct responses by order of presentation

Presentation order	**Mean Correct Responses**	**Standard Deviation**
First	M = 13.95	sd = 8.3
Second	M = 16.84	sd = 7.16
Third	M = 15.68	sd = 5.74
Fourth	M = 18.53	sd = 7.1

A pattern was observed in which an increase in mean was seen between the first and second presentation and the third and fourth presentation. This may have indicated a possible practice effect within register. Therefore a *post hoc* t-test was used to examine this effect. The t-tests comparing the upper register conditions presented first and second ($T = -1.151$, $p = .257$) and the lower register conditions presented third and fourth ($T = 1.358$, $p = .183$) resulted in no significant difference.

An order effect based on response time did not meet significance using an ANOVA ($F = .948$, $p = .422$). Because mean response times decreased between the first and second presentations (M = .469, M = .414), as well as between the third and fourth presentations

(M = .487, M = .417), a t-test was performed to examine a possible order effect within register. Results were not significant for upper register between the first and second presentations (T = 1.062, p = .296) nor for lower register between the third and fourth presentations (T = 1.262, p = .215).

Selective Attention

Selective attention was measured by task performance accuracy using three dependent variables. These included number of correct responses, number of commission errors, and response time analyzed by condition. Response time was used to indicate speed of performance with lower numbers reflecting greater attention and target recognition. Nineteen total cases were analyzed under the four conditions.

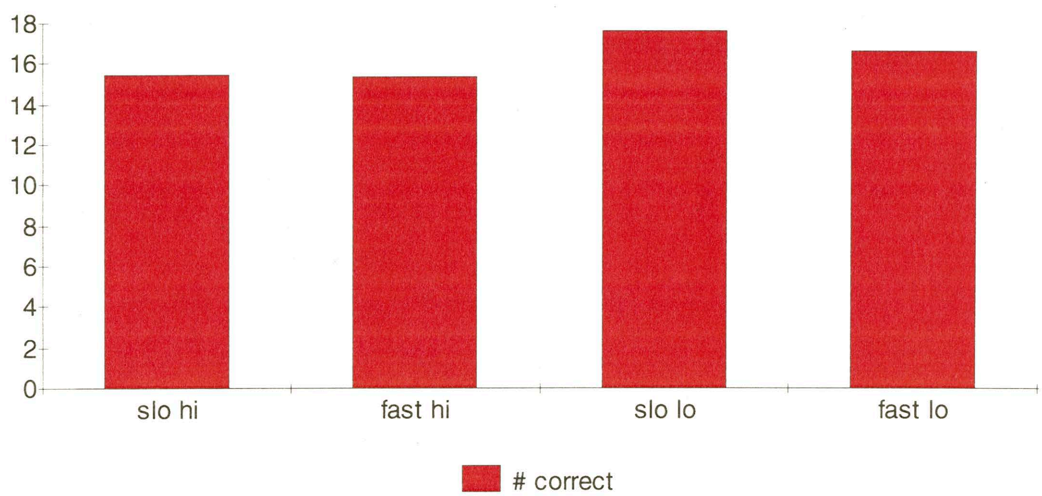
Correct Responses

Descriptive statistics demonstrated strong similarities between varying register and tempo of the musical test stimulus. The mean correct response scores under the four conditions ranged from 15.37 to 17.58, a range of 2.21. The grand mean of correct responses was 16.25, showing an average performance of 68% correctness. The means and standard deviations are presented in Table 5 and displayed in Figure 1.

Table 5: Mean correct responses by condition

Condition	Mean correct responses	Standard Deviations
Slow/upper	M = 15.42	sd = 8.6
Fast/upper	M = 15.37	sd = 7.1
Slow/lower	M = 17.58	sd = 6.1
Fast/lower	M = 16.63	sd = 7.1

Figure 1: Mean number correct by condition



An analysis of variance (2-Way ANOVA) did not demonstrate significant effects of the interaction of tempo and register on mean correct responses. Results are presented in Table 6.

Table 6: ANOVA Table: Correct responses by tempo and register

		SS	df	MS	F	Sig.
Main Effects	Tempo	4.75	1	4.75	0.09	0.765
	Register	55.59	1	55.59	1.05	0.309
Interaction Effects	Tempo x Register	3.8	1	3.8	0.07	0.789

Commission Errors

Mean commission errors under the four conditions ranged from 3.74 to 6.53, a range of 2.79. Descriptive statistics produced the following means by condition; Slow, upper register; M = 3.74. Fast, upper register; M = 6.53. Slow, lower register; M = 5.47. Fast, lower register; M = 4.16. The grand mean was 4.97. Although mean commission errors appear to vary strongest between tempo conditions, a 2-Way ANOVA of interaction effects of tempo and register by commission errors demonstrated no significant results at the .05 level. Results are displayed in Table 7.

Table 7: 2-Way ANOVA Table: Commission errors by tempo and register

		SS	df	MS	F	sig.
Main Effects	Tempo	10.316	1	10.316	0.087	0.769
	Register	1.895	1	1.895	0.016	0.9
2-Way Interactions	Tempo x Register	80.053	1	80.053	0.674	0.415

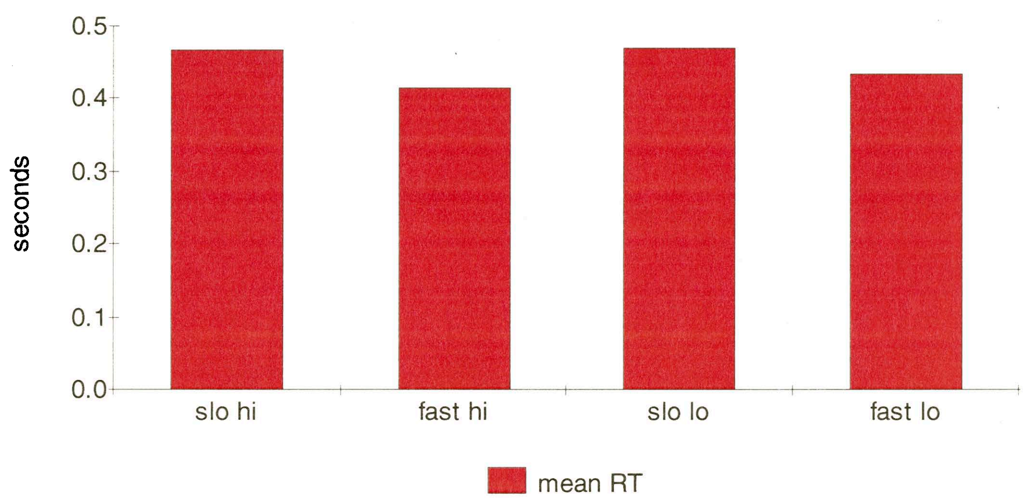
Response Time

Subjects response time was measured from the onset of the third note of the target to the attack of the subject's keyboard press in milliseconds. Correct responses prior to the onset of the third note of the target were represented as negative numbers. Mean responses by target by condition and total means of variables are displayed Table 8. Mean response times are illustrated in Figure 2. The grand mean was .457 sec.

Table 8: Mean response time by variable and by condition

Condition	Total Means by Variable	Mean Response Time
Slow/Upper	Slow = .469	M = .468
Fast/Upper	Fast = .424	M = .415
Slow/Lower	Upper Register = .441	M = .471
Fast/Lower	Lower Register = .452	M = .433

Figure 2: Mean response time by condition



There were no significant interaction effects of mean response times in seconds by tempo and register as illustrated in Table 9.

Table 9: 2-Way ANOVA Table: Response time by tempo and register

		SS	df	MS	F	Sig.
Main Effects	Tempo	0.0387	1	0.0387	1.419	0.238
	Register	0.0022	1	0.0022	0.082	0.776
2-Way Interaction	Tempo x Register	0.01062	1	1.062	0.039	0.844

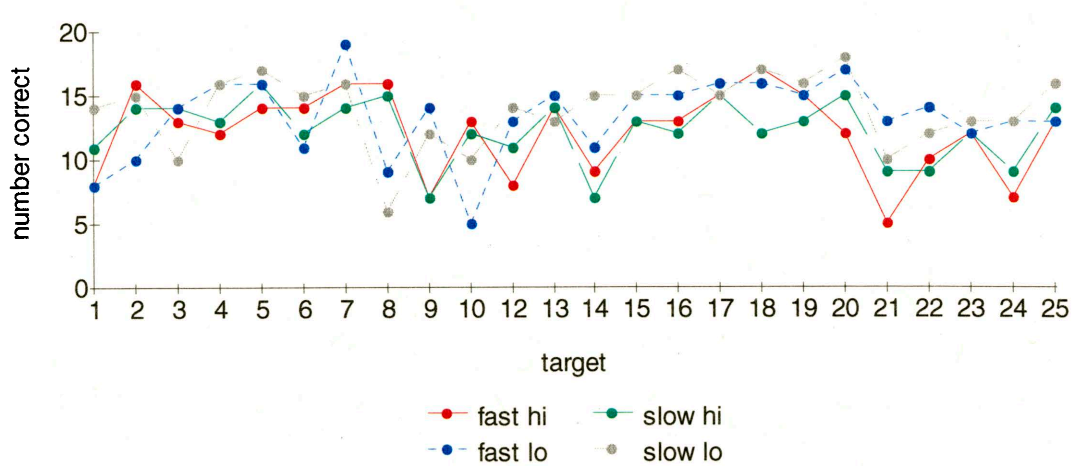
Sustained Attention

In order to examine sustained attention, two dependent variables of correct responses and response time were grouped by time segment; beginning = targets 1-8, middle = targets 9-16, end = target 17-24. Grouping of data provided information on how attention varied by time within conditions.

Correct Responses

Figure 3 illustrates the number of subjects who correctly identified each target. This provides a visual display of performance over time.

Figure 3: Correct responses by target



Number of correct responses were counted within the three time segments: beginning, middle, and end, to examine effect of accuracy over time as a measure of sustained attention. The mean number correct by time segments are displayed in Table 10. The grand mean was 5.45.

Table 10: Cell means: Number correct by tempo, register and time segment

	Beginning	Middle	End	Total
Slow	High 5.74 Low 5.74 Total 5.74	High 4.79 Low 5.84 Total 5.32	High 4.89 Low 6.05 Total 5.47	High 5.14 Low 5.88 Total 5.51
Fast	High 5.74 Low 5.42 Total 5.58	High 4.84 Low 5.47 Total 5.16	High 4.79 Low 6.11 Total 5.45	High 5.12 Low 5.67 Total 5.39
Total	High 5.74 Low 5.58	High 4.82 Low 5.66	High 4.84 Low 6.08	High 5.13 Low 5.77

Results of the 3 way ANOVA are displayed in Table 11 and show no significant interaction effects.

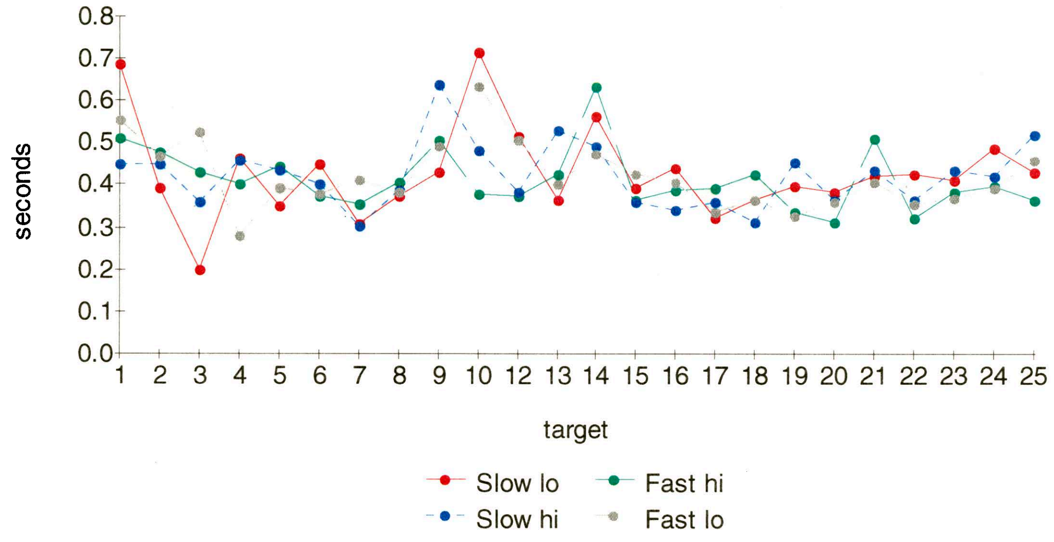
Table 11: 3-Way ANOVA: Number correct by tempo, register, and time segment

		SS	df	MS	F	Sig.
Main Effects	Tempo	0.741	1	0.741	0.115	0.735
	Register	23.373	1	23.373	3.631	0.058
	Time Segment	6.746	2	3.373	0.524	0.593
2-Way Interactions	Tempo x Register	0.531	1	0.531	0.082	0.774
	Register x Time	19.64	2	9.82	1.526	0.22
	Time x Tempo	0.219	2	0.11	0.017	0.983
3-Way Interactions	Tempo x Register x Time Segment	0.904	2	0.452	0.07	.932

Response Time

Figure 4 displays mean response time by target to illustrate sustained attention performance.

Figure 4: Mean response time by target



Response times were averaged within the three time segments. The grand mean was .447. The means are displayed in Table 12.

Table 12: Mean response time per time segment by tempo, register and time segment

	Beginning	Middle	End	Total
Slow	High .459 Low .465 Total .462	High .499 Low .474 Total .486	High .438 Low .459 Total. 449	High .466 Low .467 Total .466
Fast	High .414 Low .428 Total .421	High .468 Low .466 Total .467	High .380 Low .414 Total .398	High .420 Low .437 Total .428
Total	High .436 Low .446 Total .441	High .483 Low .470 Total .476	High .407 Low .437 Total .423	Total .447

A 3-Way ANOVA showed that no effects demonstrated statistical significance at the .05 level. Results are presented in Table 13.

Table 13: 3-Way ANOVA: Mean response time per time segment by tempo, register, and time segment.

		SS	df	MS	F	Sig.
Main Effects	Tempo	7.441	1	7.441	1.937	0.166
	Register	3.914	1	3.914	0.102	0.75
	Time Segment	0.103	2	5.174	1.347	0.262
2-Way Interactions	Tempo x Register	2.837	1	2.837	0.074	0.786
	Register x Time	1.51	2	7.552	0.197	0.822
	Tempo x Time	8.892	2	4.446	0.116	0.891
3-Way Interactions	Register x Time	4.802	2	2.401	0.006	0.994

Strategy

Strategies utilized were grouped by content analysis using responses to the debriefing question, "Did you use any particular strategies?" Responses and grouping category are previously displayed in Table 3. Whether strategy significantly effected performance was examined statistically. Descriptive statistics are displayed in Table 14.

Table 14: Descriptive statistics of strategy by total correct and mean response time.

	Strategy	**N**	**Mean**	**sd**
Mean response time	No strategy	4	.43074	.12462
	Anticipation/timing	8	.37324	.12463
	Repetition	7	.53501	.10030
Sum correct responses	No strategy	4	55.75	29.90
	Anticipation/timing	8	74.38	14.78
	Repetition	7	59.57	29.74

A 1-Way ANOVA showed a significant effect of strategy by grand mean of response time. Results are displayed in Table 15.

Table 15: ANOVA Table: Correct responses and mean response time by strategy

	SS	**df**	**MS**	**F**	**Sig.**
Mean response time					
Between groups	9.873E-02	2	4.937E-02	3.662	.049*
Within groups	.216	16	1.348E-02		
Sum correct responses					
Between groups	1251.661	2	625.830	1.052	.372
Within groups	9520.339	16	595.021		

* < .05

Since there was a significant finding in the ANOVA, a least significant difference (LSD) multiple comparison *post hoc* analysis was performed. This procedure identified the strategies used by subjects which were significantly more effective than other strategies. Results (Table 16) indicated that subjects who used the anticipation/timing strategy were significantly quicker in their responses than those using the repetition strategy.

Table 16: Multiple comparisons of strategies by mean response time

Strategy Used (I)	**Strategy Used (J)**	**Mean Diff. (I-J)**	**Std. Error**	**Sig.**
Anticipation/Timing	No strategy	-5.75E-02	.071	.431
	Repetition strategy	-.16178	.060	.016*
Repetition	No strategy	.10427	.073	.171
	Anticipation/timing	.16178	.060	.016*
No strategy	Anticipation/timing	5.75.E-02	.071	.431
	Repetition strategy	-.10427	.073	.171

* <.05

CHAPTER SIX: DISCUSSION

Discussion of findings

Finding 1: Tempo and register had no significant effect on performance.

The analysis of selective attention performance using number of correct responses, number of commission errors, and response time, showed no significant effects for tempo or register. These results may be due in part to the easiness of target recognition, as evidenced by the 68% average correctness rate. Considering that subjects all met the criterion for non-musicians, this performance rate appears surprisingly high. The high performance rate was further unexpected considering the minimal distinctiveness of the target (Marks & Crowder, 1997, Murdock, 1960) embedded within the musical pieces. Results of selective attention performance indicate two possible conclusions; the experimental test stimulus was too easy and did not measure the intended variables, or the musical elements manipulated did not produce an effect upon selective attention.

The test stimulus created by the author was modeled upon visual target detection tasks (Halperin, 1996) utilized to measure attention. It is possible that the target was too easily detected by subjects to require the intensity of attention necessary for experimental conditions. As Pawuet & Craig (1997) demonstrated, selective target processing may be effected by the level of task difficulty. Task difficulty could be enhanced by increasing the target size to more than three notes, increasing the number of rhythmically similar distractors, or making less frequent appearances of the target, thus increasing the interpresentation interval (IPI) beyond four measures. In addition to task demand, the lack of effect of tempo on performance may indicate the need to utilize a wider tempo range when investigating auditory task performance. Indeed, tempo in this experiment varied from 80 bpm to 120 bpm. Results may indicate the need for a tempo difference of more than 40%. Finally, because the musical test stimulus did not have validity and reliability measures, it may not have accurately tested for attention.

An alternate explanation for the results is that the modulation of tempo and register did not effect selective attention. Consider first the manipulation of register of target presentation. The lack of an effect of register does not support attention processing principles outlined by Sloboda (1985). Sloboda predicts that attention is pulled to the melody in the highest pitch range. On the contrary, in this study subjects performed equally when the target was in the lower register. Sloboda also included novelty as a factor in facilitating auditory attentional orienting. The repetitive target used in this study reduces the possibility that novelty was a factor. Furthermore, subjects essentially heard the same song four times. It is possible that varied harmonic distractors encompassing the target may have produced enough novelty to maintain attention to the task.

The tempo changes did not demonstrate an effect upon task performance. It is possible that the regularity of target presentation within the music stimulus may have created an entrainment effect which facilitated good attending despite the manipulation of tempo. As Jones' (1992) theory of rhythmic attending explains, the timing of attention is essential in good attending.

The results may be alternatively explained by the primacy of timing in auditory selective attention, a referent entrainment hypothesis. Because neither register or tempo manipulation effect timing, this hypothesis may explain the results of the present experiment. Although tempo was varied, the rhythm of the music and the interpresentation interval (IPI) remained constant. As others have argued (Marks & Crowder, 1997), auditory attention may demonstrate a primacy of timing mechanisms as compared to visual attention. Support for this argument is derived from Cohen's (1993) assertion that the temporal lobes contain neural systems involved in the timing and sequencing of attentional information. Considering the importance of the temporal lobes and auditory cortex in processing the musical stimulus, there may be a neurological basis for the importance of timing in auditory attention. If indeed an auditory attention timing mechanism can be easily reset, as argued by Shaffer (1993), then tempo should not effect performance where the target interpresentation interval (IPI) does not vary. The IPI did change between varied tempo conditions, but remained constant within each condition. In the fast condition (120 bpm) the IPI = 8 seconds, compared to the slow condition (80 bpm) where the IPI = 12.8 seconds. A referent entrainment hypothesis would indicate that subjects utilized a target to target time estimation to predict subsequent targets. Subjects may have utilized two referent points; the musical phrase referent which consisted of four measures, and the target IPI referent. The target IPI referent also consisted of four measures but began at a different referent point in the musical stimulus. These two main time referents may have been included in subject's cognitive time generator. Although Jones (1992) names this concept as a "rhythm" generator, a "time" generator may be more useful in explaining the results of the current investigation. It would be interesting to examine whether changes in the IPI would create specific target timing errors. Jones et. al. (1982) demonstrated timing specific errors using the musical measure as the referent. It is possible that subjects who utilized the anticipation/timing strategy were specifically making use of the cognitive time generator principle. Subjects utilizing this strategy demonstrated significantly quicker response times than those using the repetition strategy ($p = .016$).

Finding 2: There was no effect of time segment on performance.

Subjects appeared to sustain their attention across all conditions regardless of the actual length of the music stimulus. A visual analysis of Figures 3 and 4 (p. 34, 36) clearly illustrate the generally level slope of performance across time. The analysis of mean response time by time segment showed a reduction in performance in the middle time segment in terms of response times. However, no time segment; beginning, middle, or end, showed significantly different performance measures. This result is surprising considering the rapid fatigue predicted by cognitive theorists over time in performance on continuous target detection tasks (Rumbaugh & Washburn, 1996). This may be explained by the short amount of time required to attend to the present experiment, with the fast and slow tempo condition including 3.21 or 4.87 minutes respectively. In the varied register conditions, the widest range of means appeared in the end time segment. This end time segment is of particular interest because a practice effect would predict improved scores whereas attention fatigue would predict reduced scores. Mean number correct scores showed that performance improved from beginning to end time segment in the lower register conditions (5.58, 5.66, 6.08) demonstrating a possible learning effect, whereas performance diminished in the upper register conditions (5.74, 4.82, 4.84), demonstrating a possible fatigue effect. However, mean number correct were not significantly different between varied register conditions.

Another factor which effects sustained attention is motivation (Tomporowski & Tinsley, 1996). Because there was no external motivation for skillful performance, it may be that motivation to sustain attention occurred through the stimulus attributes. As LaBerge (1985) confirmed, object attributes play an important role in sustaining attention. This is supported by Berlyne (1971) who argued that the temporal unfolding of music is intrinsically motivating. Sloboda (1985) also predicted that consistent attention to the same melodic line creates conservation of attention. Because the target was either in the upper or lower register, attention conservation may have been facilitated. It would be interesting to vary the target presentation by different registers within conditions to examine effect on sustained attention.

Finding 3: Mean response time occurred at 447 milliseconds.

This result indicates some measure of response time speed. Cognitive psychologists assert that attention encompasses three stages; encoding, central processing, and response organization/motor output (Sergeant, 1996). Performance speed in this auditory task was under 1/2 second. Considering that auditory conduction time occurs in 100 milliseconds, the 347 milliseconds remaining could explain the time needed for auditory attention.

Implications for Clinical Music Therapy

This experiment investigated how musical elements affect attention. Results supported the sustaining of attention to a musical stimulus regardless of tempo and register modulation. Subjects sustained their attention without any external motivations. The musical elements of tempo of stimulus and register of target did not effect selective attention performance. Results may be explained by experimental error or a cognitive time generator hypothesis. Based upon the findings, possible models for clinical music therapy which address attention are subsequently proposed.

Model 1: Music Facilitated Attention

This study demonstrated that sustained attention may be facilitated through the use of music listening tasks. This could be a useful clinical intervention for individuals who have attention disorders resulting in a limited attention span. As Barkley, (1997) and Van der Meer et. al. (1995) indicated, sustained attention has long been recognized as an primary symptom of attention deficit-hyperactivity disorder (ADHD). The current Diagnostic and Statistical Manual of Mental Disorders (DSM-IV, APA, 1994) includes three major types of ADHD; predominantly inattentive, predominantly hyperactive-impulsive, and combined types. Music therapy interventions which use a music facilitated attention model could be useful for the predominantly inattentive type of ADHD. In addition, music is aesthetic, thus creating motivation for sustained attention (Berlyne, 1971). Indeed, subjects in the present experiment did not receive an external motivation for performance, yet they performed well (68% correctness rate).

Disorders of attention are frequently reported following traumatic brain injury (TBI) (Mateer & Mapou, 1996). The authors indicated that sustained attention may be the least impaired aspect of attention, while focused, selective, and divided attention show more impairement. “TBI patients report problems with concentration, distractibility, forgetfulness, and doing more than one thing at a time” (Mateer & Mapou, 1996, p.2). The authors also included slowed response time in terms of symptoms of attention disorders caused by traumatic brain injury. Considering that attentional processing is a fundamental cognitive ability involved in many activities (Schmitter-Edgecombe, 1996), it appears that music therapy aimed at facilitating improved attention could be useful in cognitive rehabilitation with TBI patients. Most cognitive rehabilitation approaches utilize attention training exercises which involve, among other techniques, repetition, strategy training, and the use of feedback. Mateer & Mapou, (1996) emphasized that training exercises appear to improve attention on specific psychometric tests, however, TBI patients report that their functional attention skills in the real world remain impaired. This phenomenon has led to an interest in developing more training tasks which directly generalize to real world attentional functioning. For example, the meal preparation task has been utilized which evaluates attention by a frequency count of the number of cues needed to complete the task. Music listening tasks may create a bridge between the real world and the rehabilitation environment. Indeed, music listening is common in everyday leisure lifestyles. Even recording the amount of time a TBI patient could uninterruptedly listen to music could produce a measure of sustained attention, while also serving to restore sustained attention capacity. Additionally, the strategy of anticipation/timing of attention could be trained through music listening tasks. The general strategy of timing implies temporal processing which makes music a useful therapeutic tool due to its temporal quality. The predominant model for cognitive rehabilitation of attention is based upon a resource capacity theory (Schmitter-Edgecombe, 1996). However, according to Jones (1992), models which emphasize the timing of attention over capacity may introduce new explanations of attention processing.

As cognitive psychology paradigms become more integrated with neurological models, brain activation may become a more central principle in rehabilitation of attention disorders (Mirsky, 1996, LaBerge, 1995, Riddoch & Humphreys, 1994). A cerebral activation hypothesis of facilitated attention was provided by Morton et. al. (1990) based upon their study where music listening was found to improve attention on free recall and directed report tasks. The authors concluded that the music listening caused an overall cerebral arousal, facilitated by the right hemisphere explains the improved attention performance. This provides an alternative explanation of music facilitated attention.

Model 2: Attentional Distraction

Results of the present experiment indicated that attention was sustained throughout the music task regardless of the manipulation of tempo and register. This may indicate that music sustains attention and therefore would be a useful distractor. Indeed, subjects focused their attention on the music listening tasks for approximately twenty minutes. Not only is attention pulled by music, but attention is also maintained over time.

Prior research by Eccleston (1995) hypothesized that shifting attention between pain stimulus and distractors helped subjects achieve psychoanalgesia. Indeed, McCracken (1997) supported this hypothesis by demonstrating that persons with chronic back pain who focused attention on their pain reported more discomfort, pain intensity, and emotional distress. Live music has been shown to decrease the distress of pediatric patients receiving intravenous starts, venipunctures, injections and heel sticks with the most pain reduction occurring with procedures involving lower intensity pain (Malone, 1996). These studies demonstrate the validity of a distraction model in terms of pain management.

Music therapy applications using cognitive attentional strategies may be applicable to mood disorders as well. As Teasdale et al. (1995) outlined, using an Attention Control Training (ACT) program may reduce depressive relapses for individuals with major depression. The basis for this model involves the utilization of attentional resources in non-depressive tasks in order to eliminate the possibility of these resources being utilized more automatically in creating additional depressive schemas. Although not specifically mentioned in the article, music may serve as a useful distractor from negative interpretations of reality which lead to depression.

In order to validate the use of music as such a distractor, we must continue to study how music attracts attention. This direction of investigation may lead to principles of creating or choosing music which most facilitate attention, thereby creating a more applicable distractor. Huron's (1992) research identified the ramp archetype principle using dynamics to draw attention. Sloboda (1985) reported that attention is pulled to the melody in the highest pitch range, howver, this was not supported by the present study. Timbre, and novelty are additionally recognized by Sloboda as musical elements which pull attention. Results of this experiment did not support the manipulation of tempo to attract attention.

Clinical models, associated results of this study, and clinical populations affected are summarized in Table 17.

Table 17: Clinical implications

Clinical Model	Results	Clinical Population
Music Facilitated Attention	A. Music sustains attention. B. Anticipation/timing strategy facilitates attention.	Attention deficit-hyperactivity disorder (ADHD) Traumatic Brain Injury (TBI)
Attentional Distraction	A. Music sustains attention. B. Specific musical elements have varied effects on attention.	Chronic Pain Pain caused by medical procedures Depression

Limitations

The music listening task was created by the author in an attempt to apply the paradigms of visual search tasks to the auditory modality. Results of perceived task difficulty seem to indicate that the task's difficulty varied similarly to a normal distribution. Lack of validity and reliability measurements may raise questions regarding the strength of the results. The small sample size may have also limited the results. A design error occurred in the lack of counter-balancing the upper and lower register conditions. Because the lower register represented a more difficult condition, the author chose to present the higher register conditions first and second, and the lower register conditions third and fourth. Although there was no significant order effect, there may have been a practice effect which accounts for the slightly improved performance measurements in the lower register condition.

Future research

To further knowledge of attention-based music therapy interventions, it would be advantageous to compare the performance of college age subjects diagnosed with Attention Deficit Disorder to the subjects studied in this paper. Exploring more variations in the target in an experimental study would contribute to the knowledge of how music pulls attention and thus creates a useful distraction stimulus. For example, the regularity of target presentation could be varied to study the usefulness of various strategies of auditory attention. This study compared upper and lower register targets in separate conditions, however, an inclusion of both within one music stimulus may produce information on attention shifting within the auditory modality.

The cognitive timing generator hypothesis could be further investigated through an examination of possible target anticipation errors created by manipulation of the interpresentation interval (IPI) of an auditory target.

Appendix 1: Demographic data collection form

1. Demographic information

A. Age ___________

B. Gender M F

C. Major ___________

D. Current GPA ____

2. Musical experience

A. Have you had any musical training, playing in a band, or sung in a chorus?
Y N

B. If yes, please describe your musical experience.

Instrument	**Number of years studied/played**	**Number of years since last studied/played**

Appendix 2: Informed consent form

COLORADO STATE UNIVERSITY

INFORMED CONSENT TO PARTICIPATE IN A RESEARCH PROJECT

Thank you for agreeing to participate in this experiment, the effect of tempo and register modulation on sustained and selective auditory attention in a musical target detection task conducted by Christine Stevens and Michael Thaut, Ph.D. This experiment will study music and attention. Information gained will inform music therapy clinical practice in work with clients with attention problems or using music for distraction. During this experiment, you will be asked to listen to four musical excerpts lasting 3-5 minutes each. Within each piece of music there are a number of "targets", a 3-note melodic and rhythmic pattern, which you'll be asked to listen for specifically. When you hear the target, immediately press a note on the keyboard. Your responses will be recorded and analyzed later. At the end of the study, all recorded responses will be erased. Each participant will be assigned a number to protect your confidentiality. You will have a 1 minute music piece with a target for practice. The total time of the experiment will be between 15-25 minutes.

Although there are no known benefits, participants in this research may gain satisfaction knowing that they are helping advance scientific study of music and attention. Participants may also improve their musical perception skills. There are no known risks involved in this music listening task. It is not possible to identify all potential risks in an experimental procedure, but the researcher has taken reasonable safeguards to minimize any known and potential, but unknown, risks. If you have any questions or concerns please feel free to contact Christine Stevens at (970) 416-8974. Questions about subjects' rights may be directed to Celia Walker at (970) 491-1563.

The Colorado Governmental Immunity Act determines and may limit Colorado State University's legal responsibility if an injury happens because of this study. Claims against the University must be filed within 180 days of the injury.

Your participation in this research is voluntary. If you decide to participate in the study, you may withdraw your consent and stop participating at any time without penalty or loss of benefits to which you are otherwise entitled.

Your signature acknowledges that you have read the information stated and willingly sign this consent form. Your signature also acknowledges that you have received, on the date signed, a copy of this document containing 1 page.

____
Participant name (printed)

______________________________ _________
Participant signature Date

______________________________ _________
Investigator signature Date

Appendix 3: Introduction to experiment

Hello, my name is Christine and I want to thank you again for participating in this study. This will take about 20 minutes. Let me explain what you'll be asked to do. This experiment is an auditory version of what's called a target detection task. The target detection task has been used to research visual attention, but I'm using it to study auditory or listening attention. Let me give you an example. Imagine you are at a crowded concert searching for a friend. The friend is like the target and all the other people around are distractors. This experiment is like that scenario, but there will be a musical target that you will be asked to search for throughout each of four short music pieces.

Let me show you the target you'll be listening for. The musical target contains a three note melody that sounds like this....(experimenter plays the target twice). Could you play it back to me? (subject plays target once). Every time you hear this target, try to press the piano key immediately. The target will be played twice before each music piece to refresh it in your mind. There is a 10 seconds break between each piece of music.

There is no good or bad in this experiment. Just do your best and try to pay attention throughout the four pieces of music. If at any point you have a question, feel stressed, confused, or tired, please removed your head-phones and I'll assist you. Do you have any questions?

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