

THESIS

MUSICAL NEGLECT TRAINING FOR UNILATERAL VISUAL NEGLECT IN  
RIGHT HEMISPHERIC STROKE PATIENTS

Submitted by

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## ABSTRACT

### MUSICAL NEGLECT TRAINING FOR UNILATERAL VISUAL NEGLECT IN RIGHT HEMISPHERIC STROKE PATIENTS

The purpose of this study was to examine the immediate and longer-lasting effect of Musical Neglect Training (MNT) on unilateral visual neglect. A single-subject design was used, as participants served as their own control. Two individuals participated in this study. Participants underwent two weekly 30-minute individual sessions over a time period of three weeks, for a total of six MNT sessions for each participant. Two standardized assessments (Albert's and Line Bisection Test) were used. The assessments were administered immediately before and after each of the 6 MNT sessions to assess the immediate effect of MNT. During the training, participants played a set of horizontally arranged tone bars tuned to an ascending triads and scales. At the endpoint of each sequence a cymbal was positioned and played to give a strong audiovisual target in the left visual field for the participants. The experimenter provided a chordal accompaniment on the keyboard to provide harmonic-rhythmic pacing and to cue continuous playing to the end of the sequence. Follow-up testing was done one week after their 6<sup>th</sup> session to examine the longer-lasting effects of MNT.

Paired *t*-tests were used to test for statistical improvement between pre- and post-test of interventions (immediate effects). Also, nonparametric statistics (Wilcoxon Signed Rank Test) was also calculated in parallel with the paired *t*-tests due to the small sample size and possible violations of normal distribution. For the longer-lasting effects, raw data were compared between the average of 6 sessions' pre-test and follow-up test since there was only one follow-up test.

Both participants showed statistical improvement with Albert's Test in the immediate effect (Participant 1:  $p=.02$ , Participant 2:  $p=.01$ ). Results for the immediate effect of MNT on the Line Bisection Test were not significantly different, but means were lower for post-test (Participant 1:  $M=24.17\%$ , Participant 2:  $M=9.16\%$ ) compared to pre-test (Participant 1:  $M=25.65\%$ , Participant 2:  $M=10.39\%$ ), indicating positive improvement. Although not statistically significant for the longer-lasting effect, participant 2 had a lower score (score=7) compared to averaged pretest scores of the 6 treatment sessions ( $M=9.5$ ), indicating a positive outcome, while participant 1 was unchanged at follow-up score (score=14) compared to the pretest average ( $M=14.5$ ) in the Albert's Test. Moreover, participant 1 showed increased deviation percentages from the averaged pre-test ( $M=25.65\%$ ) to follow-up test (deviation =27.18%), indicating no positive effect for the longer-lasting effect in the Line Bisection Test. Participant 2 showed a decreased deviation in follow-up score (deviation=7.70%) compared to averaged pre-test score ( $M=10.39\%$ ).

The study indicates MNT as a potentially positive intervention for clients with unilateral visual neglect. Future research should employ this music-based intervention with clients in subacute recovery stages post stroke. Furthermore, developing the intervention protocol with increased duration and a higher number of sessions may result in stronger results. Based on the results from this study and previous studies, research focusing on the underlying neural mechanism and tailoring the intervention protocol appropriately to the clinical situation is warranted.

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## **CHAPTER I: INTRODUCTION**

### **Purpose**

The presence of unilateral visual neglect may decrease functional recovery and require more rehabilitation in patient's daily life. There are several techniques that are used to reduce neglect, such as visual scanning (Pizzamiglio et al., 2004), prism adaptation (Maravita et al., 2003), limb activation (Eskes, Butler, McDonald, Harrison, & Phillips, 2003), transcutaneous electrical nervous stimulation (TENS) technique (Beschlin, Cocchini, Allen, & Sala, 2012; Rose, Brooks, & Rizzo, 2005), and virtual reality (Rose et al., 2005). However, potential rehabilitation interventions based on adopting auditory stimulation and musical practice for unilateral visual neglect have not been studied in depth. With this in mind, the purpose of this study was to examine the effectiveness of Musical Neglect Training (MNT) on unilateral visual neglect in patients who have suffered a right hemisphere stroke. Specifically, this study was intended to provide initial data regarding immediate and longer-lasting effectiveness of MNT on unilateral visual neglect.

### **Problem/Need**

Unilateral visual neglect, also called hemi-spatial neglect, spatial neglect, hemi-neglect, is a neurological disorder characterized by a deficit in attention to stimuli on one side of the body, mostly, contralateral to the side of the lesion (Kim et al., 1999). Unilateral visual neglect typically occurs after right-hemisphere stroke (Cherney & Halper, 2001). According to the website of the National Stroke Association, there are an estimated 7,000,000 stroke survivors in the United States, and stroke is the fourth leading cause of death in America and a prominent cause of adult disability. Only 10% of stroke survivors completely recover. Another 75% have



mild to severe impairments, and the remaining 15% die shortly after the stroke. These data indicate that 75% of stroke patients still need functional rehabilitation to maximize their potential to regain function (National Stroke Association, 2014). Motor rehabilitation after stroke is well established (Barnes & Good, 2013). However, rehabilitation for unilateral visual neglect patients has been limited since visual neglect can be hard to identify (Lindén, Samuelsson, Skoog, & Blomstrand, 2005). Nevertheless, spatial neglect is a frequent outcome from right hemispheric stroke, and therefore it is hard to estimate the actual prevalence (Ringman, Saver, Woolson, Clarke, & Adams, 2004; Stone, Halligan, & Greenwood, 1993; Sunderland, Wade, & Hewer, 1987). Luauté, Halligan, Rode, Rossetti, and Boisson (2006) have pointed out that clinicians recognize the presence of left visuo-spatial neglect as one of the major factors related to poor functional outcomes. According to Barrett et al. (2006), despite the high prevalence, visual neglect was overlooked in 61% of patients during hospitalization in the United States. Persons who suffered from unilateral visual neglect are unable to process stimuli to one side of the body or in the environment. The symptoms cause significant difficulties engaging in functional daily life and crucial routines, such as eating, writing, reading, getting dressed, and combing hair.

Even though there are a number of different rehabilitation techniques/treatments that have been developed for visual neglect, many of the existing techniques do not demonstrate significant clinical effectiveness (Bowen, Lincoln, & Dewey, 2007; Riestra & Barrett, 2013). For this reason, an approach, using music as a rehabilitation technique for visual neglect has been developed by Thaut (2005) as a positive potential intervention to enable independent living in patients with visual neglect. Specifically related to this current study, a recently published study of neglect patients MNT study showed positive outcomes using training on a horizontally aligned tone bar instrument (Bodak, Malhotra, Bernardi, Cocchini, & Stewart, 2014).

## **Background/Rationale**

According to the *Handbook of Neurologic Music Therapy* edited by Thaut and Hoemberg (2014), “Neurological Music Therapy (NMT) is a research-based system of 20 standardized clinical techniques for sensorimotor training, speech and language training, and cognitive training” (p. 6). In NMT, therapists use music as a therapeutic tool to treat motor, speech, and language, emotional, social, and cognitive needs of individuals. NMT is specifically based on utilizing the physiological mechanisms inherent in music perception and production.

Some studies have introduced music as a rehabilitation stimulus in cognitive domains for visual neglect based on the evidence that music can affect a large range of sensory and cognitive processes. The first study investigating music with visual neglect was carried out by Hommel et al. (1990) who examined the effectiveness of passive tactile and auditory stimuli involved with visual neglect with 14 right hemisphere stroke patients. The researcher suggested that passive nonverbal auditory stimuli have the potential to rehabilitate neglect patients. Specifically, they proposed that music may preferentially engage the right hemisphere which is under aroused in neglect syndrome. Landi et al. (1997) published a case study, with unilateral visual neglect patients playing the piano. Not only active music playing, but also listening to music may enhance cognitive recovery and mood after middle cerebral artery stroke (Särkämö et al., 2008). Likewise, listening to and playing a musical instrument may enhance attention processing in the injured brain. It is commonly agree upon that visual spatial neglect is characterized by deficiencies in two separate neuropsychological process: the perceptual-attentional ‘where’ construct and a premotor-intentional ‘aiming’ component (Mort et al., 2003). The combination of spatial orientation and motor execution in the spatial setup and playing of musical instruments during MNT training may simultaneously address both critical processes effectively together.

Based on these clinical and mechanism research findings, the present study sought to gather initial data on the immediate and longer-lasting effectiveness of MNT for visual neglect in right hemisphere stroke patients.

## **Hypotheses**

### Hypothesis 1.

Ho: There will be no statistical differences in gain scores for immediate effects MNT for pre- and post-test scores as assessed by Albert's Test and Line Bisection Test.

Ha: There will be statistical differences in gain scores for immediate effects of MNT for pre-and post-test scores as assessed by Albert's Test and Line Bisection Test.

### Hypothesis 2

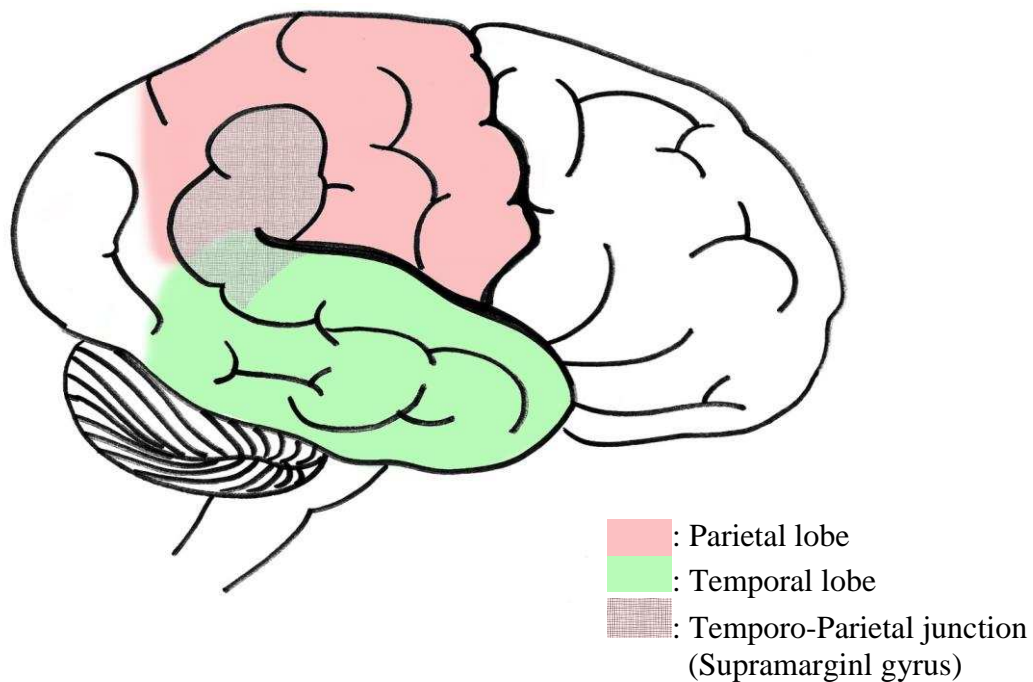
Ho: There will be no statistical differences in gain scores for longer lasting effects of MNT for means of 6 sessions' pre- and follow-up test on Albert's Test and Line Bisection Test.

Ha: There will be statistical differences in gain scores for longer lasting effects of MNT for mean of 6 sessions' pre- and follow-up test scores on Albert's Test and Line Bisection Test.

## CHAPTER II: RELATED LITERATURE

### Unilateral Visual Neglect

**Description.** Unilateral (left) visual neglect is a condition that reduces a person's ability to attend to and process stimuli in one half of their environment. This perceptual processing deficit can affect their daily living tasks such as eating, grooming, writing, and getting dressed, which restricts patients who have suffered a right hemisphere stroke from being independent in their daily life. Detecting the deficit in perception can be accomplished by tasks which require the patient to demonstrate their perception of the world graphically. For example, when asked to draw a picture of a flower or clock, they may fail to draw the contra-lesional side. Figure 1 is the drawing of brain lesion that visual neglect patients usually have.



Drawing by Dr. Fails

*Figure 1* Common Brain Lesion in Right Hemisphere for Visual Neglect

According to Halligan, Fink, Marshall, and Vallar (2003), most anatomo-clinical correlation studies show that the lesion responsible involves the right inferior parietal lobe, particularly the supramarginal gyrus, at the temporo-parietal junction. Mort et al. (2003) mentioned that in a series of middle cerebral artery (MCA) patients most experienced large strokes with the most consistent observations showing that the brain area most commonly associated with neglect is in the right posterior parietal lobe, particularly the region around the temporo-parietal junction. The results of a study by Sterzi et al. (1993) found that patients with damage to the right hemisphere run a greater risk to develop contralateral visual half-field, somatosensory (including position sense) and motor deficits, compared to patients with left brain damage. Deficits of sense of pain are also closely associated with right brain insult. As shown in these studies, unilateral visual neglect usually occurs after a right brain injury, which means patients who have unilateral visual neglect commonly can not perceive the left sided visual field.

**Mechanism underlying unilateral visual neglect.** Albert (1973) proposed the theory that visual neglect is not a singular process but rather a manifestation of several different types of neurologic dysfunctions. Many subtypes of neglect have been described by multiple researchers. Karnath, Milner, and Vallar (2002) summarized mechanisms underlying visual neglect into deficiencies regarding sensory processing (Battersby, Bender, Pollack, & Kahn, 1956; Eidelberg & Schwartz, 1971; Làdavas & Pavani, 1998; McFie, Piercy, & Zangwill, 1950; Sprague, Chambers, & Stellar, 1961), hemispatial information processing (Anzola, Bertoloni, Buchtel, & Rizzolatti, 1977; Goldenberg, 1986; Heilman & Valenstein, 1972, 1979), attentional processing (Kinsbourne, 1970; Watson, Heilman, Cauthen, & King, 1973; Watson, Heilman, Miller, & King, 1974), motor planning and execution (Bisiach, Geminiani, Berti, & Rusconi, 1990; Mattingley, Husain, Rorden, Kennard, & Driver, 1998; Tegner & Levander, 1991), and memory

(Bisiach & Luzzatti, 1978). Each of these mechanisms may be experienced in different types and degrees of deficits according to the individual. Therefore, treating neglect may require a multi-modal and multifaceted approach. One of approaches, which has no known harmful side effects, is music as a sensory language stimulating cognitive, emotional, and motor functions. (Luauté, Halligan, Rode, Rossetti & Boisson, 2006).

## **Therapeutic Mechanisms**

**Music and brain plasticity.** Brain plasticity refers to the extraordinary ability of the brain to modify its own structure and function following changes within the body or in the external environment (Frostig, 2014). This means that the brain has the ability to change as a result of any experiences including musical experiences, which may be used for improving visual processing. Brain plasticity, which is the dramatic potential of the brain to reorganize itself during activated working, has been widely studied for application in the clinical field. Recently, brain plasticity has been implicated in the various neurologic disorders including stroke, Parkinson's disease, Alzheimer, Traumatic Brain Injury. Research has been published in studying the relationship between music and brain plasticity. Using brain plasticity mechanisms, music can be used as therapeutic tool for various functions such as motor control, cognition, and emotion, with musical components (such as rhythm, dynamics, melody, etc.) structured to facilitate therapeutic exercises and goals to retrain the injured brain (Jäncke, 2009; Peretz & Zatorre, 2005; Wan & Schlaug, 2010).

Specifically related to neglect, the stimulating effect of music and rhythm on intentional motor activity is particularly important in regard to the noted premotor intentional interruptions in neglect states. Studies have shown the effect of auditory rhythm on motor control and motor-

related brain plasticity (Altenmüller, Marco-Pallares, Münte, & Schneider, 2009; Luft et al., 2004).

In regard to the influence of musical training on brain plasticity in cognitive attentional functions, specifically related to pitch and melody, Moreno et al.(2009) examined whether musical training improves non-musical brain functions such as reading and linguistic pitch processing with 32 non-musician children over 9 months. Event-related brain potentials were recorded while 8 year old children performed tasks. The result showed that 6 months of musical training lead to significant improvement of behavior and influenced the development of neural processes as reflected in specific pattern of brain waves.

**Music, rhythm, and motor control.** Besides studies showing the effect of music on motor-related brain plasticity in neurorehabilitation, there are numerous kinematic and behavioral research studies supporting applications of music and rhythm to movement rehabilitation. Priming of movement through sound patterns, facilitating the initiation of movement, and anticipatory timing of movement through the rhythmic structure are considered the prime mechanisms (Thaut et al., 1999). It is well documented that even listening to rhythm and music, without a motor task, activates motor areas in the brain, supporting a strong trigger function for music and rhythm to initiate volitional movement. The motor system is very sensitive to arousal by the auditory system, couples quickly into sound patterns, and this process can take place at subliminal levels of sensory perception (Thaut et al., 1999). Furthermore, studies have shown that music and rhythm promote motivation for movement, measuring movement involvement with the self-reported Motor Activity Log (MAL) (Malcolm, Massie & Thaut, 2009).

Based on these studies, the musical structure of MNT may have an important role in facilitating the ‘aiming’ component and strengthening the premotor-intentional deficiencies in neglect to aim motorial into the neglect side with playing musical patterns. This may be one important mechanism for the role of music in successful neglect rehabilitation. However, the neural basis of this potential mechanism has not been researched.

### **Music Supports Cognitive Function**

Music has been used as a therapeutic tool in a variety of settings to promote not only motor but also emotional and cognitive functions (Thaut, 2010). Of particular relevance for neglect rehabilitation are clinical and mechanism data showing how and if music based therapeutic exercises, especially with the NMT model, can stimulate audiovisual attention. Also, listening to music can help to improve positive emotion and cognitive attentional functions. An important study by Sarkamo et al. (2008) with stroke patients has shown that listening to music can help to improve positive emotion and cognitive attentional functions. They designed single-blind, randomized, and controlled trials to determine whether everyday music listening can facilitate the recovery of cognitive attentional functioning in healthy subjects and in various clinical patient groups. Participants were assigned to one of three groups: a music group that listened to recorded music (n = 20), a language group that listened to audio books (n = 20) and a control group that had no additional stimuli (n=20). All patients underwent a clinical neuropsychological assessment, magnetoencephalographic (MEG) measurement, and a magnetic resonance imaging (MRI). The results showed that recovery for participants from the music group were better than the results for the language and control groups in areas of verbal memory, focused attention, and less depression. The authors hypothesized that listening to music promotes positive emotion and cognitive function, even when delivered passive-receptively.



Other studies have shown positive effects of music on attention in older adults (Gregory, 2002; Groene, 2001), and in traumatic brain injury rehabilitation (Barrow, Collins & Britt, 2006; Knox, Yokota-Adachi, Kershner & Jutai, 2003). Tracking and responding to repetitive auditory stimuli is part of the widely used and well-researched Attention Process Training by Sohlberg and Mateer (1989). Also, Robertson et al. (1997) has shown that auditory stimuli can activate the right hemisphere in the brain which is dominant for sustained attention and that those stimuli can influence spatial attention including unilateral visual neglect. Finally, two recent studies, which are very important for MNT, showed that music and rhythm can also improve visual attention (Miller, Carlson & McCauley, 2013; Escoffier, Herrmann, & Schirmer, 2015). These findings are very important for understanding the perceptual-cognitive mechanisms of MNT.

### **Neurologic Music Therapy (NMT)**

MNT is part of NMT. This section will therefore (a) briefly review the treatment system and theory of NMT, and b) the existing research evidence specifically for MNT.

**Definition.** NMT has been developed to facilitate sensorimotor, speech/language, and cognitive rehabilitation and is based on scientific evidence. Specifically, NMT is based on the Rational Scientific Mediating Model (R-SMM). The R-SMM is an epistemological model to adopt the concept of music as a mediating stimulus for non-musical behavior, and it has four levels to provide the transformational framework for music from nonmusical behavior. The four stages are musical response models (logical foundations of musical behaviors), nonmusical parallel models (processes in nonmusical brain and behavior function), mediating models (influence of music on nonmusical brain and behavior function), and clinical research models

(therapeutic effects of music) (Thaut, 2008, p. 118). These levels have an important role as a linkage to using music as a therapeutic tool from basic to applied research.

The four essential paradigms of NMT for rehabilitation are following: (1) neuroscience-guided rehabilitation which is based on data and concepts from brain research and clinical studies, (2) learning and training models which is using rhythm motor learning and training to organize therapeutic interventions and stimuli to enhance cognitive, speech, and language training, (3) cortical plasticity models that can drive neural network patterns through temporal modulation of sensory input, music as complex, rhythmically organized, and spectrally diverse language, and (4) neurological facilitation models to enhance motor, speech/language, and cognitive functions via auditory rhythmicity, musical patterns (Thaut, 2008, p. 129).

**NMT in cognitive domain.** For cognitive deficits, NMT technique has been used as an arousal tool for attention/perception, memory, and executive function. For attention/perception, Musical Sensory Orientation Training (MSOT), Musical Neglect Training (MNT), Auditory Perception Training (APT), and Musical Attention Control Training (MACT) are used. For memory, Musical Mnemonics Training (MMT) and Associative Mood and Memory Training (AMMT) are used. Finally, Musical Executive Function Training (MEFT) are used to practice executive function skills, such as organization, decision making, comprehension, and problem solving. Rhythm, a key element of music not only affects sensorimotor and speech areas, but also, influences cognitive areas by recognizing the importance of temporal organization (Thaut, Peterson, McIntosh, 2005). Attention and perception are crucial for functional outcomes with any population. Numerous clinical research studies have shown that musical attention training improves attention (Gregory, 2002; Knox, Yokota-Adachi, Kershner, & Jutai, 2003; Wolfe &

Noguchi, 2009) and memories (Simmons-Stern, Budson, & Ally, 2010; Thaut, Peterson, McIntosh, & Hoemberg, 2014).

**Musical Neglect Training (MNT).** MNT is one of the NMT techniques in cognitive rehabilitation. The exercise protocols for NMT are fairly standardized with little variation (Thaut & Hoemberg, 2014). To focus attention to the neglect visual field, MNT uses musical exercises which are structured in pitch, time and tempo, and musical equipment (tone bars, keyboards, drums) set up in appropriate configurations. A second application type in MNT consists of receptive music listening to stimulate hemispheric brain arousal while engaging in exercises addressing visual neglect or inattention (Thaut, 2014). After the initial study by Hommel et al. (1990), studies have shown that an auditory stimulus promotes improvements in the patient's visual field, supporting the potential of MNT as a rehabilitation technique for neglect deficits. Frassinetti, Bolognini, Bottari, Bonora, and Ladavas (2005) studied 21 patients with brain damage to investigate the possibility that bimodal audiovisual stimulation of the affected hemifield can improve visual perception in the blind hemifield. The results showed that the patients with visual disorders largely benefitted from multisensory integration, and the authors suggested a possibility of recovery from visual and spatial impairments.

Van Vleet and Robertson (2006) indicated that an auditory event can ameliorate spatial and non-spatially lateralized attention deficits in a patient with neglect. Also, a functional magnetic resonance imaging (fMRI) study completed by Soto et al. (2009) supported that positive affect, generated by preferred music, can decrease visual neglect by increasing attentional resources. In this study, Soto and colleagues induced a pleasant and positive affective response in patients with chronic visual neglect by allowing them to listen to their pleasant preferred music. The authors found enhanced activity in the orbitofrontal cortex and the

cingulate gyrus associated with emotional responses when tasks were performed with preferred music relative to unpreferred music.

Some clinical research has indicated that MNT can be effective for improving visual field to visual neglect patients. Noto, Mouri, Amimoto, Sugimoto, and Futaki (1999) examined the effects of limb activation using a xylophone with unilateral spatial neglect, for a 49-years-old, right-handed woman who suffered cerebral infarction, and demonstrated a clear left unilateral spatial neglect. In this study, the xylophone was placed to ascend the keys from right to left. Significant improvement was observed in the intervention phase compared with the baseline. These results suggested that unilateral spatial neglect field could be reduced by triggering the right hemisphere concerning to the motor intention in exploring the musical scale from right to left, and music as the stimulus of tone and rhythm.

Recent study by Bodak et al. (2014) found evidence that active music-making with horizontally aligned instruments may help neglect patients attend more to their affected side. In this study, two patients with left neglect had four weekly 30-minute music sessions. During these sessions, participants played the scales and familiar melodies on tone bars from right to left. The researchers collected the data three times during a preliminary baseline phase, before and after the four intervention sessions during the intervention phase to define short-term effects, and 1 week after the last intervention session to investigate long-lasting effects from two cancellation test (Mesulam shape, Behavioral Inattention Test (BIT) star), the neglect subtest from the computerize TAP (Test of Attentional Performance) battery, and the Line Bisection Test. These clinical studies support that MNT has a strong potential for use in rehabilitation for neglect patients. Another recent study by Bernardi et al. (2015) assessed whether the auditory stimulus provided by a music scale could improve spatial field with keyboard in right brain damaged

patients with left spatial neglect. Eleven right hemisphere stroke patients with left spatial neglect, 12 patients without neglect, and 12 age-matched healthy participants played descending scales on a music keyboard. Specifically, researchers set the counterbalanced design to determine whether the auditory stimulus provided by a music scale or not with congruent sound, no-sound, or random sound feedback provided by the keyboard. The results showed congruent sound influenced in spatial exploration by patients with left neglect compared to both silence and random sound condition. This study supports that performing a scale with congruent sounds would trigger at some extent preserved auditory and spatial awareness.

Experimental research to examine the effectiveness of MNT is still limited because of small sample sizes and few studies. Active research is necessary in order to fill the theoretical and applicative gaps found in the literature concerning music and, more specifically, musical practice. Based on these clinical evidence-based research, this study is an applied study using MNT to provide initial information regarding immediate and longer-lasting outcomes for participants who are diagnosed with visual neglect after right hemisphere stroke.

## CHAPTER III: METHODOLOGY

### Study Design

A single subject design was used in this study to determine the immediate and longer-lasting effectiveness of MNT for two individual patients with unilateral visual neglect from right hemispheric stroke. This study followed a pre-and post- test design to observe behavior before and after interventions with participants who were acting as their own control to see the immediate effects, and follow-up test to determine the longer-lasting effects. The experiments consisted of two phases: (1) pre- and posttests around 6 MNT interventions, and (2) follow-up test measures with no intervention one week after the end of the session.

### Participants

All participants gave written consent in accordance with the policies of the Institutional Review Board in Colorado State University. Two participants with right hemisphere stroke who were diagnosed with a neglect syndrome were recruited for this study. Both participants met the following criteria: (1) right handed, (2) medically stable, (3) no previous music therapy experiences, (4) no hearing impairments, and (5) no cognitive deficits. Exclusion criteria were (1) hemianopia, and (2) previous music therapy treatment experiences.

#### *Participant 1*

Participant 1 was a 62 years old female who sustained an ischemic stroke 2 years and 2 months ago. Her medical documentation showed that she suffered from a stroke in the right internal capsule and medial right temporal lobe resulting in left hemiparesis and loss of attention in left side with decreased functional performance. Hypertension and diabetes were causes of stroke. She described her vision saying that she seemed to lose half side of screen in the world.

## *Participant 2*

Participant 2 was a 69 years old male who sustained a stroke that occurred in May 2005. His ischemic stroke in right parietal lobe region from the atrial fibrillation resulted in left hemiparesis, and sensory impairment in the left side. He described that he could button on the right side of his shirts without seeing, but could not do this on the left side. Also, he said that he seemed to lose quarter to half field of vision on the left side.

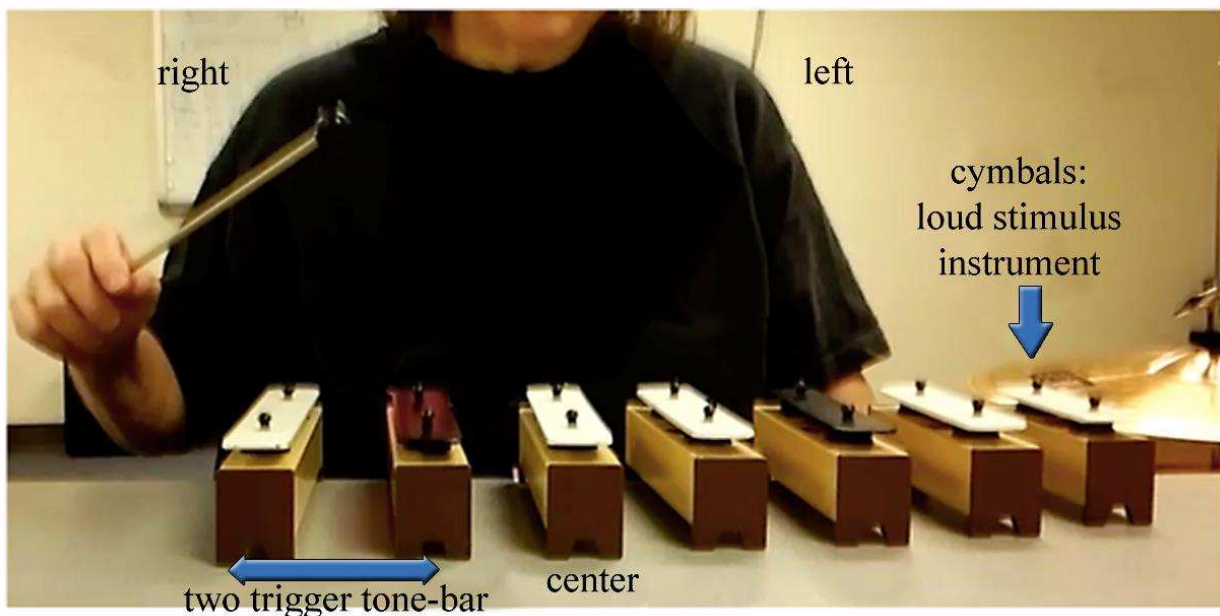
## **Instrumentation/Materials**

The Albert's Test (Line Cancellation Test) and the Line Bisection Test are used commonly to assess neglect (Lee et al., 2004). The Albert's Test is a screening tool used to detect the presence of unilateral visual neglect in patients with stroke. Participants are required to crossing out 40 black lines that are randomly orientated on a sheet of paper. The test paper was placed on a table and presented in front of a patient, parallel to their midsection. The experimenter asked the participant to cross over all of the lines they see in front of them. Patients had a maximum of 5 minutes to complete the activity. Assessment tools to be used for this test included an A4 sheet (11x8.5-inch), with 40 lines 2 centimeters in length and a pencil (Barrett et al., 2006). Internal consistency reliability is not shown in previous studies, but excellent test-retest reliability is reported with a score of  $r=0.79$  (Sea & Henderson, 1994). For validity, Albert's Test has excellent correlation with the Line Bisection Test ( $r=0.85$ ) (Agrell, Dehlin, & Dahlgren, 1997).

The Line Bisection Test is also a screening tool used to diagnose and assess neglect. Participants must place a mark with a pencil in the center of horizontal lines. A displacement of the mark towards the side of the brain lesion is assessed as a symptom of neglect. The equipment

for this test is an A4 sheet (11x8.5-inch) with 17 vertically staggered horizontal lines and a pencil (Strokeengine, 2014). Menon & Korner-Bitensky (2004) found the Line Bisection Test showed strong test-retest reliability, construct validity, convergent and discriminant validity, and criterion validity. Bailey, Riddoch and Crome (2004) reported the intraclass correlation coefficient was excellent for neglect patients (ICC=0.97).

## Procedure



*Figure 2* Musical Neglect Training (MNT) Setting

First, participants completed the consent procedures and agreed for video recording the sessions. There were two weekly 30 minute individual sessions over a time period of three weeks, a total of six MNT sessions per participant. The participants started with the Albert's Test and the Line Bisection Test for assessment before training. During the training, participants followed these protocol levels (Figure 2): (1) playing 3 ascending scale (D, F#, A) with 3.5cm narrow tone bars from non-neglect (right) to neglect field (left), (2) playing 4 ascending scale (D, F#, A, D) with 3.5cm narrow tone bars from non-neglect (right) to neglect field (left), (3) playing



5 ascending scale (D, F#, A, C#, D) with 3.5cm narrow tone bars from non-neglect (right) to neglect field (left), (4) playing 6 ascending scale (D, E, F#, A, C#, D) with 3.5cm narrow tone bars from non-neglect (right) to neglect field (left), (5) playing full ascending scale (D, E, F#, G, A, B, C#, D) with 3.5cm narrow tone bars from non-neglect (right) to neglect field (left).

Participants sat comfortably in a chair, playing the tone bars on the desk with the non-paretic side (right). In each level, first tone bar (D) was put in the center of participants. Also, two tone bars (B, C#) were set to the right side before starting the scale or triad to start the playing movement from right to left in the healthy visual field. A cymbal was located in the last position to give a strong sound target for completion of the pattern. In each pattern, the cymbals' edge matched the end of the very last tone bar's edge. The experimenter was positioned on the patient's non-neglect side (right) to give instruction and play a chordal accompaniment for each tone bar pitch. Verbal and rhythmic cues were given to help anticipation and completion. Participants repeated each pattern 5 times before moving to the next step. The Albert's test and the Line Bisection test were given to participants after training to observe immediate effects.

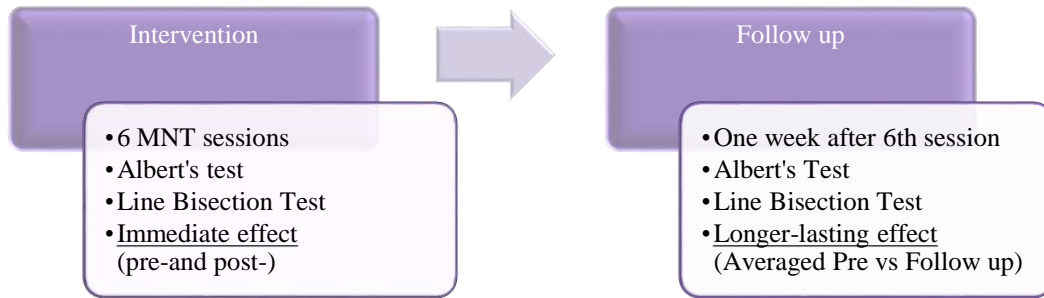
### **Data Collection**

The experimenter collected the data for all dependent variables pre-and post-interventions and follow-up stage. The Albert's Test and the Line Bisection Test were collected before and after every 6 each interventions to examine the immediate effects. Also, same assessments, Albert's Test and Line Bisection Test were collected at the follow-up test to determine the effectiveness of MNT and the longer-lasting effects. Also, combined data from participant 1 and 2 were calculated with descriptive statistics only.

## Data Analysis

The Albert's Test was scored as the number of uncrossed lines on the left side. The test paper consisted of 17 lines on each side, and 4 lines in the center. The Line Bisection Test was calculated as percentage of the deviation from the true center of the line. There were 17 horizontal lines, which had different length and calculated by the following methods: the means of the deviations of all 17 lines were divided by center point length of all 17 lines/17, and shown as percentage. The formula was  $[\text{Sum of all deviations} / \text{Sum of all center point length of 17 lines}) / 17]$ .

Descriptive statistics, means and standard deviation were calculated for both tests (Albert's Test and Line Bisection Test) to display in numbers and graphically pre- and post-test results. Paired sample *t*-tests were calculated to examine significant differences, and compare means by subtracting pre- intervention scores from post- test scores. Nonparametric statistics (Wilcoxon sign-ranked test) was also calculated in parallel with the paired *t*-tests due to the small sample size and possible violations of normal distribution. For the longer-lasting effects, statistical analysis was not done because there were only one follow-up test data per subject. Raw data were compared between all 6 averaged sessions pre-test and follow-up test. Also, descriptive statistics only were calculated for the data of the two participants combined for training trials, post- vs follow up, and pre- vs follow up. Figure 3 illustrates the summary of study design, data collection, and data analysis.



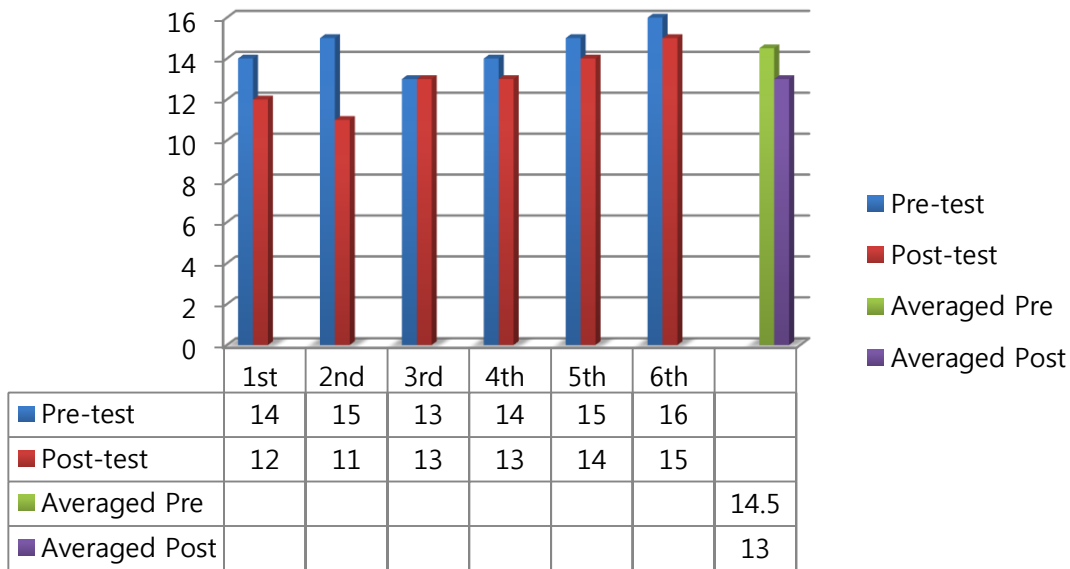
*Figure 3:* Summary of study design, data collection, and data analysis

## CHAPTER IV: RESULTS

Data were collected from two participants using the Albert's Test and Line Bisection Test. Pre-and post-tests of each 6 sessions for the immediate effects, and follow-up test for the longer-lasting effects were compared with descriptive statistics, paired *t*-tests, and non-parametric tests (Wilcoxon Signed Rank Test). Also, data from participant 1 and participant 2 were combined and displayed using descriptive statistics only.

### Participant 1

**Albert's Test.** Figure 4 shows score differences between pre and post-test of 6 sessions, and between averaged pre and post-test of 6 sessions.



*Figure 4* Descriptive Data for Participant 1's Albert's Test

All scores from pre to post-test of six sessions decreased, except 3<sup>rd</sup> session (remained same). The scores were calculated as the number of uncrossed line, so a reduced score meant improvement. The mean of the scores that the participant did not mark for pretest was 14.5 and 13 at post-test. Pre-test and post-test difference of the means of all 6 sessions' indicated positive

outcomes regarding immediate effects – but with small differences only (14.5 to 13). Also, it is interesting to note that the 6<sup>th</sup> session was worse than the pre-test in the 1<sup>st</sup> session.

A Wilcoxon signed rank test was conducted to determine whether there was a difference in the ranking of pre-and post-test by MNT sessions. Results of that analysis indicated that there was a significant difference in pre-and post-interventions,  $Z = -2.06, p < .05$  (Table 1).

Table 1  
*Wilcoxon Signed Rank Test for Albert's Test in Participant 1*

	Posttest -Pretest
Z	-2.060
Asymp. Sig. (2-tailed)	*.039

Note: \* $p < .05$ , two-tailed

Table 2 shows a paired  $t$ -test for participant 1 in Albert's Test. There was a significant difference in mean scores before and after MNT training ( $t=-2.67, p<.05$ )

Table 2  
*Paired t-test for Albert's Test of Participation 1*

	Pre-test	Post-Test
Mean	14.5	13
Standard Deviation	1.05	1.41
$t$	-2.67	
$p$ -value (one-tailed)	*0.02	
$p$ -value (two-tailed)	† 0.04	

Note: \* $p < .05$ , one-tailed, †  $p < .05$ , two-tailed

Average of all 6 sessions' pre-test and follow-up test were compared to observe the longer-lasting effect. Figure 6 shows raw score differences between averaged pre-test of 6 sessions and follow-up test. This bar graph of raw scores slightly decreased (from 14.5 to 14).

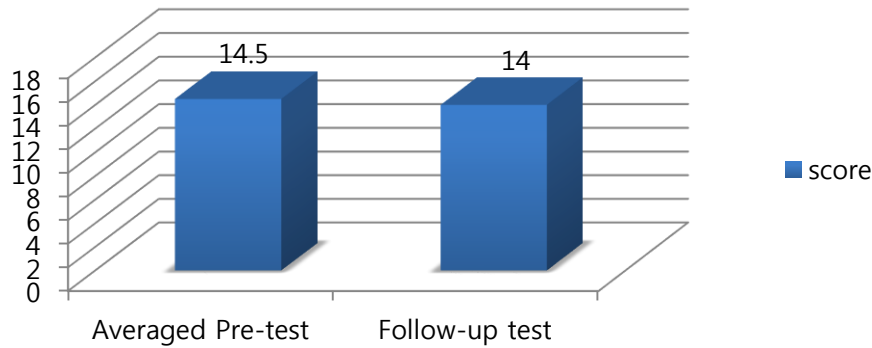


Figure 6 Participant 1's Averaged Pre-test and Follow-up Test Score

**Line bisection test.** Line Bisection Test was analyzed by following methods. Means of all 17 lines' deviation were divided by center point length of all 17 lines/17, and shown with percentage. The formula is  $[(\text{Sum of all 17 lines' deviation} / \text{Sum of all center point length of 17 lines}) / 17]$ .

Figure 7 presents percentage differences between pre and post-test of 6 sessions, and averaged pre and post-test in Line Bisection Test.

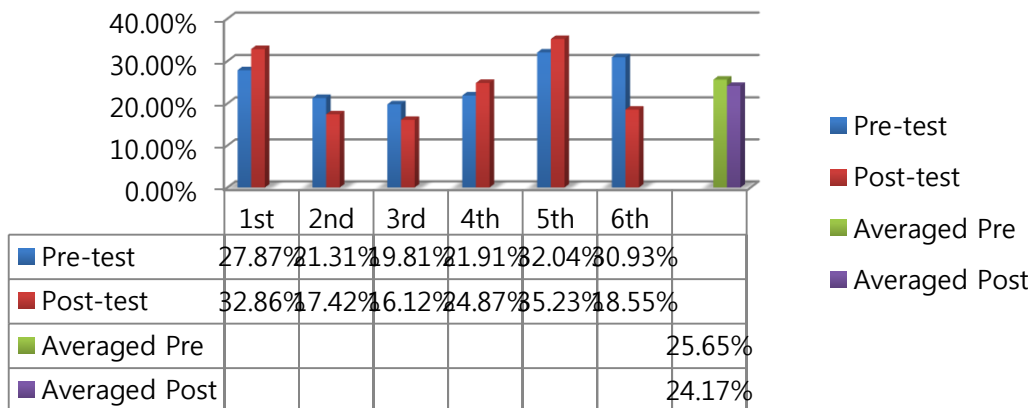


Figure 7 Descriptive Data for Participant 1's Line Bisection Test

Decreased percentage meant positive effects; because shorter deviation from the center point indicated having better awareness of left side. (All the deviation from the center was right side- it meant that participant who has unilateral visual neglect's center leaned to right side because of their left side visual field loss). These percentages of deviation in all 6 sessions were not seen as sustainable. Three sessions (2<sup>nd</sup>, 3<sup>rd</sup>, and 6<sup>th</sup>) showed improvements, but other three sessions (1<sup>st</sup>, 4<sup>th</sup>, and 5<sup>th</sup>) did not indicate improvements. However, overall, once averaged pre-test and averaged post-test was compared, the deviation from the center declined from 25.65% to 24.17%, about 1.5% decreased. The interesting result was that participant 1 showed obvious decreased percentage of deviation from 30.93% to 18.55%, about 12% decreased.

Table 3 shows indicated that there was no significant difference in pre-and post-interventions,  $Z = -2.06$ ,  $p = .60$ .

Table 3  
*Wilcoxon Signed Rank Test for Line Bisection Test in Participant 1*

	Posttest -Pretest
Z	-0.52
Asymp. Sig. (2-tailed)	.60

Note: \* $p < .05$ , two-tailed

Table 4 shows the paired  $t$ -test of participant's Line Bisection Test. With the  $t$ -test ( $t = -0.55$ ) for Line Bisection Test, there was no significant improvement. Even though, mean of pre-test to mean of post-test showed a decrease, inferential statistics did not show significant differences.

Table 4  
*Paired t-test for Line Bisection Test of Participation 1*

	Pre-test	Post-Test
Mean	25.65%	24.17%
Standard Deviation	0.05	0.08
<i>t</i>	-0.55	
<i>p</i> -value (one-tailed)	0.30	
<i>p</i> -value (two-tailed)	0.60	

Note: \* $p < .05$ , two-tailed, † $p < .05$ , one-tailed

For the longer-lasting effect, averaged pre-test percentage deviation of 6 sessions and follow-up test were compared (Figure 8). Percentage of deviation in Line Bisection Test for Participant 1 increased from 25.65% to 27.18%, which is not a positive effect.

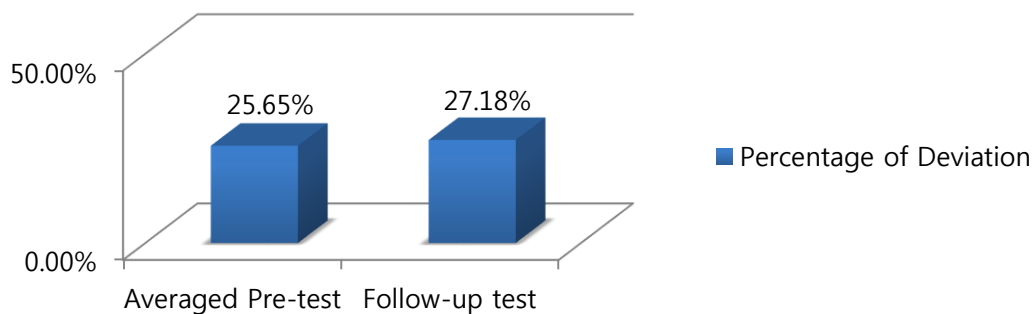


Figure 8 Percentage of Deviation Data for Averaged Pre-test and Follow-up test



## Participant 2

**Albert's Test.** Figure 9 displays the score differences between pre and post-test of 6 sessions, and between averaged pre and post-test in Albert's test.

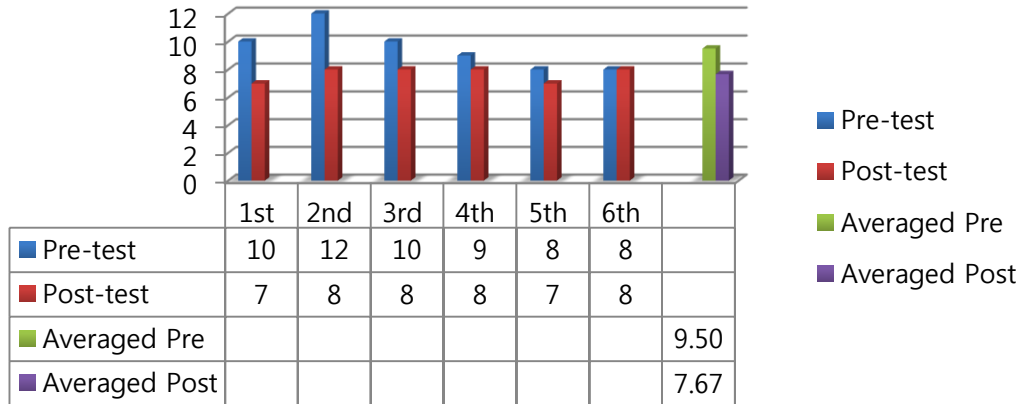


Figure 9 Descriptive Data for Participant 2's Albert's Test

From first session to last session, participant 2's bar graph showed a steady decline except from first session to second session. Also, in each session, there were all decreased scores except last session (remained same), which indicated positive outcomes in immediate effects of MNT. Between averaged pre-test and post-test, scores indicated a positive result.

Table 5 shows result of Wilcoxon signed rank test. Wilcoxon signed rank test indicated post-test of intervention was statistically significantly higher than pre-test of intervention,  $Z = -2.03, p < .05$ .

Table 5  
Wilcoxon Signed Rank Test for Albert' Test in Participant 2

	Posttest -Pretest
Z	-2.03
Asymp. Sig. (2-tailed)	.04

Note:  $*p < .05$ , two-tailed

Table 6 shows the result of paired t-test. There was significant differences in the scores for pre-test (M=9.5, SD=1.52), and post-test (M=7.67, SD=0.52);  $t=-3.05$ ,  $p < .05$ . These data supported the significant differences in immediate effects of MNT technique.

Table 6  
Paired t-test for Albert's Test for Participant 2

	Pre-test	Post-Test
Mean	9.50	7.67
Standard Deviation	1.52	0.52
$t$	-3.05	
$p$ -value (one-tailed)	*0.01	
$p$ -value (two-tailed)	†0.03	

Note: \* $p < .05$ , one-tailed, † $p < .05$ , two-tailed

Figure 10 indicates compared scores between averaged all pre-test of 6 sessions and follow-up test to determine the longer-lasting effect in Albert's test for participant 2. Score was decreased from averaged pre-test of 6 sessions (score=9.5) to follow-up test (score=7) that showed positive outcome from bar graph.

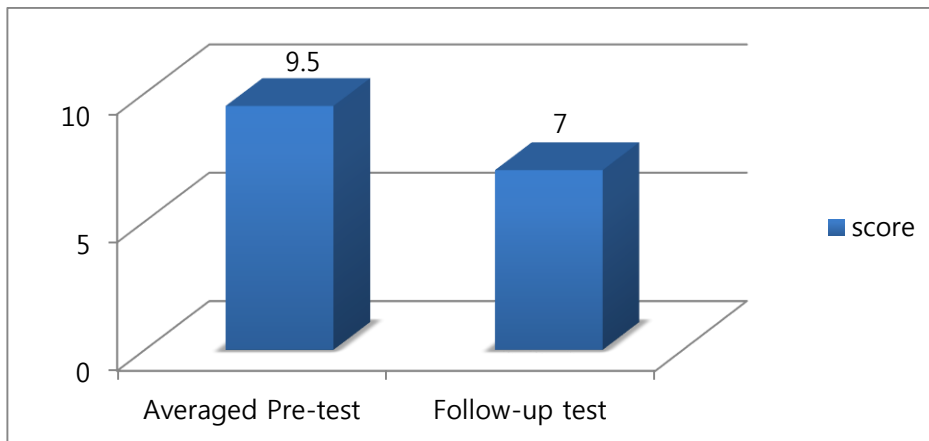


Figure 10 Participant 2's Averaged Pre-test and Follow-up Test Score

**Line Bisection Test.** Figure 11 showed percentage of deviation differences between pre and post-test of 6 sessions, and between averaged pre and post-test in Line Bisection Test.

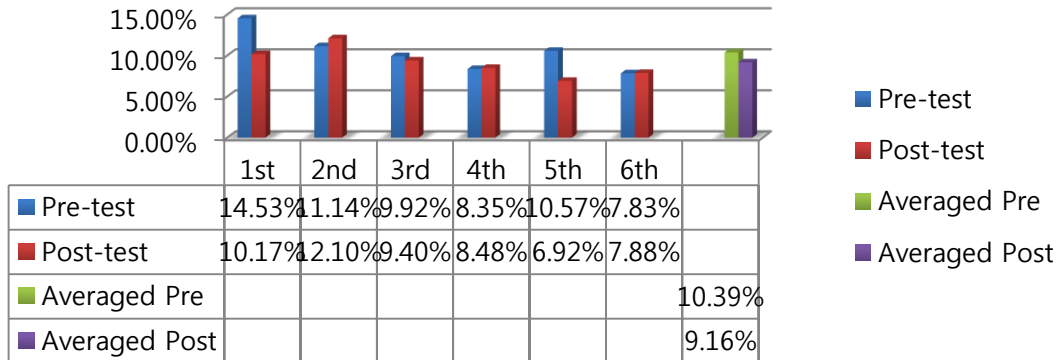


Figure 11 Descriptive Data for Participant 2’s Line Bisection Test

From this data, there was a gradually negative trend from first session to last session, except three times (2nd, 4th, and 6<sup>th</sup>) that were very slightly increased (2nd: 1%, 4th:0.1%, and 6th: 0.05%). However, the averaged percentage of deviation from pre-test to post-test decreased about 1.2%.

Table 7 shows the result of Wilcoxon signed rank test. Wilcoxon signed rank test indicated post-test of intervention was no statistically significantly improvement,  $Z=-2.03$ ,  $p=.17$ .

Table 7  
Wilcoxon Signed Rank Test for Line Bisection Test in Participant 2

	Posttest -Pretest
Z	-1.57
Asymp. Sig. (2-tailed)	.17

Note: \* $p < .05$ , two-tailed

Table 8 shows paired *t*-test of participant 2’s Line Bisection Test. With the *t*-test, one-paired *p*-value was 0.11 and two-paired *p*-value was 0.22, which did not show significant improvement.

Table 8  
Paired *t*-test for Line Bisection Test for Participant 2

	Pre-test	Post-Test
Mean	10.39%	9.16%
Standard Deviation	0.02	0.02
<i>t</i>	-1.37	
<i>p</i> -value (one-tailed)	0.11	
<i>p</i> -value (two-tailed)	0.23	

Note: \**p* < .05, two-tailed, †*p* < .05, one-tailed

To see the longer-lasting effect, same as Albert’s test, averaged pre-test of 6 sessions and follow-up test were compared, and percentage decreased from 10.39% to 7.70% (Figure 12).

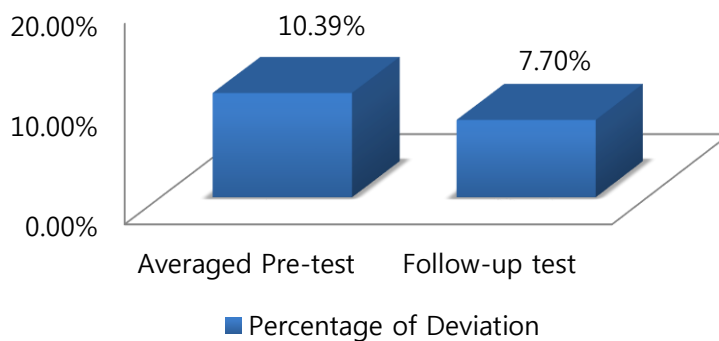


Figure 12 Percentage of Deviation Data for Averaged Pre-test and Follow-up test

## Combined Participant 1 and Participant 2

Data from participant 1 and participant 2 were combined, and compared between averaged pre-test of 6 sessions vs averaged post-test of 6 sessions, post-test of 6 sessions vs follow-up test, and averaged pre-test of 6 sessions vs follow-up test for both assessment, Albert's test and Line Bisection test. Figure 13 showed summary of mean of combined data of participant 1 and 2 in Albert's and Line Bisection Test graphically.

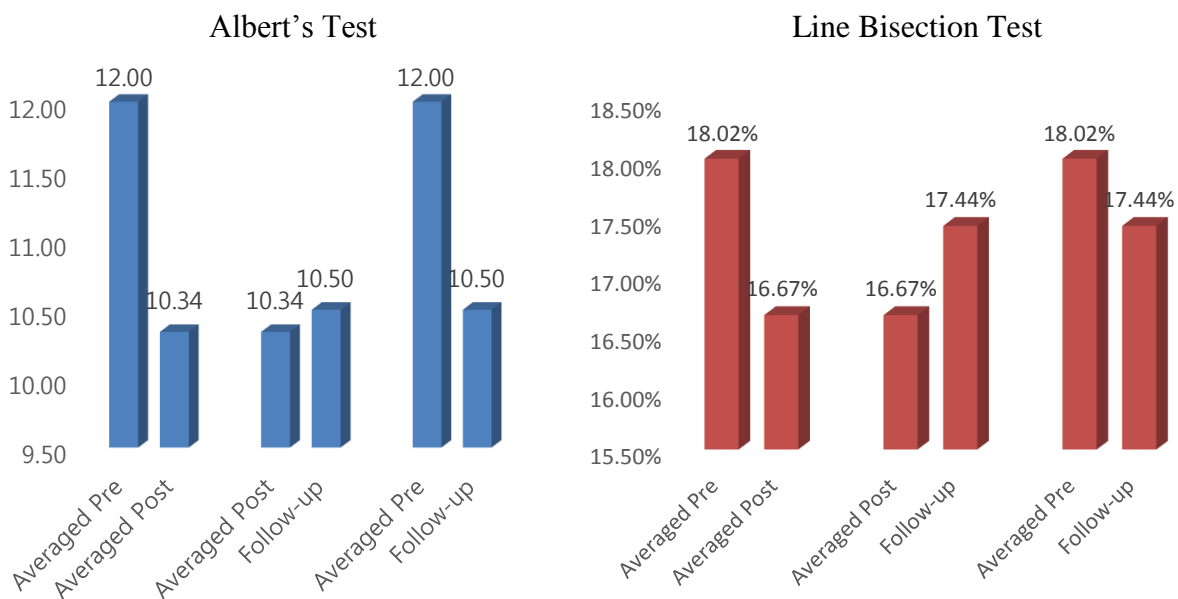


Figure 13 Compare Combined Means (Averaged Pre vs Averaged Post, Averaged Post vs Follow-up, Averaged Pre vs Follow-up)

Data of participant 1 and participant 2 were combined since their clinical symptoms were similar and also to generalize the overall effects of MNT. Descriptive statistics were calculated for combined data (Table 9 and Table 10). Means and standard deviation of combined averaged pre-test, averaged post-test, and follow-up test were compared. Averaged pre vs averaged post ( $M=12$ ,  $SD=3.54$  to  $M=10.34$ ,  $SD=3.77$ ) and averaged pre vs follow-up ( $M=12$ ,  $SD=3.54$  to  $M=10.50$ ,  $SD=4.95$ ) for Albert's test showed improvement except comparing

between averaged post and follow-up ( $M=10.34$ ,  $SD=3.77$  to  $M=10.50$ ,  $SD=4.95$ ). Similarly, results from Line Bisection Test showed improvements in averaged pre vs averaged post ( $M=18.02$ ,  $SD=10.79$  to  $M=16.67$ ,  $SD=10.61$ ) and averaged pre vs follow-up ( $M=18.02$ ,  $SD=10.79$  to  $M=17.44$ ,  $SD=13.77$ ) except comparing between averaged post and follow-up ( $M=16.67$ ,  $SD=10.61$  to  $M=17.44$ ,  $SD=13.77$ ), which supported the immediate and longer-lasting effects.

Table 9  
*Descriptive Statistics for Combined Data in Albert's Test*  
 Averaged Pre vs Averaged Post

	N	Minimum	Maximum	Mean	Std. Deviation
Averaged Pre-test	2	9.50	14.50	12.00	3.54
Averaged Post-test	2	7.67	13.00	10.34	3.77
<i>Averaged Post vs Follow up</i>					
	N	Minimum	Maximum	Mean	Std. Deviation
Averaged Post-test	2	7.67	13.00	10.34	3.77
Follow up test	2	7.00	14.00	10.50	4.95
<i>Averaged Pre vs Follow up</i>					
	N	Minimum	Maximum	Mean	Std. Deviation
Averaged Pre-test	2	9.50	14.50	12.00	3.54
Follow up test	2	7.00	14.00	10.50	4.95

Table 10  
*Descriptive Statistics for Combined Data in Line Bisection Test*

<u>Averaged Pre vs Averaged Post</u>					
	N	Minimum	Maximum	Mean	Std. Deviation
Averaged Pre-test	2	10.39	25.65	18.02	10.79
Averaged Post-test	2	9.16	24.17	16.67	10.61
<u>Averaged Post vs Follow up</u>					
	N	Minimum	Maximum	Mean	Std. Deviation
Averaged Post-test	2	9.16	24.17	16.67	10.61
Follow up test	2	7.70	27.18	17.44	13.77
<u>Averaged Pre vs Follow up</u>					
	N	Minimum	Maximum	Mean	Std. Deviation
Averaged Pre-test	2	10.39	25.65	18.02	10.79
Follow up test	2	7.70	27.18	17.44	13.77

## CHAPTER V: DISCUSSION

The purpose of this study was to examine the effectiveness of MNT on unilateral visual neglect for the immediate and longer-lasting effect on chronic unilateral visual neglect patients. The hypotheses of this study were that 1) participants would show improvement on scores of Alberts and Line Bisection Tests immediately after each of six sessions, and 2) participants would show better scores after one week at follow-up testing to examine the longer-lasting effects of MNT training on the Alberts and Line Bisection Test. Results from paired *t*-tests indicate that both participant 1 ( $t=-2.67, p < .05$ ) and participant 2 ( $t= -3.05, p < .05$ ) showed significant improvement in immediate effects with Albert's Test. Results from Wilcoxon Signed Rank Test also showed statistically significant improvement in immediate effects from participant 1 ( $Z = -2.06, p < .05$ ) and participant 2 ( $Z=-2.03, p < .05$ ). Comparing between the raw scores of averaged pre-test and follow-up test, both participants (participant 1 with 14.5 to 14, participant 2 with 9.5 to 7) had decreased scores, which means positive effects of MNT as measured by the Albert's Test. Reduced numbers of uncrossed lines indicated an increase in the participant's attention to the left visual field.

Participant 1 showed interesting result in Albert's Test. Looking at the overall scores of all 6 sessions, the scores gradually increased, which did not indicate a positive outcome. The score on the pre-test of 1<sup>st</sup> session was 14, and at the 6<sup>th</sup> session was 16. Also, the score in post-test was increased from 12 to 15. However, at each session - with the exception of the third - participant 1's score decreased. Overall, even though participant 1 did not show a steady decline across 6 sessions, she showed improvement in each individual session, meaning possibly that she benefited from the immediate training but showed no carry-over from session to session. On the other hand, participant 2 showed improvement across all 6 sessions. Interestingly, there was a



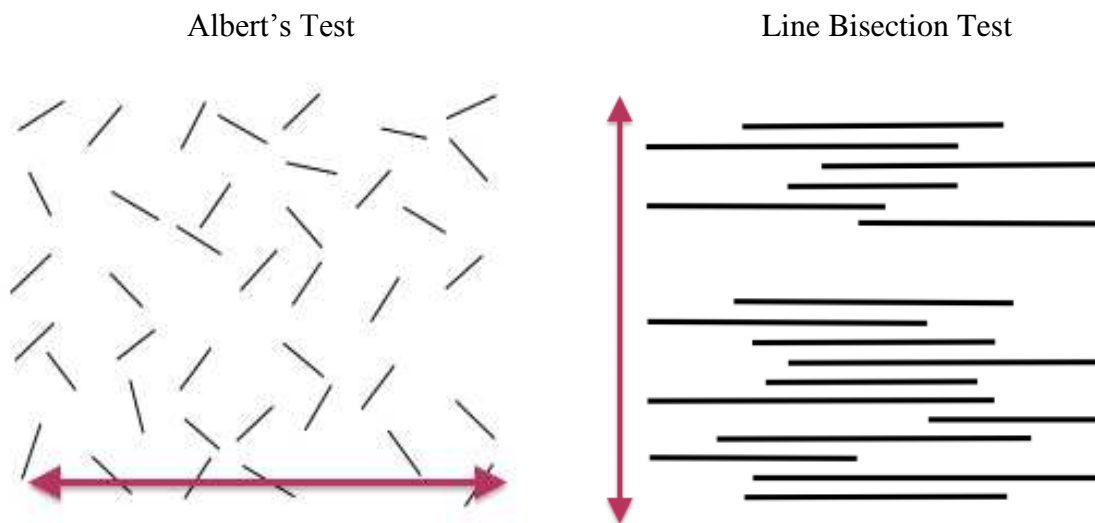
drastic improvement in the first 3 sessions, and differences scores between pre and post-test were getting smaller to the end (posttest – pretest from 1<sup>st</sup> session to 6<sup>th</sup> session= -3, -4, -2, -1-1, 0).

There were no significant differences in immediate effect with Line Bisection Test for both participants. Participant 1 showed some positive outcomes in each session, but they were not sustained overall. However, when comparing between averaged pre-test of 6 sessions and averaged post-test, the percentage of deviations from the central point decreased. Same as for the Albert's Test, decreased percentage meant a positive result in Line Bisection Test. Reduced percentage of deviations indicated that participant's attention expanded to the left side. Especially participant 1 showed a dramatic decrease of percentage of deviation from 30.93% to 18.55% in 6<sup>th</sup> session (last session).

Participant 2 also did not show significant differences, but his percentage of deviations gradually decreased from 1<sup>st</sup> to 6<sup>th</sup> session from 14.53% to 7.88%. For the longer-lasting effect of Line Bisection Test, participant 1 showed an increase in percentage of deviation from averaged pre-test to follow-up test, which did not result in a positive outcome. Participant 2 had a positive outcome in the longer-lasting effect from 10.39% to 7.70%.

Interestingly, both participants showed significant improvements in Albert's Test, but did not show significance on the Line Bisection Test. Especially, participant 1 reported difficulties to do the Line Bisection Test. She exhibited frustration sometimes with this test by stopping during testing. In contrast, when participant 2 took the Line Bisection Test, he said that the Line Bisection Test seemed to be easier than Albert's Test. Albert's Test focuses on horizontal work and the Line bisection Test focuses on vertical perception along long distance view point. Especially, each line in the Line Bisection Test needs horizontal work to find the center point, but participants needed vertical work to find the central line for all 17 lines during

assessment. This might have been the reason for the different results between Albert's Test and Line Bisection Test (Figure 14).



*Figure 14* Compare between Pattern of Albert's Test and Line Bisection Test

To determine the overall differences between pre-test vs post-test, post-test vs follow-up test, and pre-test vs follow-up test in Albert's Test and Line Bisection Test, data collected from both participants were combined and displayed descriptively.

Interestingly, both Albert's Test and Line Bisection Test displayed similar pattern (Figure 13). The largest differences was shown in immediate effects (averaged pre-test vs averaged post-test for both assessment, Albert's Test and Line Bisection Test). The second largest difference was in the longer-lasting effects (averaged pre-test and follow-up test) for both assessments. Also, another interesting outcome was that comparisons between averaged post-test and follow-up test did not show positive results (increased scores in Albert's Test and increased deviation percentage in Line Bisection Test) for both tests. However, the combined scores should be treated with great caution because there were only 2 subjects involved and both subjects showed great individual differences in their etiology and their test performances.

There are several factors that could have led to differences in the results of this study. One could have been that each participant had a different onset of stroke. Participant 1 suffered from stroke in 2013, and participant 2 suffered from stroke in 2005. Table 11 showed differences scores in Albert's Test and percentage of deviation in Line Bisection Test from participant 1 and participant 2.

Table 11  
*Summary of Data from Participant 1 and Participant 2 in Albert's Test and Line Bisection Test*

	Albert's Test		Line Bisection Test	
	Participant 1	Participant 2	Participant 1	Participant 2
Averaged Pre-Test	14.5	9.5	25.65%	10.39%
Averaged Post-Test	13	7.67	24.17%	9.16%
Follow-up Test	14	7	27.18%	7.70%

All scores of participant 2, (averaged pre-test, averaged post-test, and follow-up test) were lower than participant 1's score in Albert's Test, which meant that participant 2 had a less impaired visual field than participant 1 from the onset of the study. Similar results were shown in Line Bisection Test. The overall threshold of attention on the left side in participant 2 was higher than participant 1 in both tests, Albert's Test and Line Bisection Test. One possible explanation is that during 10 years following his stroke, participant 2 would have been working on compensatory strategies to be alert regarding his spatial awareness of the left side in order to accommodate his daily life. On the other hand, participant 1 had a stroke two years ago. She has not had any rehabilitation training for visual neglect. She mentioned that she was learning to scan left by herself for 2 years. Ten years training versus 2 years training may account for the

different outcomes in both assessments. Visual neglect patients were able to anticipate their skewed spatial orientation and to compensate for neglect in structured and predictable circumstances as time went on (Jehkonen et al., 2000).

A second factor could have been that each participant had a different musical experience background. Participant 1 belonged to a musical environment. Her father is a pianist, and other siblings are also musicians. Especially, she also has been participating in a string trio in the community as an amateur violinist. In contrast, participant 2 has been in exposed musical environments (attending concerts, listening to music privately) but has no active experiences like participant 1. This factor could be one of the reasons that they showed different outcomes. However, the non-musician participant benefited more, making the musician argument probably less meaningful than other factors.

In addition, behavior patterns, personal attitude, etc. could have influenced the different results between participant 1 and participant 2. However, some common positive outcomes from the data in this study provide support that an active music intervention using a horizontally aligned tone bar sequence (MNT) may help both participants to improve their visual field. Self-reports also indicated that they enjoyed the exercises.

The current study has presented the positive potentials of MNT for visual neglect patients in both, immediate and longer-lasting effects. Two other aspects were used in this study: (1) sequential aspects: putting the cymbals as a loud stimulation instruments after playing the simple scales to help participants to expect the final completion of each sequence, and (2) systematic aspects by accompanying participants' scale playing with chords cueing their motor movements to the next tone bar.

Even though both participants showed a significant improvement in immediate effects and had trends that suggested the possibility of longer-term improvement, this study had several limitations, which would impact the strength of the findings. The first limitation was the size of the sample in this study (n=2). Because only two participants participated in this study, the generalizability to larger sample sizes is limited. The second limitation was the time elapsed since suffering a stroke. Both participants were chronic visual neglect patients. Especially, participant 2 has been almost 10 years since he suffered from stroke. Even though he could not attend to his left visual field perfectly, he has been training by himself to scan the left visual field. This factor could influence the results. However, the study adds new data regarding the use of MNT with highly persistent visual neglect since most studies have investigated subacute patient groups. Third, there are clear limitation in interpretation the statistical results that the data were analyzed on an individual subject basis which prohibit large sample generalizability.

The recommendation for the future research could be a rearrangement of the limitations of this study as previously mentioned. First, a larger sample size would increase the external validity of MNT's effectiveness on unilateral visual neglect. Second, it would be desirable to recruit patients with a more recent onset of visual neglect so as to remove the complicating factors of other forms of rehabilitation and self-training that participant 2 had experienced.. With acute or subacute visual neglect patients one would be able to investigate demonstrate a more controlled effect of MNT. Also, if further research would expand the study design by including several base lines and follow-up tests, research would be strengthened to determine the effectiveness of MNT. The desired goal of therapy is the longer-lasting effects and the transition those effects to quality of daily living. The researcher would need to have several follow-up tests rather than only one follow-up test on which to perform statistical analysis. Also, longer protocol

and/or more sessions would provide better statistical power to the results. Additionally, it would be interesting to compare between auditory effects and motor effects to find an extended visual field separately. Researcher will be able to set up both ways to determine which components between auditory and motor lead their attention more to discover the left visual. First, auditory only design would be set up by setting tone bar in the center point only or playing different recording sounds only in the left side. Second, motor only design would be set up by using muffled soundless tone bar. Using a design like this would help to separate the effect of the auditory feedback from the motor component. Nevertheless, it is noteworthy that the study was able to investigate the effectiveness of MNT with long-term persistent neglect. Additionally, small sample studies are important for clinical research when large homogeneous patient groups are not available which can be quite common in neurorehabilitation units.

In conclusion, the purpose of this study was to determine the effectiveness of MNT in providing immediate and longer-lasting improvement of left-sided visual neglect. Both participants showed significance immediate effects when tested by Albert's Test. Also, trends toward positive outcomes were shown in the longer-lasting effects. Even though neither participants did showed significant effect in Line Bisection Test for the immediate and longer-lasting effects, they still showed improvement of their visual field. To generalize the effectiveness of NMT, further study would include a larger sample size, recruiting acute or subacute visual neglect patients, and adjusting the length and level of intervention to the individuals. Moreover, a sufficient high quality of randomize control trials with appropriate functional measures will provide strong evidence for clinical practice (Bowen & Lincoln, 2007). Better understanding is needed of the neurophysiological and biomechanical mechanisms that underlie compensation-related learning of functional tasks after stroke (Kwakkel, 2006). In

addition, a better understanding of the neural mechanisms will help to adjust knowledge appropriately to the clinical situation.

## REFERENCES

- Agrell, B. M., Dehlin, O. I., & Dahlgren, C. j. (1997). Neglect in elderly stroke patients: a comparison of five tests. *Psychiatry and clinical neurosciences*, *51*(5), 295-300. doi: 10.1111/j.1440-1819.1997.tb03201.x
- Albert, M. L. (1973). A simple test of visual neglect. *Neurology*.
- Albert, M. L., Sparks, R. W., & Helm, N. A. (1973). Melodic intonation therapy for aphasia. *Archives of Neurology*, *29*(2), 130-131. doi: 10.1001/archneur.1973.00490260074018
- Altenmüller, E., Marco- Pallares, J., Münte, T., & Schneider, S. (2009). Neural Reorganization Underlies Improvement in Stroke- induced Motor Dysfunction by Music- supported Therapy. *Annals of the New York Academy of Sciences*, *1169*(1), 395-405. doi: 10.1111/j.1749-6632.2009.04580.x
- Anzola, G., Bertoloni, G., Buchtel, H., & Rizzolatti, G. (1977). Spatial compatibility and anatomical factors in simple and choice reaction time. *Neuropsychologia*, *15*(2), 295-302. doi: 10.1016/0028-3932(77)90038-0
- Bailey, M. J., Riddoch, M. J., & Crome, P. (2004). Test–retest stability of three tests for unilateral visual neglect in patients with stroke: Star Cancellation, Line Bisection, and the Baking Tray Task. *Neuropsychological Rehabilitation*, *14*(4), 403-419. doi: 10.1080/09602010343000282
- Barnes, M. P., & Good, D. C. (Eds.). (2013). *Neurological Rehabilitation: Handbook of Clinical Neurology* (Vol. 110). Newnes.
- Barrett, A. M., Buxbaum, L. J., Coslett, H. B., Edwards, E., Heilman, K. M., Hillis, A. E., . . . Robertson, I. H. (2006). Cognitive rehabilitation interventions for neglect and related



- disorders: moving from bench to bedside in stroke patients. *Journal of cognitive neuroscience*, 18(7), 1223-1236. doi:10.1162/jocn.2006.18.7.1223
- Barrow, I. M., Collins, J. N., & Britt, L. D. (2006). The influence of an auditory distraction on rapid naming after a mild traumatic brain injury: A longitudinal study. *Journal of Trauma and Acute Care Surgery*, 61(5), 1142-1149.
- Basso, A., & Capitani, E. (1985). Spared musical abilities in a conductor with global aphasia and ideomotor apraxia. *Journal of Neurology, Neurosurgery & Psychiatry*, 48(5), 407-412.
- Battersby, W. S., Bender, M. B., Pollack, M., & Kahn, R. L. (1956). Unilateral “spatial agnosia”(“inattention”) in patients with cerebral lesions. *Brain*, 79(1), 68-93. doi: 10.1093/brain/79.1.68
- Bernardi, N. F., Cioffi, M. C., Ronchi, R., Maravita, A., Bricolo, E., Zigiotta, L., ... & Vallar, G. (2015). Improving left spatial neglect through music scale playing. *Journal of neuropsychology*. doi: 10.1111/jnp.12078
- Beschin, N., Cocchini, G., Allen, R., & Sala, S. D. (2012). Anosognosia and neglect respond differently to the same treatments. *Neuropsychological Rehabilitation*, 22(4), 550-562. doi: 10.1080/09602011.2012.669353
- Bisiach, E., Geminiani, G., Berti, A., & Rusconi, M. (1990). Perceptual and premotor factors of unilateral neglect. *Neurology*, 40(8), 1278-1278. doi: 10.1212/WNL.40.8.1278
- Bisiach, E., & Luzzatti, C. (1978). Unilateral neglect of representational space. *Cortex*, 14(1), 129-133. doi: 10.1016/S0010-9452(78)80016-1
- Bodak, R., Malhotra, P., Bernardi, N. F., Cocchini, G., & Stewart, L. (2014). Reducing chronic visuo-spatial neglect following right hemisphere stroke through instrument playing. *Frontiers in Human Neuroscience*, 8, 413. doi: 10.3389/fnhum.2014.00413

- Bowen, A., Lincoln, N., & Dewey, M. (2007). Cognitive rehabilitation for spatial neglect following stroke. *Cochrane Database Syst Rev*, 2. doi: 10.1002/14651858.CD003586.pub2
- Bowen, A., & Lincoln, N. (2007). Cognitive rehabilitation for spatial neglect following stroke. *The Cochrane Library*. doi: 10.1002/14651858.CD003586.pub2
- Cherney, L. R., & Halper, A. S. (2001). Unilateral visual neglect in right-hemisphere stroke: a longitudinal study. *Brain Injury*, 15(7), 585-592. doi: 10.1080/02699050117415
- Dalla Bella, S., & Penhune, V. B. (2009). The neurosciences and music III: Disorders and plasticity (Vol. 1169). John Wiley & Sons.
- Edwards, D. F., Hahn, M. G., Baum, C. M., Perlmutter, M. S., Sheedy, C., & Dromerick, A. W. (2006). Screening patients with stroke for rehabilitation needs: validation of the post-stroke rehabilitation guidelines. *Neurorehabilitation and Neural Repair*, 20(1), 42-48. doi: 10.1177/1545968305283038
- Eidelberg, E., & Schwartz, A. (1971). Experimental analysis of the extinction phenomenon in monkeys. *Brain*, 94(1), 91-108. doi: 10.1093/brain/94.1.91
- Escoffier, N., Herrmann, C. S., & Schirmer, A. (2015). Auditory rhythms entrain visual processes in the human brain: Evidence from evoked oscillations and event-related potentials. *NeuroImage*, 111, 267-276.
- Eskes, G. A., Butler, B., McDonald, A., Harrison, E. R., & Phillips, S. J. (2003). Limb activation effects in hemispatial neglect. *Archives of physical medicine and rehabilitation*, 84(3), 323-328. doi: doi:10.1053/apmr.2003.50012
- Frassinetti, F., Bolognini, N., Bottari, D., Bonora, A., & Ladavas, E. (2005). Audiovisual

- integration in patients with visual deficit. *Journal of cognitive neuroscience*, 17(9), 1442-1452. doi: 10.1162/0898929054985446
- Frostig, R. (2014). What is Brain Plasticity? Retrieved 08.20., 2014, from <http://www.brainfacts.org/about-neuroscience/ask-an-expert/articles/2012/what-is-brain-plasticity>
- Goldenberg, G. (1986). Neglect in a patient with partial callosal disconnection. *Neuropsychologia*, 24(3), 397-403. doi: 10.1016/0028-3932(86)90025-4
- Gregory, D. (2002). Music listening for maintaining attention of older adults with cognitive impairments. *Journal of Music Therapy*, 39(4), 244-264. doi: 10.1093/jmt/39.4.244
- Groene, R. (2000). The effect of presentation and accompaniment styles on attentional and responsive behaviors of participants with dementia diagnoses. *Journal of music therapy*, 38(1), 36-50.
- Halligan, P. W., Fink, G. R., Marshall, J. C., & Vallar, G. (2003). Spatial cognition: evidence from visual neglect. *Trends in cognitive sciences*, 7(3), 125-133. doi:10.1016/S1364-6613(03)00032-9
- Heilman, K. M., & Valenstein, E. (1972). Frontal lobe neglect in man. *Neurology*, 22(6), 660-660. doi: 10.1212/WNL.22.6.660
- Heilman, K. M., & Valenstein, E. (1979). Mechanisms underlying hemispatial neglect. *Annals of neurology*, 5(2), 166-170.
- Hommel, M., Peres, B., Pollak, P., Memin, B., Besson, G., Gaio, J.-M., & Perret, J. (1990). Effects of passive tactile and auditory stimuli on left visual neglect. *Archives of Neurology*, 47(5), 573-576. doi: 10.1001/archneur.1990.00530050097018
- Jäncke, L. (2009). The plastic human brain.

- Jehkonen, M., Ahonen, J. P., Dastidar, P., Koivisto, A. M., Laippala, P., Vilkki, J., & Molnar, G. (2000). Visual neglect as a predictor of functional outcome one year after stroke. *Acta Neurologica Scandinavica*, *101*(3), 195-201. doi: 10.1034/j.1600-0404.2000.101003195.x
- Karnath, H.-O., Milner, A. D., & Vallar, G. (2002). *The cognitive and neural bases of spatial neglect*: Oxford University Press Oxford:.
- Kim, M., Na, D., Kim, G., Adair, J., Lee, K., & Heilman, K. (1999). Ipsilesional neglect: behavioural and anatomical features. *Journal of Neurology, Neurosurgery & Psychiatry*, *67*(1), 35-38. doi: 10.1136/jnnp.67.1.35
- Kim, J., Wigram, T., & Gold, C. (2008). The effects of improvisational music therapy on joint attention behaviors in autistic children: a randomized controlled study. *Journal of autism and developmental disorders*, *38*(9), 1758-1766. doi:10.1007/s10803-008-0566-6
- Kinsbourne, M. (1970). A model for the mechanism of unilateral neglect of space.
- Knox, R., Yokota-Adachi, H., Kershner, J., & Jutai, J. (2003). Musical attention training program and alternating attention in brain injury: an initial report. *Music Therapy Perspectives*, *21*(2), 99-104. doi: 10.1093/mtp/21.2.99
- Kwakkel, G. (2006). Impact of intensity of practice after stroke: issues for consideration. *Disability and rehabilitation*, *28*(13-14), 823-830. doi:10.1080/09638280500534861
- Làdavvas, E., & Pavani, F. (1998). Neuropsychological evidence of the functional integration of visual, auditory and proprioceptive spatial maps. *Neuroreport*, *9*(6), 1195-1200.
- Landi, F., Zuccala, G., Cocchi, A., Bernabei, R., Tafani, A., & Carbonin, P. (1997). Playing piano in visuospatial neglect: a case study. *Journal of neurology, neurosurgery, and psychiatry*, *62*(5), 543.

- Luauté, J., Halligan, P., Rode, G., Rossetti, Y., & Boisson, D. (2006). Visuo-spatial neglect: a systematic review of current interventions and their effectiveness. *Neuroscience & Biobehavioral Reviews*, *30*(7), 961-982.  
doi:10.1016/j.neubiorev.2006.03.001
- Luft, A. R., McCombe-Waller, S., Whittall, J., Forrester, L. W., Macko, R., Sorkin, J. D., ... & Hanley, D. F. (2004). Repetitive bilateral arm training and motor cortex activation in chronic stroke: a randomized controlled trial. *Jama*, *292*(15), 1853-1861.
- Lee, B., Kang, S., Park, J., Son, Y., Lee, K., Adair, J., . . . Na, D. (2004). The Character-line Bisection Task: a new test for hemispatial neglect. *Neuropsychologia*, *42*(12), 1715-1724.  
doi: 10.1016/j.neuropsychologia.2004.02.015
- Lindén, T., Samuelsson, H., Skoog, I., & Blomstrand, C. (2005). Visual neglect and cognitive impairment in elderly patients late after stroke. *Acta Neurologica Scandinavica*, *111*(3), 163-168. doi: 10.1111/j.1600-0404.2005.00391.x
- Malcolm, M. P., Massie, C., & Thaut, M. (2009). Rhythmic auditory-motor entrainment improves hemiparetic arm kinematics during reaching movements: a pilot study. *Topics in stroke rehabilitation*, *16*(1), 69-79. DOI: 10.1310/tsr1601-69
- Maravita, A., McNeil, J., Malhotra, P., Greenwood, R., Husain, M., & Driver, J. (2003). Prism adaptation can improve contralesional tactile perception in neglect. *Neurology*, *60*(11), 1829-1831. doi: <http://dx.doi.org/10.1212/WNL.60.11.1829>
- Marsh, N. V., & Kersel, D. A. (1993). Screening tests for visual neglect following stroke. *Neuropsychological Rehabilitation*, *3*(3), 245-257. doi: 10.1080/09602019308401439

- Mattingley, J. B., Husain, M., Rorden, C., Kennard, C., & Driver, J. (1998). Motor role of human inferior parietal lobe revealed in unilateral neglect patients. *Nature*, 392(6672), 179-182. doi: 10.1038/32413
- McFie, J., Piercy, M., & Zangwill, O. (1950). Visuospatial agnosia associated with lesions of the right cerebral hemisphere. *Brain: a journal of neurology*. doi: 10.1093/brain/73.2.167
- McIntosh, G. C., Brown, S. H., Rice, R. R., & Thaut, M. H. (1997). Rhythmic auditory-motor facilitation of gait patterns in patients with Parkinson's disease. *Journal of Neurology, Neurosurgery & Psychiatry*, 62(1), 22-26. doi:10.1136/jnnp.62.1.22
- Menon, A., & Korner-Bitensky, N. (2004). Evaluating unilateral spatial neglect post stroke: Working your way through the maze of assessment choices. *Topics in stroke rehabilitation*, 11(3), 41-66. doi: 10.1310/KQWL-3HQL-4KNM-5F4U
- Miller, J. E., Carlson, L. A., & McAuley, J. D. (2012). When what you hear influences when you see listening to an auditory rhythm influences the temporal allocation of visual attention. *Psychological science*, 0956797612446707.
- Moreno, S., Marques, C., Santos, A., Santos, M., Castro, S. L., & Besson, M. (2009). Musical training influences linguistic abilities in 8-year-old children: more evidence for brain plasticity. *Cerebral Cortex*, 19(3), 712-723. doi: 10.1093/cercor/bhn120
- Moreno, S., Bialystok, E., Barac, R., Schellenberg, E. G., Cepeda, N. J., & Chau, T. (2011). Short-term music training enhances verbal intelligence and executive function. *Psychological science*, 22(11), 1425-1433. doi: 10.1177/0956797611416999
- Mort DJ, Malhotra P, Mannan SK, Rorden C, Pambakian A, Kennard C, Husain M (2003). The anatomy of visual neglect. *Brain* 126 (9), 1986-1997. doi: <http://dx.doi.org/10.1093/brain/awg200>

- National Stroke Association. (2014). *Understand Stroke*. Retrieved 08.20, 2014, from <http://www.stroke.org/understand-stroke>
- Noto, S., Fumiko, M., Amimoto, K., Sugimoto, S., & Futaki, T. (1999). [Effect of “xylophone therapy” for a patient of unilateral spatial neglect]. *Journal of the Japanese Occupational Therapy Association, 18*, 126–133.
- Peretz, I., & Zatorre, R. J. (2005). Brain organization for music processing. *Annu. Rev. Psychol., 56*, 89-114. doi: 10.1146/annurev.psych.56.091103.070225
- Pizzamiglio, L., Fasotti, L., Jehkonen, M., Antonucci, G., Magnotti, L., Boelen, D., & Asa, S. (2004). The use of optokinetic stimulation in rehabilitation of the hemineglect disorder. *Cortex, 40*(3), 441-450. doi:10.1016/S0010-9452(08)70138-2
- Riestra, A. R., & Barrett, A. M. (2013). Rehabilitation of spatial neglect. *Handbook of clinical neurology, 110*, 347.
- Ringman, J., Saver, J., Woolson, R., Clarke, W., & Adams, H. (2004). Frequency, risk factors, anatomy, and course of unilateral neglect in an acute stroke cohort. *Neurology, 63*(3), 468-474. doi: 10.1212/01.WNL.0000133011.10689.CE
- Robertson, I. H., Manly, T., Beschin, N., Daini, R., Haeske-Dewick, H., Hömberg, V., ... & Weber, E. (1997). Auditory sustained attention is a marker of unilateral spatial neglect. *Neuropsychologia, 35*(12), 1527-1532.
- Rose, F. D., Brooks, B. M., & Rizzo, A. A. (2005). Virtual reality in brain damage rehabilitation: review. *CyberPsychology & Behavior, 8*(3), 241-262. doi:10.1089/cpb.2005.8.241
- Särkämö, T., Tervaniemi, M., Laitinen, S., Forsblom, A., Soinila, S., Mikkonen, M., . . . Laine, M. (2008). Music listening enhances cognitive recovery and mood after middle cerebral artery stroke. *Brain, 131*(3), 866-876. doi: 10.1093/brain/awn013

- Sea, M. J. C., & Henderson, A. (1994). The reliability and validity of visuospatial inattention tests with stroke patients. *Occupational Therapy International, 1*(1), 36-48. doi: 10.1002/oti.6150010106
- Simmons-Stern, N. R., Budson, A. E., & Ally, B. A. (2010). Music as a memory enhancer in patients with Alzheimer's disease. *Neuropsychologia, 48*(10), 3164-3167. doi: 10.1016/j.neuropsychologia.2010.04.033
- Soto, D., Funes, M. J., Guzmán-García, A., Warbrick, T., Rotshtein, P., & Humphreys, G. W. (2009). Pleasant music overcomes the loss of awareness in patients with visual neglect. *Proceedings of the National Academy of Sciences, 106*(14), 6011-6016. doi: 10.1073/pnas.0811681106
- Sprague, J. M., Chambers, W. W., & Stellar, E. (1961). Attentive, Affective, and Adaptive Behavior in the Cat Sensory deprivation of the forebrain by lesions in the brain stem results in striking behavioral abnormalities. *Science, 133*(3447), 165-173. doi: 10.1126/science.133.3447.165
- Sterzi, R., Bottini, G., Celani, M., Righetti, E., Lamassa, M., Ricci, S., & Vallar, G. (1993). Hemianopia, hemianaesthesia, and hemiplegia after right and left hemisphere damage. A hemispheric difference. *Journal of Neurology, Neurosurgery & Psychiatry, 56*(3), 308-310. doi: 10.1136/jnnp.56.3.308
- Stone, S., Halligan, P., & Greenwood, R. (1993). The incidence of neglect phenomena and related disorders in patients with an acute right or left hemisphere stroke. *Age and Ageing, 22*(1), 46-52. doi: 10.1093/ageing/22.1.46
- Strokeengine. (2014b). *Line Bisection Test*. Retrieved 08.20, 2014, from [http://strokengine.ca/assess/module\\_lbt\\_indepth-en.html](http://strokengine.ca/assess/module_lbt_indepth-en.html)



- Sunderland, A., Wade, D. T., & Hewer, R. L. (1987). The natural history of visual neglect after stroke Indications from two methods of assessment. *Disability & Rehabilitation*, 9(2), 55-59. DOI:10.3109/03790798709166235
- Tegner, R., & Levander, M. (1991). Through a looking glass. A new technique to demonstrate directional hypokinesia in unilateral neglect. *Brain*, 114(4), 1943-1951. doi: 10.1093/brain/114.4.1943
- Thaut, M. (2010). Neurologic Music Therapy in Cognitive Rehabilitation. *Music Perception* 27:281-285
- Thaut, M., Kenyon, G., Schauer, M., & McIntosh, G. (1999). The connection between rhythmicity and brain function. *Engineering in Medicine and Biology Magazine, IEEE*, 18(2), 101-108. 10.1109/51.752991
- Thaut, M., McIntosh, G., Rice, R., Miller, R., Rathbun, J., & Brault, J. (1996). Rhythmic auditory stimulation in gait training for Parkinson's disease patients. *Movement disorders*, 11(2), 193-200.
- Thaut, M., Peterson, D., McIntosh, G. C., & Hoemberg, V. (2014). musical mnemonics aid verbal memory and induce learning related brain plasticity in multiple sclerosis. *Frontiers in Human Neuroscience*, 8, 395. doi: 10.3389/fnhum.2014.00395
- Thaut, M. H. (2008). *Rhythm, Music, and the Brain*. UK: Routledge.
- Thaut, M. H., & Hoemberg, V. (2014). *Handbook of neurologic music therapy*: Oxford University Press.
- Van Vleet, T. M., & Robertson, L. C. (2006). Cross-modal interactions in time and space: auditory influence on visual attention in hemispatial neglect. *Journal of cognitive neuroscience*, 18(8), 1368-1379. doi:10.1162/jocn.2006.18.8.1368

- Wan, C. Y., & Schlaug, G. (2010). Music making as a tool for promoting brain plasticity across the life span. *The Neuroscientist*, *16*(5), 566-577. doi: 10.1177/1073858410377805
- Watson, R. T., Heilman, K. M., Cauthen, J. C., & King, F. A. (1973). Neglect after cingulectomy. *Neurology*.
- Watson, R. T., Heilman, K. M., Miller, B. D., & King, F. A. (1974). Neglect after mesencephalic reticular formation lesions. *Neurology*, *24*(3), 294-294. doi: 10.1212/WNL.24.3.294
- Wolfe, D. E., & Noguchi, L. K. (2009). The use of music with young children to improve sustained attention during a vigilance task in the presence of auditory distractions. *Journal of Music Therapy*, *46*(1), 69-82. doi: 10.1093/jmt/46.1.69