

THESIS

ACTIVE MUSIC MAKING FOR PATIENTS WITH UNILATERAL SPATIAL NEGLECT IN
THE SUBACUTE STAGE OF STROKE

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ABSTRACT

ACTIVE MUSIC MAKING FOR PATIENTS WITH UNILATERAL SPATIAL NEGLECT IN THE SUBACUTE STAGE OF STROKE

Unilateral neglect is the decreased awareness of events or items in the contralesional side of space, on the opposite side of the brain affected by a stroke. This study examined the effect of a music therapy procedure on the severity of unilateral spatial neglect in patients in the subacute stage of stroke. Three individuals were recruited from a large Midwestern hospital to participate in this study, all with a presentation of left neglect. One functional assessment (Kessler Foundation Neglect Assessment Process) was completed at admission and discharge to measure severity of neglect during activities of daily living. Two written assessments (Line Bisection Test and Line Cancellation Test) were administered at the start and end of each music therapy session to examine any immediate effects. During each session, patients were asked to hit a paddle drum gradually moved from the non-neglected side of space (right) toward the neglected side of space (left) over the course of every four beats. Patients then completed musical sequences on resonator bells following a descending pattern, also directed right to left. Results showed inconsistent performance between and within sessions for all participants on the Line Bisection Test. Written performance varied for two participants on the Line Cancellation Test, while one participant showed no change from the second treatment session through hospital discharge. These preliminary findings support further exploration into the use of musical instruments as a possible intervention for neglect, though future research involving larger sample sizes or a control group is needed.

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CHAPTER I: INTRODUCTION

Every 40 seconds, an individual in the United States experiences a stroke, resulting in almost 800,000 people impacted each year nationwide (American Heart Association, 2016). Stroke, formally referred to as a cerebrovascular accident (CVA), occurs when blood supply to the brain is interrupted, and may be classified as either ischemic or hemorrhagic in nature based on underlying cause (National Stroke Association, 2013). Approximately 87% of all strokes are considered ischemic, occurring when either a thrombus within the brain or an embolism formed in another part of the circulatory system, obstructs a blood vessel to the brain. The remaining 13% of strokes are classified as hemorrhagic, resulting from a weakened blood vessel rupturing or bleeding within surrounding brain tissue (American Heart Association, 2016). As a leading cause of long-term disability (American Heart Association, 2016), individuals that survive a stroke may have decreased strength or coordination, cognitive function, and production of or understanding of speech, as well as a number of other deficits that impact overall daily functioning (National Stroke Association, 2013). One specific behavioral deficit, unilateral neglect, or the inability to report or respond to environmental stimuli on one side of the body, has been observed in up to 82% of patients following a right-hemispheric stroke and up to 65% of individuals following a left-hemispheric stroke (Plummer, Morris, & Dunai, 2003).

Unilateral neglect is when individuals lack awareness of events or items in the contralesional side of space, on the opposite side of the brain affected by a stroke. Neglect impacts almost all activities of daily life, and may manifest itself as eating only half of a plate of food, only washing one side of the body, or running into items during mobility exercises (Bernardi et al., 2015). Neglect may result in a diverse set of behaviors, which may be attributed

to the differences in anatomical lesions following an infarct (Plummer, Morris, & Dunai, 2003; Shenk & Karnath, 2012). Furthermore, this heterogeneity of symptoms adds to the complex nature of the disorder, as the variety of presentations are more difficult to treat (Karnath & Rorden, 2012; Schenk & Karnath, 2012).

Research Problem

While a third of patients with neglect show a partial recovery in the first few months post-stroke, another third of people remain severely disabled with daily activities (Kerkhoff & Schenk, 2012). Neglect negatively impacts not only acute rehabilitation progress, but also relates to long-term functional outcomes and recovery in patients following stroke (Cherney, Halper, Kwasnica, Harvey, & Zhang, 2001; Diamond, 2001; Gillen, Tennen, & McKee, 2005; Kerkhoff & Schenk, 2012). Individuals with neglect have a lower chance for recovery in comparison to their stroke or brain injury counterparts without neglect (Katz, Hartman-Maier, Ring, & Soroker, 1999) and many exhibit difficulties in completing activities of daily living as well as mobility tasks (Eschenbeck et al., 2010; Katz et al., 1999; Paolucci, Antonucci, Grasso, & Pizzamiglio, 2001).

Acute intervention and rehabilitation are essential in helping to retrain the injured brain following stroke, due to the role of neuroplasticity (Wan & Schlaug, 2010). While progress may be made years following a stroke, most improvement has been found to occur within the first five months after stroke onset (Katz, Hartman-Maeir, Ring, & Soroker, 1999). As such, timely and effective interventions are essential in a rehabilitative model of care. While about 18 different methods have been used to treat the symptoms of visual neglect (Luauté, Halligan, Rode, Rossetti, & Boisson, 2006), many have transient effects (Kerkhoff, 2003) or fail to generalize to daily activities (Pierce & Buxbaum, 2002).

Rationale and Potential Impact of Study

Few research studies report on the effect of music-based interventions to address neglect. Music therapy, or the “clinical and evidenced-based use of music interventions to accomplish individualized goals within a therapeutic relationship by a credentialed professional who has completed an approved music therapy program,” (American Music Therapy Association, 2018) is a form of treatment for individuals following stroke to address a variety of functional goals. More specifically, music can be used as a therapeutic tool to treat sensorimotor, speech and language, cognitive, and psychosocial needs of individuals (Davis, Gfeller, & Thaut, 2008; Thaut & Hoemberg, 2014).

While one Neurologic Music Therapy (NMT) technique, Music Neglect Training (MNT), offers a framework for music therapy clinicians working with individuals with neglect (Thaut & Hoemberg, 2014), there is not much current evidence to support the implementation of such an intervention. Furthermore, no studies to date report on the effect of music therapy-based methods with patients in the acute or subacute phase of stroke, defined as within the first few weeks or months following initial onset. Many studies also lack a functional assessment of neglect, using only written tools to determine severity of neglect, not accounting for other behaviors that impact activities of daily living (ADLs).

This study aimed to help close the gap between theory and methods presented in the existing literature to provide greater insight into the effectiveness of such interventions in a clinical setting. Participants in this study were in the subacute stage of stroke and assessments conducted were written as well as functional, accounting for everyday behaviors such as colliding with objects during mobility or cleaning after meals. Results of this study may have implications for individuals living with neglect, family members and caregivers supporting loved

ones with neglect, and clinicians and organizations treating or providing services to those with neglect.

Purpose of Study

The purpose of this study was to determine the effect of a music therapy procedure on the presentation of left spatial neglect in patients with right-hemispheric stroke on a rehabilitation unit of a large Midwestern hospital. Specific research questions included:

- 1) Would there be a difference in severity of neglect on written assessments such as the line bisection test (LBT) or line cancellation test (Albert's Test) following a music therapy intervention for neglect?
- 2) Would there be a difference in severity of neglect on a functional assessment such as the Kessler Foundation Neglect Assessment Process (KF-NAPTM) upon hospital discharge as compared to admission?

Hypotheses

Null hypotheses:

- 1) There would be no difference in severity of neglect on a Line Bisection Test following a music-based intervention.
- 2) There would be no difference in severity of neglect on a Line Cancellation Test following a music-based intervention.
- 3) There would be no difference in severity of neglect on the Kessler Foundation Neglect Assessment Process upon hospital discharge as compared to admission.

Hypotheses:

- 1) There would be a difference in severity of neglect on a Line Bisection Test following a music-based intervention.

- 2) There would be a difference in severity of neglect on a Line Cancellation Test following a music-based intervention.
- 3) There would be a difference in severity of neglect on the Kessler Foundation Neglect Assessment Process upon hospital discharge as compared to admission.

CHAPTER II: LITERATURE REVIEW

Unilateral neglect, also referred to as hemineglect (Spierer, Meuli, & Clarke, 2007), hemispacial neglect (Vleet & Robertson, 2006), visuospatial neglect (Harvey & Rossit, 2011), or simply neglect (Karnath, 2015), is characterized by a lack of awareness or failure to report, respond to, or orient to various types of stimuli presented in the contralesional side of space (Eschenbeck et al., 2010). Neglect may result in abnormal behaviors such as washing only one side of the face, eating only half a plate of food, writing on only one side of a paper, or dressing only one half of the body (Bernardi et al., 2015; Gabrieli & Whitfield-Gabrieli, 2007).

Neglect in the acute phase has an estimated total annual incidence of 239,000 people in the United States, or at least 30% of all stroke survivors, with about 3% of all stroke survivors living chronically with neglect (Riestra & Barrett, 2013). Neglect is often more severe and persistent following a neurological insult to the right hemisphere of the brain, thereby affecting the left side of the body (Rode, Pagliari, Huchon, Rossetti, & Pisella, 2016), and occurs in about 50% of right hemisphere stroke survivors (Riestra & Barrett, 2013).

Neglect not only prolongs and complicates the rehabilitation process, but is also a major predictor of overall functional outcome (Cherney et al., 2001; Eschenbeck et al., 2010). Individuals have a lower chance of returning home following a stroke with neglect (Paolucci et al., 2001), along with a higher level of family burden and requirements for care (Riestra & Barrett, 2013). As such, rehabilitation efforts for treating neglect are considered essential in helping to lower long-term costs and improve overall functional outcomes for individuals post stroke living with neglect.

Link to Functional Outcomes

Neglect is predictive of both acute rehabilitation and recovery outcomes as well as long-term outcomes for individuals post stroke (Diamond, 2001). Upon admission for rehabilitation, patients often have severe neurocognitive deficits coupled with poor functional status and are more likely to be incontinent (Paolucci et al., 2001). Even when compared to those with an equally poor functional status at admission, patients with neglect progress slower than other rehabilitation patients (Gillen et al., 2005; Katz et al., 1999).

Neglect is a major predictor of rehabilitation outcomes, as patients with neglect typically have a longer length of stay at the hospital along with significantly worse Functional Independence Measures (FIM) scores (Fiedler & Granger, 1996) when compared to stroke survivors without neglect (Katz et al. 1999). Related to decreased FIM scores, neglect has also been associated with difficulties in accomplishing activities of daily living (ADLs; Eschenbeck et al., 2010) as well as decreased performance on the Rabideau Kitchen Evaluation for independent activities of daily living (IADLs; Katz et al., 1999). Additionally, Paolucci et al. (2001) reported the decreased effectiveness and efficiency of treatment for both ADLs and mobility for patients with neglect, while Cherney et al. (2001) indicated decreased functional outcomes for reading and writing as well.

Katz et al. (1999) suggested that most improvement occurs within the first five months after stroke onset and Ting et al. (2011) supported this notion by indicating that early recognition and prompt rehabilitation following a multidisciplinary approach is best. While one third of patients with neglect have a partial recovery in the first few months, another third remain severely disabled with daily activities (Kerkhoff & Schenk, 2012). As a result, patients are less likely to return home following stroke with neglect (Paolucci et al. 2001).

Shared Characteristics and Symptoms

Neglect is characterized by a combination of reduced attention, a deficit in visuospatial or spatial working memory, impaired exploratory motor behaviors, or perseveration (Ronchi, Posteraro, Fortis, Bricolo, & Vallar, 2009). Ricci et al. (2016) found that more demanding, non-spatial cognitive tasks appeared to worsen neglect, which the researchers attributed to a combination of decreased sustained attention with a selective deficit of spatial attention. Other researchers supported these findings, noting that deficits in non-spatial attention such as selective or sustained attention may influence spatial attention (Robertson et al., 1997; Vleet & Degutis, 2013).

Within visuospatial working memory, there are two components: spatial and visual subsystems. Spatial working memory was found to predict score on spatial imagery tasks, while visual working memory did not predict performance on visual imagery tasks (Wansard, Meulemans, & Geurten, 2016). Malhotra, Manna, Driver, & Husain (2004) supported this claim that an impaired spatial working memory intensifies neglect following a study showing that individuals with neglect were impaired in retaining the spatial location of an item on a vertical spatial working memory task, which was used to eliminate directional bias. Within the visual search task, patients with neglect repeatedly searched to the right, treating all stimuli as a new discovery. During recovery, patients made concurrent improvements in both spatial working memory and left neglect, further supporting this claim (Malhotra et al., 2004). Finally, Pisella, Berberovic, and Mattingly (2004) noticed an impaired working memory for location, but not for color or shape in visual neglect. The researchers attributed this to deficits in the parietal cortex, which is involved in updating and remembering spatial representations, highlighting that neglect may cause impairments in these mechanisms (Pisella et al., 2004).

Anatomical Correlates

Many observed characteristics of patients with neglect are supported from a neurological perspective. Ricci et al. (2012) found that right lesions, which are more common in those with neglect, impair the ability to maintain and sustain attention, while He et al. (2007) noted that more severe neglect is typically associated with a disconnection of white matter tracts in the frontal-parietal cortices. Shomstein, Kravitz, and Behrmann (2012) justified these findings by reporting that frontal networks are often implicated with a shift of attention and that parietal networks are responsible for the attention modulation of sensory events.

Much of the current research supports a network view of neglect based on the idea that distinctive actions and impaired attentional processes are dependent on different cortical networks (Harvey & Rossit, 2011; He et al., 2007). Specifically, this disrupted functional connectivity may originate in the ventral and dorsal attention networks (Clarke & Thiran, 2004; Gabrieli & Whitfield-Gabrieli, 2007).

Neural areas impacted within the ventral stream may include the temporoparietal junction, ventral frontal cortex (Gabrieli & Whitfield-Gabrieli, 2007; He et al., 2007), and the occipito-temporal or parahippocampal cortices (Harvey & Rossit, 2011) along with the oculomotor system (Smith & Schenk, 2012). Within this network, connectivity is diffusely disrupted and there is a lower chance of recovery (Bartolomeo & Chokron, 2002; He et al., 2007). Ventral networks rely on offline actions (Harvey & Rossit, 2011) facilitated by bottom-up processes that are stimulus-driven and not target-driven (Karnath, 2015; Smith & Schenk, 2012). Neglect associated with this network is often referred to as exogenous or allocentric, also referred to as scene-based, as individuals are unable to orient or detect a target in space (Karnath, 2015).

On the contrary, neural regions connected to the dorsal stream may consist of the intraparietal sulcus (Gabrieli & Whitfield-Gabrieli, 2007; He et al., 2007) and the visuomotor control network, consisting of the basal ganglia, frontal, and parieto-occipital regions (Harvey & Rossit, 2011). In comparison to ventral networks, dorsal networks rely on online actions (Harvey & Rossit, 2011) facilitated by top-down neurological processes that are goal-directed and target-driven (Karnath, 2015; Smith & Schenk, 2012). Neglect related to this network is typically classified as endogenous or egocentric, also known as viewer-based, as individuals maintain voluntary exploration with a preserved, but slow processing speed (Bartolomeo & Chokron, 2002; Karnath, 2015; Rossit et al. 2012). Connectivity in this stream is acutely disrupted, leading to a greater chance of recovery (He et al., 2007).

Through the differentiation of these networks, neglect shows how neural processes encode topographical information and organize spatially-oriented attention (Karnath, 2015). Despite the widespread acceptance of the two different neural networks, Rorden et al. (2012) also reported a large corresponding overlap for anatomical regions and noted that allocentric neglect is often strongly associated with severe egocentric deficits.

Types of Neglect

While a number of neuroanatomical regions have been associated with neglect (Schenk & Karnath, 2012), many of the underlying mechanisms of neglect are still unclear (Ogourtsova, Korner-Bitensky, & Ptito, 2010). A variety of presentations of neglect exist resulting in what Karnath & Rorden (2012) classified as a “heterogeneous collection of symptoms (p. 1010).”

Rode et al. (2016) outlined seven major subtypes of neglect: visual, auditory, somatosensory, motor, egocentric, allocentric, and representational neglect, and categorize each type based on extrapersonal or personal space, processing modality, symptoms, and anatomical

lesion. Due to the diverse nature of neglect, Rode et al. (2016) called for the need for the development of targeted rehabilitation protocols to match neural deficits. Pierce and Buxbaum (2002) supported this idea by suggesting patients be assigned to appropriate treatments based on neuroanatomical and behavioral profiles to maximize rehabilitative efforts. To effectively define each presentation of neglect, Rode et al. (2016) recommended using specific assessment tasks for each different type of neglect to best evaluate the various underlying deficits unique to each subtype.

Assessment of Neglect

A test battery of multiple clinical assessments has been recommended to best assess neglect (Plummer et al., 2003; Ting et al., 2011). Two major types of assessments exist in order to best diagnose and define symptoms of neglect: traditional assessments completed on paper as well as functional assessments linked to ADL performance. While a variety of traditional paper assessments exist, many are classified as falling into one of a few categories.

In line bisection tasks (LBT), individuals are asked to mark the center of a horizontal line on a piece of paper and measure the deviation from the exact midpoint of the line. For cancellation tasks, individuals search for and cross out target symbols on a page and may include the cancellation of items such as “shapes, stars, numbers, letters, lines, bells, and circles” (Plummer et al., 2003, p. 734). To assess not only the presence of neglect, but also the severity level, Rorden and Karnath (2010) recommend the Center of Cancellation (CoC) test. Varying design and structure (Plummer et al., 2003) as well as patient perseveration on such tasks (Ronchi et al., 2009) may impact performance. Copying and drawing tests are also used to test for representational neglect, as patients are asked to copy figures such as “flowers, stars, cubes, and geometric shapes” or a clock face (Plummer et al., 2003, p. 736). Despite the widespread

application of the tests, Plummer and colleagues (2003) do not recommend using copying and drawing tests to assess neglect as they are subjective and are unable to identify all patients with neglect.

Another form of assessment is the Behavioral Inattention Test (BIT), or a 15-item test battery that includes six of the most common tests including line crossing and bisection, letter and star cancellation, figure copying, and free drawing as well as nine behavioral tasks such as scanning pictures, dialing a telephone, reading a menu or article, telling and setting time, sorting coins or cards, copying an address and sentence, and navigating a map (Cherney et al., 2001; Plummer et al., 2003). While still subjective, clear criteria help to enhance objectivity. On the other hand, the BIT is unable to identify personal or extrapersonal neglect as well as distinguish between sensory and motor neglect, and as such should only be used in combination with other tests (Plummer et al., 2003). While comprehensive, the BIT may require more time for administration compared to other individual assessments.

Functional assessments linked to ADL performance have also been suggested for the assessment of neglect, as they assess items beyond conventional tests (Eschenbeck et al., 2010) and have been found to correlate with severity of neglect (Vossel, Weiss, Eschenbeck, & Fink, 2013). One functional measure is the Catherine Bergego Scale (CBS), which consists of a checklist to assess neglect in a variety of daily activities. Items evaluated include: grooming and shaving, wearing clothing, eating food, cleaning mouth after eating, spontaneous leftward gaze orientation, 'knowledge' of the left part of the body, attending to auditory stimuli, collisions with objects, navigating familiar places, and item location (Azouvi et al., 1996; Plummer et al., 2003). One benefit of the CBS compared to other assessments is that the test includes personal, peripersonal, and extrapersonal items. Additionally, the CBS is recommended for its

consideration of anosognosia, or awareness of deficits (Azouvi et al., 1996). One process for administering the CBS, the Kessler Foundation Neglect Assessment Process (KF-NAP™) was designed to help standardize administration of the CBS among rehabilitation clinicians (Chen, Hreha, Fortis, Goedert, & Barrett, 2012). The KF-NAP™ examines ten different items: gaze orientation, limb awareness, auditory attention, personal belongings, dressing, grooming, navigation, collisions, meals, and cleaning after meals, measuring neglect-related ADLs in an ecological environment (Chen & Hreha, 2015; Chen et al., 2012).

Vossel et al. (2013) recommended routine assessment of both neglect and anosognosia, although Ronchi et al. (2014) noted a lack of evaluation for anosognosia in the literature. Researchers indicated discrete processes involved in monitoring awareness of physical and cognitive performance, specifically that individuals may have a preserved awareness of decreased performance on complex visuo-motor spatial and reading tasks, but may be unaware of spatial difficulties on the LBT or when drawing from memory (Ronchi et al., 2014). Awareness of deficits is the most important predictor of ADL performance according to Vossel and colleagues (2013), likely due to the patient's increased ability to correct or compensate for errors.

Non-Musical Rehabilitation Efforts and Limitations

Researchers support the development of targeted rehabilitation protocols that address various presentations of neglect (Rode et al., 2016). Some researchers called for interventions that target specific neural areas and processes (Ogurtsova et al., 2010), while others suggested that patients with neglect be assigned to various treatments based on their neuroanatomical and behavioral profiles (Pierce & Buxbaum, 2002). Other researchers proposed the use of interventions that are action-based and supported by motor movements (Robertson, Nico, &

Hood, 1995). Specifically, Robertson et al. (1995) found a reduction in neglect when individuals were asked to reach for an item or when completing an action task compared to when they were asked to simply point to an item. From the results of this study, the researchers found that motor manipulative responses remained unaffected, and thereby could provide greater insight regarding the spatial extent of neglect. As such, interventions that include goal-directed motor movements are favored in the rehabilitation of neglect.

While many rehabilitation efforts use purposeful cueing or force the individual to attend to stimuli presented in contralateral space (Riddoch & Humphreys, 1983), not all patients respond to treatment in the same way due to the heterogeneity of neglect (Pierce & Buxbaum, 2002). As a result, around 20 different methods have been developed to help alleviate the symptoms of unilateral neglect (Luaute et al., 2006), including caloric vestibular stimulation (Chokron, Dupierrix, Tabert, Bartolomeo, 2007; Diamond, 2001; Kerkhoff, 2003; Kerkhoff & Schenk, 2012), eye patching or partial visual occlusion (Beis, Andre, Baumgarten, & Challier, 1999; Diamond, 2001; Freeman, 2001; Ogourtsova et al., 2010), visual or mental imagery (Diamond, 2001; Luaute et al., 2006), motor imagery (Johansson, 2012), action observation (Johansson, 2012), video feedback (Diamond, 2001; Luaute et al., 2006), transcutaneous mechanical muscle and electrical neural stimulation (Chokron et al., 2007; Kerkhoff, 2003; Kerkhoff & Schenk, 2012; Luaute et al., 2006), limb activation (Chokron et al., 2007), trunk rotation (Chokron et al., 2007; Luaute et al., 2006; Wiart et al., 1997), virtual reality (Johansson, 2012; Ting et al., 2011), constraint-induced therapy (Freeman, 2001), flashes of light (Fan, Wu, Tsai, & Lin, 2015), mirror therapy/training (Pandian et al., 2014), visual scanning training (Diamond, 2001; Luaute et al., 2006; Piccardi, Nico, Bureca, Matano, & Guariglia, 2006; Ting et al., 2011), optokinetic stimulation (Chokron et al., 2007; Diamond, 2001; Kerkhoff, 2003;

Kerkhoff et al., 2012; Kerkhoff & Schenk, 2012; Schenk & Karnath, 2012), pharmacologic treatments with dopamine agonists (Diamond, 2001; Kerkhoff, 2003), and/or prism adaptation therapy (Chokron et al., 2007; Kerkhoff & Schenk, 2012; Ladavas, Bonifazi, Catena, & Serino, 2011; Luaute et al., 2006; Newport & Schenk, 2012; Ogourtsova et al., 2010; Redding & Wallace, 2006; Schenk & Karnath, 2012; Ting et al., 2011).

Learning and rehabilitation is considered to be most effective in a multisensory environment that consists of multiple rehabilitation efforts, as the combination of different modalities facilitates the ability to detect, discriminate, and recognize sensory stimuli (Johansson, 2012; Kerkhoff, 2003). Treatment efforts following a multidisciplinary approach should be implemented as early as possible for the best clinical outcomes (Johansson, 2012; Ting et al., 2011). Despite any advanced research efforts, many of the current treatment efforts are limited, as they may be ineffective (Pizzamiglio et al., 2004), produce transient effects (Kerkhoff, 2003; Kerkhoff et al., 2012; Nijboer, Nys, Smagt, Stigchel, & Dijkerman, 2011; Pierce & Buxbaum, 2002; Serino, Angeli, Frassinetti, & Ladavas, 2006), or fail to generalize to daily activities (Pierce & Buxbaum, 2002). As such, future research should consider the duration of treatment effects and include functional measures of assessment.

Connections to Audition

Neglect is a complex neurological disorder that disturbs an integrated multimodal system used to process stimuli. Jacobs, Brozzoli, and Farne (2012) indicated that neglect may impact multiple sensory modalities including vision, touch, proprioception, and motor, as well as audition. To support the existence of auditory neglect, researchers reported that individuals with neglect often present with an inability to detect sounds as well as recognize and identify the source of the sounds (Clarke & Thiran, 2004; Guilbert et al., 2016; Pavani, Husain, Ládavas, &

Driver, 2004; Pavani, Ládavas, & Driver, 2003; Pavani, Meneghello, & Ládavas, 2001; Spierer et al., 2007). Auditory deficits in the identification and localization of sounds have also been found to correlate with clinical measures of neglect severity (Guilbert et al., 2016; Pavani et al., 2003; Pavani et al., 2004).

Due to the cross-modal spatial interaction and integration between the different types of stimuli (Frassinetti, Bolognini, & Ládavas, 2002; Frassinetti, Pavani, & Ládavas, 2002; Vleet & Robertson, 2006), auditory cues may be used to entrain visual processes and direct attention to neglected space (Escoffier, Herrman, & Schirmer, 2015). One specific study by Frassinetti, Pavani, and Ládavas (2002) illustrated that visual detection is improved when both visual and auditory stimuli are combined and presented in a similar position. In the study, participants were presented with a flash of light in six different spatial positions following either a unimodal (visual stimuli only) or cross-modal (sound with a target in a similar or different position) presentation. Following the results of the study, researchers discovered that there was no improvement when the stimuli were presented separately, but that sensitivity for visual stimuli was enhanced when presented with auditory stimuli that followed a predictable spatial and temporal pattern. As such, these findings indicated that predictable auditory cues could be used as an effective prompt to direct visual attention toward the neglected side of the body.

The process of rhythmic entrainment allows individuals with neglect to appropriately predict and respond to stimuli found in their environment. Rhythmic expectations are supported by a reorganization of neural oscillations, as presenting stimuli at expected time points allows the brain to better predict environmental signals (Escoffier et al., 2015). Furthermore, event-related potentials have been associated with spatial shifts in attention (Shomstein et al., 2012). Escoffier et al. (2015) maintained this as well, noting that temporal regularities may guide the allocation of

attention over time. Additional research by Robertson, Mattingly, Rorden, and Driver (1998) as well as Vleet and Degutis (2013) supported the use of a tonic and phasic warning sound to alert patients of left visual events and thereby improve visual awareness, as the use of rhythmic cues may not only improve attention, but also enhance stimuli perception in patients following stroke (Escoffier et al., 2015).

Connections of Music to Space

Beyond acting as a predictive prompt for visual stimuli, auditory cues may also be used to influence spatial representations (Ishihara et al., 2013). To illustrate this, researchers reported a Spatial-Musical Association of Response Codes (SMARC) effect, where high pitches are commonly associated with up-right responses and low pitches are associated with down-left responses (Bernardi et al., 2015; Ishihara et al., 2013; Lega, Cattaneo, Merabet, Vecchi, & Cuchi, 2014). These responses have also been shown to influence performance on line bisection tasks, showing a close link between auditory perception and spatial representation (Ishihara et al., 2013).

At the same time, the strength of the association may also depend on the musical skills of each individual. During their study investigating whether different tones impacted the representation of space in musicians and nonmusicians, Lega et al. (2014) noted that there was no effect of pitch height on the bisection performance for the nonmusicians, illustrating that performance on the task may have been related to musical training. The authors also indicated that practicing a bimanual musical instrument may impact hemispheric representation of space and that a history of musical training could enhance spatial skills and improve performance on line bisection tasks (Lega et al., 2014).

Music for Inducing Positive Emotions

Although cortical lesions may impair the ability to maintain arousal following a stroke (Robertson, Mattingly, Rorden, & Driver, 1998), listening to pleasant music has been shown to reverse these effects and increase arousal (Chen, Tsai, Huang, & Lin, 2013). Beyond arousal, Russell, Li, and Malhotra (2013) indicate that attention may be increased through motivational rewards like listening to preferred music. When attentional resources increase, signs and symptoms of neglect often begin to decrease (Soto et al., 2009), supporting the idea that neglect rehabilitation should be motivating and engaging to increase arousal and attention. Additionally, feelings of motivation have been associated with an increase in dopaminergic stimulation (Russell et al., 2013), which in turn has been linked to an enhancement in cognitive performance (Guilbert, Clement, & Moroni, 2014). As a result, motivating treatments such as music should be considered in the cognitive rehabilitation of unilateral neglect.

Dominguez-Borras, Saj, Armony, and Vuilleumier (2012) reported that although spatial attention is impacted by neglect, sensory pathways usually remain intact. As a result, the emotional content of stimuli can still be processed, such as faces with emotions, voices with emotional prosody, or pictures of scenes, which may increase attention and subsequently counteract spatial biases, decreasing symptoms of neglect (Dominguez-Borras et al., 2012). Since emotional attention mechanisms may operate differently than other spatial attention circuits, they play a large role in the potential rehabilitation of patients with neglect (Dominguez-Borras et al., 2012) and may be used to modulate awareness (Soto et al., 2009).

Music has been shown to induce positive emotions and increase affect (Lim, Miller, & Fabian, 2011) and may be a way to include emotional stimuli in the treatment of neglect. Researchers have found that older adults with cognitive impairments showed affective responses

to music (Gregory, 2002) and that music therapy might be an effective way to impact mood states in neurological populations (Magee & Davidson, 2002). Specifically, pleasant music may increase arousal and create a more positive mood (Chen et al., 2013) by acting as a reward to improve emotions (Schlaug, Altenmüller, & Thaut, 2010). Through its motivational components that increase arousal, attention, and affect, music is a suggested treatment modality for the rehabilitation of neglect.

Finally, Lim, Miller, and Fabian (2011) illustrated the importance of positive mood and affect for physical rehabilitation populations following a study examining the impact of a Neurologic Music Therapy (NMT) technique, Therapeutic Instrumental Music Performance (TIMP). Specifically, the authors found that TIMP in a physical rehabilitation setting could significantly decrease self-perceptions of fatigue and exertion when compared to traditional therapies, again highlighting the importance of music for producing affective responses during rehabilitation.

Music for Neurological Activation

Neuroplasticity allows the brain to readily modify its structural and functional organization in response to environmental changes and plays a large role in helping to rehabilitate the neurologically injured brain (Wan & Schlaug, 2010). Plasticity has been shown to occur when individuals engage in new skills, like learning to play a musical instrument (Wan & Schlaug, 2010).

Music is considered a multimodal stimulus that can remediate neural processes as well as re-activate or reorganize neural networks (Schlaug et al., 2010), which may be attributed to the shared cognitive/perceptual mechanisms between musical and non-musical cognitive functions (Thaut, 2010). In particular, music allows for the transmission of multiple types of sensory

information to the frontotemporoparietal regions of the brain, supporting the connection linking perception and action (Schlaug et al., 2010). In this sense, music may serve as a bridge between the gap of perceptual dysfunction in neglect (Jacobs et al., 2012) and an often-spared ability to complete purposeful actions (Robertson et al., 1995). Specifically, active music making has been supported as an appropriate form of treatment for neurological rehabilitation (Schlaug et al., 2010; Thaut, 2010; Wan & Schlaug, 2010), as a history of musical training has been shown to strengthen neural connections between the auditory and motor regions of the brain (Wan & Schlaug, 2010).

Robertson (1999) called for the systematic application of cognitive neuroscience models for rehabilitation, noting that any treatments for neglect should be derived from theoretical models of cognitive function. Wan & Schlaug (2010) encouraged that future studies continue to test the use of music making for therapeutic rehabilitation while Schlaug, Altenmüller, & Thaut (2010) further indicated that any music-based interventions for neural rehabilitation should be grounded in neuroscience.

Music for Cognitive and Stroke Rehabilitation

Music is recommended for cognitive rehabilitation due to what Thaut defined as shared “cognitive and perceptual mechanisms and shared neural systems between musical cognition and parallel nonmusical cognitive functions” (2010, p. 281). Additionally, music listening and playing has been shown to increase cognitive performance on various tasks related to memory, attention, and executive functioning (Schlaug et al., 2010). Through the use of rhythm, music is an effective tool in modulating and maintaining attention (Thaut, 2010), which has been shown with a variety of populations across the lifespan (Gregory, 2002; Wolfe & Noguchi, 2009). Wolfe and Noguchi (2009) reported that a musical story was more effective in sustaining

attention and improving vigilance in comparison to a verbal or spoken story with children, while Gregory (2002) found that music listening interventions could be used to maintain attention with older adults with cognitive impairments. Additionally, Knox and colleagues (2003) discovered that individuals with a brain injury showed enhanced performance on a listening test after a musical attention training program, indicating that music may also be used to modulate attention in individuals with a neurological insult.

Neurologic Music Therapy

An approach to music therapy called Neurologic Music Therapy (NMT) proposes various standardized clinical techniques with scientific support for rehabilitation (Thaut & Hoemberg, 2014), some of which play a crucial role in the rehabilitation of individuals post-stroke (Thaut & McIntosh, 2014). One NMT technique, Musical Neglect Training (MNT), offers a framework for music therapy clinicians working with individuals with neglect (Abiru, 2014). In the protocol, two types of exercises are recommended: receptive music listening and active performance on musical instruments. During receptive music listening exercises, individuals are provided with auditory, tactile, and/or vibratory stimulation or are presented with familiar and preferred music played in the neglected side of space. In active performance exercises, musical instruments are placed in various spatial configurations that encourage physical exploration toward the neglected side of space (Abiru, 2014). According to Thaut and McIntosh (2014), one of the underlying components of NMT is a reliance on the auditory structures and predictable patterns of music to retrain brain function. To accomplish this, rhythmic patterns, musical scales, and arranged chord progressions or melodies are used to provide structure, familiarity, and motivation as well as to direct attention and movement from the non-neglected field to the neglected field (Abiru, 2014;

Kang & Thaut, 2019). Active performance exercises may include instruments such as drums, tambourines, wind chimes, tone bars, and/or a keyboard.

Music Listening for Neglect Rehabilitation

General auditory retraining studies support the use of music as a mechanism for rehabilitation of neglect (Guilbert et al., 2014). Hommel and colleagues (1990) found that passive nonverbal stimulation, such as music or white noise, helped to reduce neglect shown on tasks of copying drawings, while a similar study two decades later compared classical music to white noise as well as silence (Tsai et al., 2013). In this study, Tsai et al. (2013) discovered that participants under the classical music condition had the highest scores on the Behavioral Inattention Test (BIT), while participants with the lowest scores were asked to sit in silence. Researchers attributed the differences in BIT performance to participants self-rating their arousal level as higher after listening to classical music (Tsai et al., 2013). While this study may support the role of arousal in rehabilitation of neglect, researchers did not indicate or control for whether participants were agreeable to classical music.

A study by some of the same researchers also examined the effect of pleasant music, unpleasant music, or white noise on performance on the Star Cancellation Test/Picture Scanning Test (Chen et al., 2013). Each participant was asked to select his or her own music to be used in the study, as musical preferences often vary between individuals. Researchers found that participants tested better when listening to preferred pleasant music rather than unpleasant music or white noise (Chen et al., 2013), illustrating the importance of an appropriate musical selection during treatment of neglect.

Soto and colleagues (2009) supported this idea of using preferred music as well, as they discovered that participants had increased visual awareness during tasks performed with

preferred music relative to un-preferred or silence conditions. Researchers believed the findings may have been associated with enhanced activity observed in the orbitofrontal cortex and cingulate gyrus, areas associated with emotional responses, during the preferred music condition, once again providing support for the role of arousal and mood to improve awareness and attention. Three years later, Särkämö and Soto (2012) found that listening to pleasant music could increase auditory and verbal memory, focused attention, and mood, as well as lead to neurological changes in the early post-stroke stage. Additionally, the authors reported that music could have a short-term effect on visual awareness in patients with visual neglect by targeting emotional and attentional brain regions (Särkämö & Soto, 2012). Combined, all studies support the use of preferred, pleasant music in the rehabilitation of neglect.

Active Music Making for Neglect Rehabilitation

Learning best occurs in a multisensory environment, as the combination of information from various sensory modalities allows for an increased ability to “detect, discriminate, and recognize” stimuli (Johansson, 2012, p. 1). Active music making, such as playing a musical instrument, often combines visual, tactile, and auditory feedback, making it a multimodal stimulus that activates a variety of neural regions related to sensory processing (Johansson, 2012).

Bodak, Malhotra, Bernardi, Cocchini, and Stewart (2014) published a study examining the effect of musical scales on visuospatial neglect. Two patients with chronic left neglect completed an intervention of four weekly 30-minute music sessions involving playing scales and familiar melodies on chime bars moving from right to left. Assessments of neglect included two cancellation tests (Mesulam shape and BIT star), the neglect subtest from the Test of Attentional Performance battery, and the line bisection test. Researchers found that both patients

demonstrated significant short-term and longer-lasting improvements on the Mesulam shape cancellation test. Findings of the study suggest that active music making targeting sequential, goal-directed actions on a horizontally aligned instrument may help those with neglect better attend to the left side of space (Bodak et al., 2014). Additional studies conducted in Japan also recommended the use of xylophone or tone bar instruments to address neglect (Abiru, Mihara, & Kikuchi, 2007; Kouya & Saito, 2004; Noto, Mouri, Amimoto, Sugimoto, Futaki, 1999).

Following the previous study, Bernardi and colleagues (2015) examined the effect of keyboard scale playing on left neglect. In the study, 11 patients with neglect, 12 patients without neglect, and 12 age-matched healthy participants were asked to play descending scales on a musical keyboard. Musical scales were used to encourage further exploration of the left side of space, as a predictable succession of pitches creates a feeling of expectation that makes listeners want to hear the next subsequent note. While playing scales, participants were provided with a congruent sound, no-sound, or random sound feedback offered by the keyboard. Researchers reported that spatial exploration was best with congruent sound feedback compared to the other two conditions and that musical scales could improve exploration of the left side of space in patients with left neglect (Bernardi et al., 2015).

Kang (2015) examined the use of the specific Neurologic Music Therapy (NMT) protocol, Musical Neglect Training (MNT), with patients following a right hemispheric stroke. Two patients with chronic stroke were seen for music therapy sessions twice a week for three weeks, for a total of six sessions. During the study, participants were asked to play various ascending triads and scales on horizontally arranged tone bars, moving from right to left. Kang (2015) examined both immediate as well as long lasting effects of the intervention through two written standardized assessments administered before and after treatment as well as six weeks following

the sessions. Both participants in the study demonstrated statistical improvement with the Albert's Test in the immediate effect and had lower post-test means on the Line Bisection Test. While the study implicated MNT as a positive intervention for individuals with neglect, the researcher suggested future studies involve individuals in the subacute stages of stroke with a greater number of sessions.

Research Limitations

While previous studies supported the use of music or NMT interventions such as MNT in the rehabilitation of neglect, current research still offers a number of limitations. Many studies in the research often examined participants that were in the chronic stage of stroke, or individuals more than six months post-stroke. Participants may have only been seen for a few times, or were asked to continue the intervention outside of the study without any clinical supervision. Studies also included patients with decreased visual acuity, such as following a previous retinal vein occlusion. Current research also included chime/tone bars placed in reverse of the SMARC effect, where high pitches were placed to the left and low pitches were placed to the right. Finally, current studies lacked functional assessment measures, such as the Catherine Bergego Scale (CBS) through the Kessler Foundation Neglect Assessment Process (KF-NAP™).

This study aimed to control for these various factors and to report on the inclusion of patients in the subacute stage of stroke seen consistently as part of an acute rehabilitation program involving close supervision by a Board-Certified Music Therapist (MT-BC). The purpose of this study was to determine the effect of a music therapy procedure on the presentation of left spatial neglect in patients undergoing inpatient physical rehabilitation. Research questions included if there would be a difference in severity of neglect on written

assessments (Line Bisection and Albert's Tests) following a music-based intervention for neglect or on a functional assessment such as the KF-NAPTM at discharge as compared to admission.

CHAPTER III: METHOD

A pretest-posttest small-*N* design was chosen for this study because interventions could not be reversed without harmful consequences for participants (Christensen, Johnson, & Turner, 2014). Written assessments were conducted before and after each musical procedure to measure any immediate effects, while functional assessments were conducted at admission and discharge to observe any changes in neglect during the hospital stay.

Participants

Participants involved in the study were recruited from a sample of patients with right-hemispheric stroke on an acute rehabilitation unit of a large Midwestern hospital. Individuals were in the subacute stage of a stroke, having an initial stroke onset of less than six months, with a current presentation of left spatial neglect. They were asked to complete all tasks with their right hand (non-affected side).

To ensure participants did not have baseline cognitive or language deficits, those involved in this study did not have a reported previous medical history of brain injury or dementia. Individuals had good comprehension of simple instructions and were able to follow a minimum of two-step directions and had good physical control of their non-affected side.

Participants were medically stable with appropriate endurance to tolerate more than three hours of multidisciplinary (physical, occupational, speech, and music) therapies each day. All subjects involved in the study were deemed competent and gave written consent prior to participating in the study. This study was conducted following the approval of the Human Subjects Committees and Institutional Review Boards of Colorado State University and the healthcare system involved in this study.

Measures

Written assessments

The Line Bisection Test (LBT) and Line Cancellation Test (Albert's Test) are two written screening tools to assess the presence and severity of unilateral neglect in patients following stroke. For the Line Bisection Test (LBT), participants were asked to place a mark through the center of one horizontal black line on a test sheet of paper. Some studies use as many as 18 horizontal lines placed vertical to one another, while other researchers use one single line (Parton, Malhotra, & Hussain, 2004). Any marks shifted toward the side of the brain lesion are considered to be a symptom of spatial neglect (Zeltzer, Menon, Korner-Bitensky, & Sitcoff, 2008). Patients with left neglect tend to mark the line well to the right of the true center, while patients with hemianopia without neglect tend to bisect the line slightly to the left. The test paper in this study was placed at the participant's midline. To control for a bias in performance with a small line, large horizontal lines (18-20 cm) are typically used (Parton et al., 2004). For this study, assessment tools for this test included an 8.5 x 11-inch sheet of A4 paper with one solid black line 20 centimeters in length along with a pencil.

The LBT can be quickly administered and offers strong psychometric properties when compared to other written tests (Menon & Korner-Bitensky, 2004). More specifically, past research found that the Line Bisection Test showed strong test-retest reliability as high as $r = 0.93$ (Bailey, Riddoch, & Crome, 2004; Chen-Sea & Henderson, 1994; Kinsella, Packer, Ng, Olver, & Stark, 1995; Schenkenberg et al., 1980) as well as excellent construct validity ($r = 0.85$) with Albert's Test and an adequate correlation ($r = -0.33$) with the Star Cancellation Test (Agrell, Dehlin, and Dahlgren, 1997).

For the Albert's Test, participants were instructed to cross out lines in what appeared to be random orientations on a piece of paper (Albert, 1973). In a modified version of the test, a series of 40 black lines about 2-2.5 cm long are oriented on a white sheet of paper placed at the participant's midline. Each side of the sheet contained 18 lines divided into three columns of six lines, with four lines in the center of the page. Neglect is indicated when lines are left uncrossed on the same side of the page as the brain lesion (Zeltzer, Menon, Korner-Bitensky, & Sitcoff, 2010). Some of the lines were pointed out, including those to the extreme right and extreme left, and the participant was asked to watch as the four central lines were crossed out each time. Participants had a maximum of five minutes to complete the task. Assessment tools for this test included an 8.5 x 11-inch sheet of A4 paper with 40 black lines two centimeters in length along with a pencil.

One study by Chen-Sea and Henderson (1994) examined and reported test-retest reliability for Albert's Test as high as $r = 0.79$. Excellent construct validity has been found between Albert's Test and the Line Bisection Test at $r = 0.85$ (Agrell et al., 1997), the Wundt-Jastrow Area Illusion Test at $r = 0.64$ (Massironi, Antonucci, Pizzamiglio, Vitale, Zoccolotti, 1988) and the Catherine Bergego Scale at $r = 0.73$ (Azouvi et al., 1996). Additionally, an adequate correlation at $r = 0.63$ has been shown with the Star Cancellation Test (Agrell et al., 1997). Evidence also supports the predictive validity of Albert's Test, as test scores within 48 hours of hospital admission significantly predicted functional outcome at six months post-stroke (Fullerton, McSherry, and Stout, 1986). Similar to the LBT, the Albert's Test was chosen for this study due to its timely implementation and high level of validity.

Functional assessment

The Kessler Foundation Neglect Assessment Process (KF-NAP™) is a functional assessment to assess spatial neglect and offers a detailed descriptive process for administering the Catherine Bergego Scale (CBS) that helps standardize observation and scores among clinicians and researchers (Chen et al., 2012; Chen, 2017). Researchers consider the CBS an ideal assessment for individuals with neglect, as it measures performance in personal, peri-personal, and extra-personal space, thereby capturing the heterogeneity of neglect (Chen et al., 2012). The KF-NAP™ requires the use of a scoring sheet and manual for observing behaviors and measures ten functional areas: gaze orientation, limb awareness, auditory attention, personal belongings, dressing, grooming, navigation, collisions, meals, and cleaning after meals (Chen, 2017; Chen & Hreha, 2015).

At least eight studies have verified and confirmed the validity of the CBS. More specifically, the CBS has shown significant correlations to the Behavioral Inattention Test (BIT) as well as other functional assessments such as the Barthel Index (BI), Functional Independence Measures (FIM), Postural Assessment for Stroke Scale, and wheelchair collisions. Additionally, the measure offers internal consistency, as all CBS items correlate with one another (Chen et al., 2012). Chen (2017) also reports that the KF-NAP™ has a high inter-rater reliability, as raw scores show a high linear correlation ($r = 0.86$) and high intraclass correlation between independent raters. More specifically, raters agreed on severity of spatial neglect 87.9% of the time ($k = 0.76$), indicating a substantial level of agreement. The KF-NAP™ was selected for this study due to its ease of clinical use, measurement of ecological outcomes, and confirmed validity. Therapists assigned to each patient scored various KF-NAP™ categories based on their discipline. For example, Physical Therapists were asked to score the categories of collisions and

navigations while working on mobility, while Occupational Therapists were instructed to fill-out categories of limb awareness, personal belongings, dressing, and grooming while completing activities of daily living. Speech Therapists were requested to score the categories of gaze orientation, auditory attention, meals, and cleaning after meals during observations at breakfast or lunch.

Musical Procedure

Participants were asked to participate in multiple 30-minute individual music therapy sessions occurring each week until hospital discharge. Throughout the testing, the researcher was placed directly across from the participant when speaking or giving instructions. Each participant was seated comfortably in a chair and asked to use all musical instruments with their right (non-paretic) hand. Participants completed the Line Bisection and Line Cancellation Tests before and after completing the musical procedure.

During each music therapy session, all participants were asked to use a mallet to hit a 10-inch paddle drum held in various spatial configurations gradually moving from right (non-neglected side of space) to left (neglected side of space) over the course of every four drum hits. Participants were asked to hit the drum to the beat of familiar music sung live for a total of five minutes. Auditory cues were provided as needed to locate the drum in the neglected side of space. Participants were then instructed to complete specific musical sequences on 3.5-centimeter tone bars (resonator bells) placed in various spatial configurations for the remainder of the treatment time. During this part of the exercise, the participant was seated at midline of an 80-centimeter long table. Three protocol levels were used, depending on each individualized severity of neglect and/or cognition. Participants did not progress to the next step until they had demonstrated successful completion of the previous level.

Participants were required to complete each pattern three times successfully with no additional cues prior to progressing to the next protocol level. If participants were unable to imitate a sequence independently, they were asked to complete the sequence at least three times with a visual prompt and musical cue followed by at least three times with a sung musical cue alone. All sequences followed a descending pattern to match the SMARC effect.

Level 1: In this level, the starting tone bar was placed on the right edge of the table, 40 centimeters to the right of midline while other bars gradually move toward the neglected side of space, as shown in figure 1. Participants were asked to imitate a three-note arpeggio sequence (G-E-C) on the tone bars, with all bars directly next to one another. Participants then played a five-note descending scale (G-F-E-D-C) on the tone bars, with all bars still touching one another. Upon successful completion of the scale with no additional cues, the left bar (C) was moved 20 centimeters right of midline with the other outside bars (D, E, and F) spaced equidistant from one another. This movement of the left bar (C) continued in 10-centimeter intervals until all outside bells were moved 20 centimeters left of midline. Using the key of C-Major permitted the bells to be in the range of C5-G5, with letters played in reverse alphabetical order.

Level 1

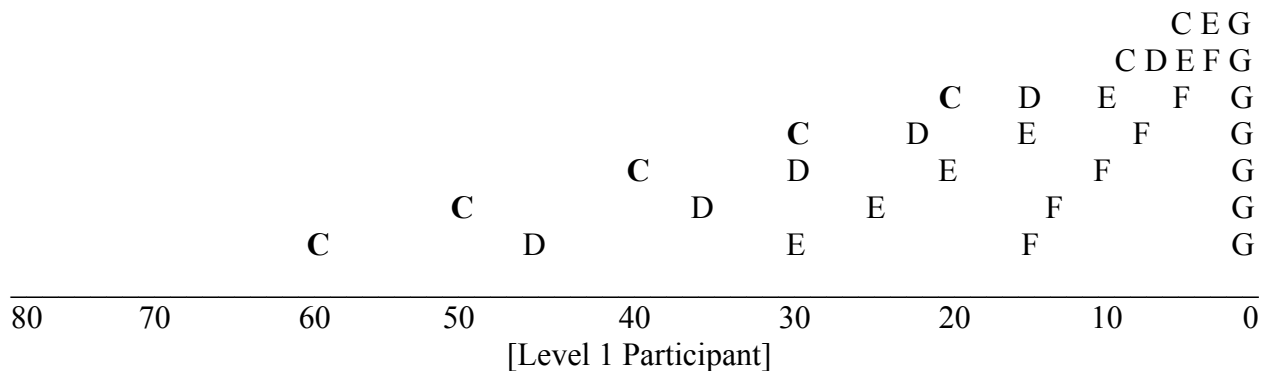


Figure 1 Instrument set-up and procedure for a level 1 participant.

progressions used in familiar music. All tone bars were placed 20 centimeters apart from one another, with the tonic (I) bell placed in the neglected side of space.

Level 3

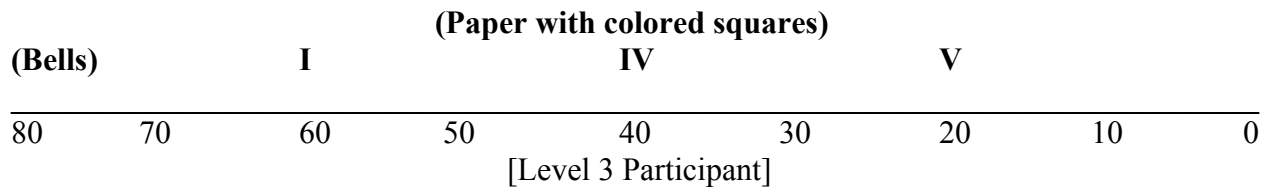


Figure 3 Instrument set-up and procedure for a level 3 participant.

Data Analysis Procedures

Prior to and after completing each musical procedure, participants were asked to complete the Line Bisection Test and Line Cancellation (Albert’s) Test to measure any immediate effects. KF-NAP™ scores were obtained for each participant upon admission to and discharge from the rehabilitation unit to determine any functional changes observed during the hospital stay.

The Line Bisection Test was scored as the deviation of the marked bisection from the true center of the line, while Albert’s Test was scored as the total number of crossed lines as well as the number of lines crossed on the opposite side of the page as the brain lesion. The KF-NAP™ was calculated as the sum of assigned scores in the 10 categories of spatial neglect. The ten individual categories were scored from 0 to 3, with greater scores indicating a more severe deficit or symptom of neglect. An overall KF-NAP™ score of 1-10 illustrated mild neglect, 11-20 as moderate neglect, and 21-30 as severe neglect (Chen & Hreha, 2015). Appropriate descriptive statistics of central tendency and measures of standard deviation were calculated for written tests to show results.

CHAPTER IV: RESULTS

Three participants were recruited to participate in this study. All individuals had left spatial neglect and were in the subacute stage of stroke. Three tests were used to measure changes in severity of neglect, including the Kessler Foundation Neglect Assessment Process (KF-NAP™), Line Bisection Test, and Line Cancellation (Albert's) Test. The first assessment, the KF-NAP™, was included to measure functional outcomes from admission to discharge. Each assessment consisted of 10 different categories ranked on a scale of 0-3 scored by Physical, Occupational, and Speech therapists. This provided an overall score out of 30 points, with higher scores indicating a greater severity of neglect. Two written assessments, the Line Bisection Test and Line Cancellation Test, were used to examine any immediate effects with pre- and post-tests conducted during each session. Between written assessments, participants were asked to engage in musical exercises involving paddle drums and resonator bells played from right to left to modulate attention toward that side of space. Line Bisection Test markings to the right of midline were recorded as having a positive value, while deviations to the left of midline were indicated as having a negative value. Deviations with an absolute value of equal to or greater than 6 mm were recorded as an indication of spatial neglect (Zeltzer et al., 2008). The third measure used in this study, Albert's Test, asked participants to cross through as many as 36 lines on a page. A higher number of crossed lines represented of a higher level of sustained attention, while a higher number of cancellations on the left side of the page meant a lower severity of spatial neglect.

KF-NAP™ Scores

KF-NAP™ scores reflected the severity of neglect observed during functional activities in physical, occupational, and speech therapy sessions. Scores were recorded upon admission

and discharge to show any changes in neglect that occurred over the course of acute rehabilitation. Illustrated in Figure 4, Participant 1 showed no change in five KF-NAP™ categories from admission to discharge. However, they experienced a 1-point improvement in the categories of personal belongings and collisions as well as a 2-point improvement in the categories of dressing, grooming, and navigation. Overall, Participant 1 demonstrated an 8-point decrease in severity of neglect from a total evaluation score of 23 indicating severe neglect to a total discharge score of 15 indicating moderate neglect.

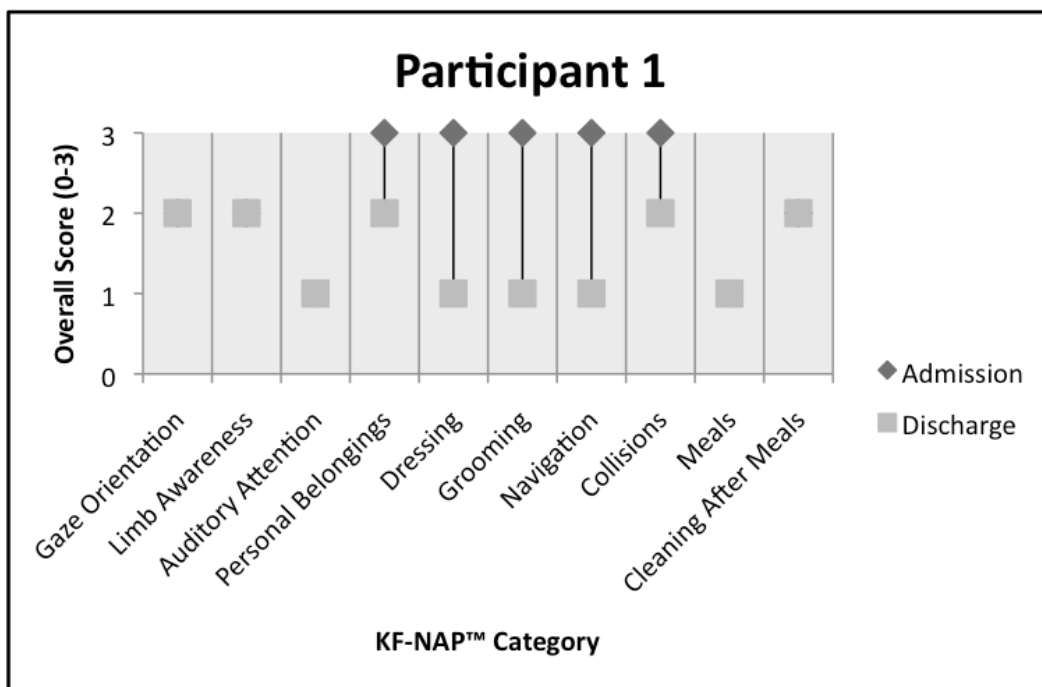


Figure 4 Admission vs. Discharge KF-NAP™ Categorical Scores for Participant 1.

Participant 2 demonstrated no change in the KF-NAP™ categories of gaze orientation or limb awareness from admission to discharge, although experienced a 1-point improvement in seven other categories as well as a 2-point improvement in dressing while on the rehabilitation unit (Figure 5). Similar to Participant 1, Participant 2 demonstrated an 8-point decrease in severity of neglect from a total evaluation score of 10 indicating mild neglect to a total discharge score of 2, still indicating mild neglect, but to a lesser degree.

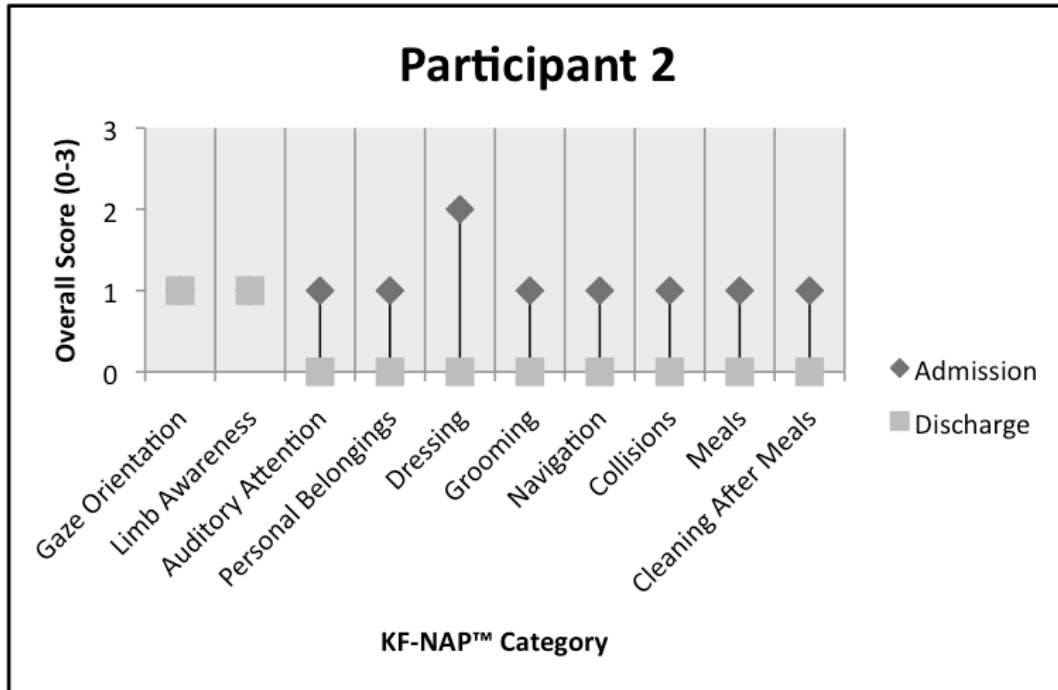


Figure 5 Admission vs. Discharge KF-NAP™ Categorical Scores for Participant 2.

Shown in Figure 6, Participant 3 did not show any changes in the KF-NAP™ categories of gaze orientation or personal belongings from admission to discharge, although they experienced a 1-point decline in five other categories. Participant 3 also demonstrated a 1-point improvement in the categories of navigation and collisions as well as a 2-point improvement in the category of auditory attention. Overall, Participant 3 demonstrated a 1-point increase in severity of neglect from an evaluation score of 17 indicating moderate neglect to a discharge score of 18, still indicating moderate neglect, but to a slightly higher degree.

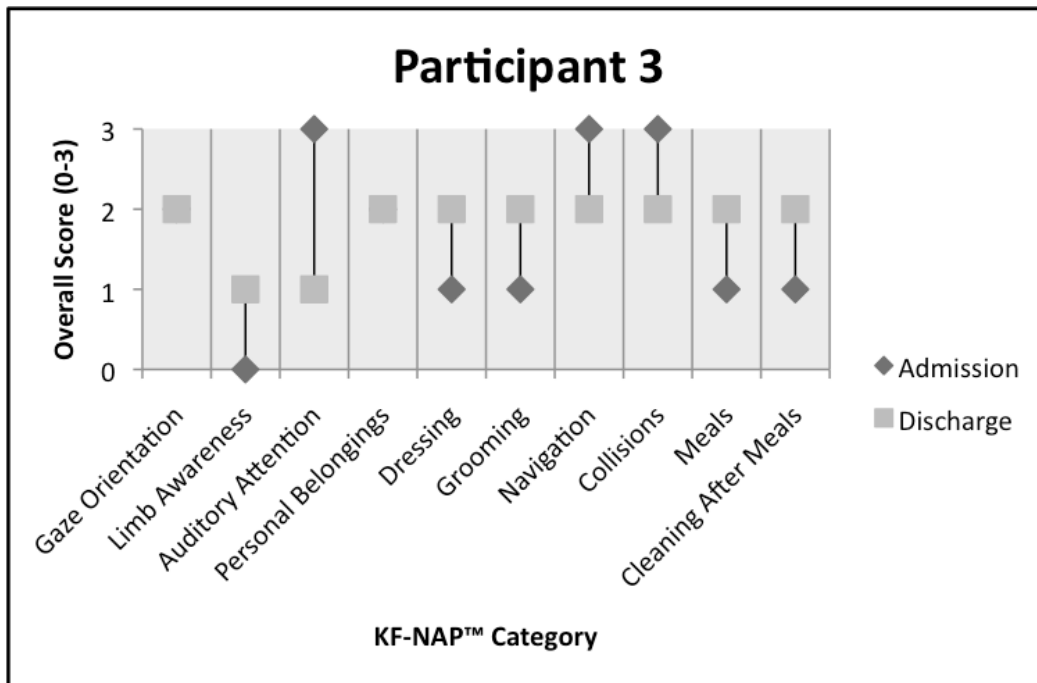


Figure 6 Admission vs. Discharge KF-NAP™ Categorical Scores for Participant 3.

Line Bisection Test Scores

Out of 15 treatment sessions with pre-and-post test data, Participant 1 demonstrated a more leftward marking in nine of 15 sessions, a more rightward marking in four of the 15 sessions, and no change in marking in two of the 15 sessions (Figure 7). Assuming a deviation of 0.6 cm or greater from midline is indicative of spatial neglect, Participant 1 displayed neglect in nine pre-tests and five post-tests. Performance on the written assessment varied, as sessions four and five had markings close to midline, but were followed by sessions six and seven, with markings farther from midline. Although treatment session five illustrated no neglect present during the pre-test or post-test, line deviation did shift left following the music therapy procedure. Additionally, session 14 showed no neglect present at the start of the session, but present at the end, despite no signs of neglect either pre- or post-test during the three sessions prior.

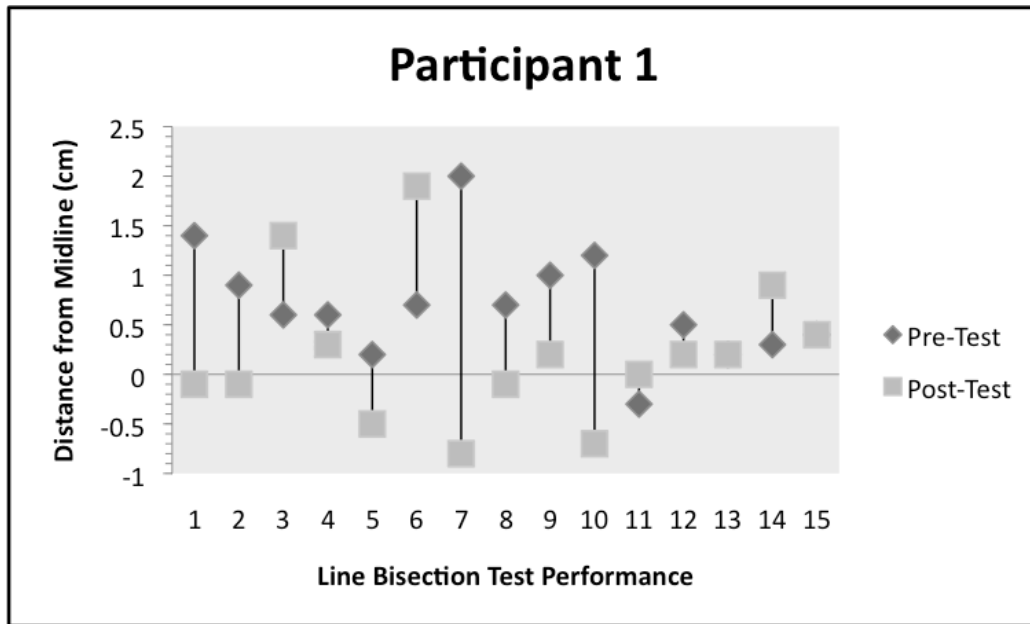


Figure 7 Session-By-Session Line Bisection Test Performances for Participant 1.

As shown in Figure 8, Participant 2 made a more leftward marking in three of five treatment sessions and a more rightward marking in two of the five therapy sessions. While not included in Figure 8, Participant 2 marked the center of the line 0.9 cm right of midline upon admission and exactly at midline (0.0 cm) their final day of therapy, for a perfect performance on the Line Bisection Test. Overall, Participant 2 deviated more than 0.6 cm from midline in two of five pre-tests and two of five post-tests, although these occurred in different therapy sessions. Once again, performance on the written assessment varied, as treatment session four illustrated no neglect present during the pre-test or post-test, though line deviation did shift right following the music therapy procedure. Additionally, Participant 2 marked the line 0.2 cm left of midline at the start of the session three and 1.9 cm right of midline at the end of the same session, despite no obvious signs of neglect on either the pre- or post-test during session two.

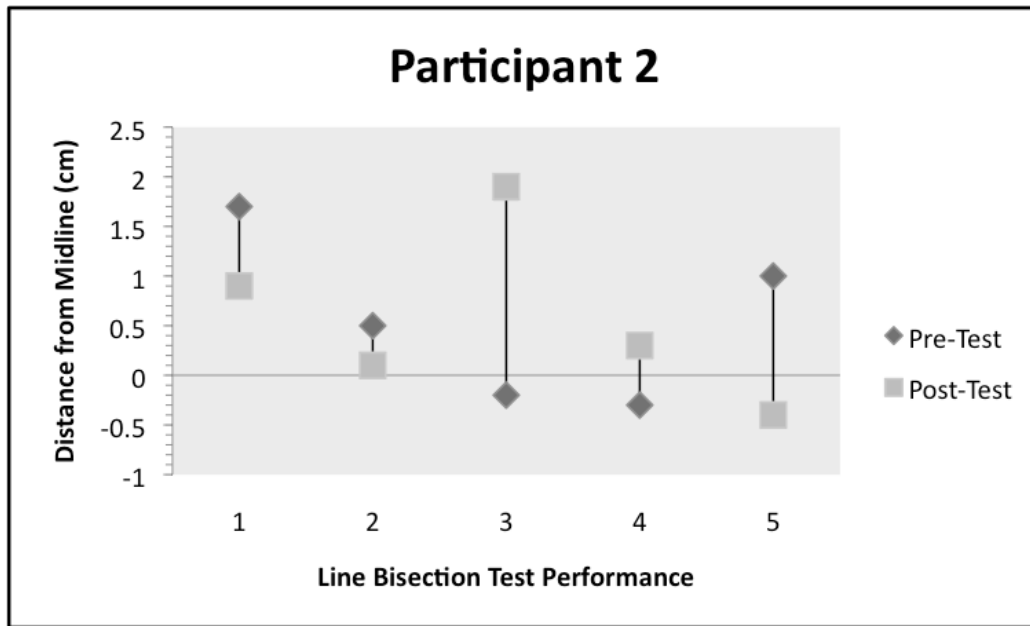


Figure 8 Session-By-Session Line Bisection Test Performances for Participant 2.

For Participant 3, there was no change in post-test markings in two of eight sessions, while post-test markings were more leftward in two of the eight sessions and more rightward in four of the eight sessions (Figure 9). Participant 3 deviated more than 0.6 cm from midline in six of the eight pre-tests and in all post-tests. While all markings were consistently made to the right of midline, performance on the written assessment also varied for Participant 3. While pre- and post-test performance was the exact same in sessions five and eight, session six resulted in a change of 2.8 cm more to the right during the post-test than the pre-test.

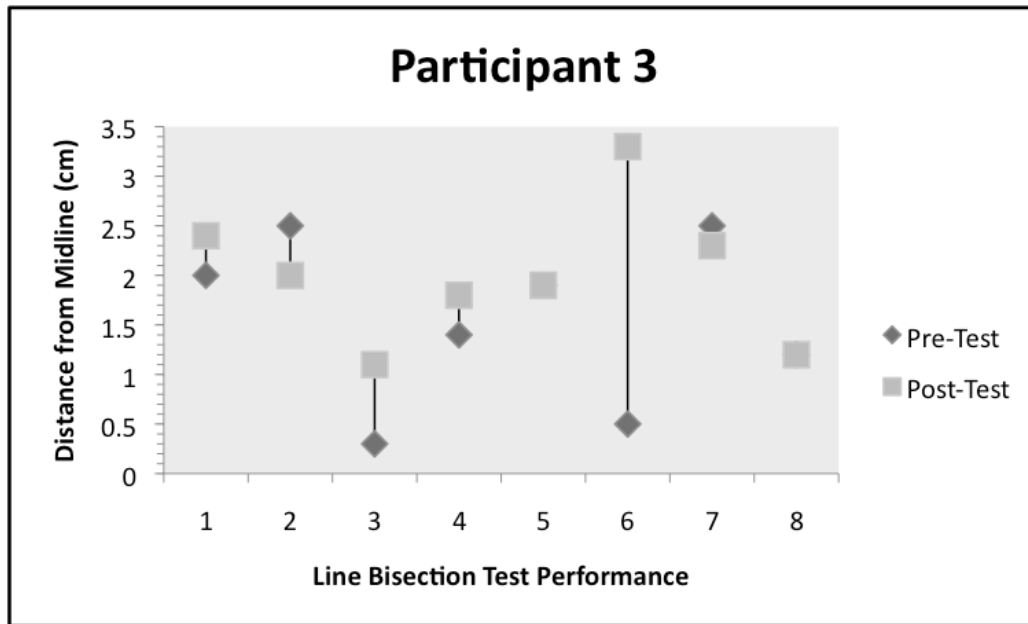


Figure 9 Session-By-Session Line Bisection Test Performances for Participant 3.

Shown in Table 1, Participant 1 demonstrated an average post-test deviation more to the left, while Participant 2 showed little to no average change from pre-test to post-test, and Participant 3 showed a deviation more to the right during the post-test.

Table 1. Line Bisection Test Scores for Participants 1-3.

Participant	Pre-Test Mean	Post-Test Mean	Pre-Test SD	Post-Test SD
1	0.69 cm	0.21 cm	0.56	0.73
2	0.54 cm	0.56 cm	0.84	0.78
3	1.54 cm	2.00 cm	0.84	0.70

Line Cancellation Test Scores

Participant 1 demonstrated a short-term improvement in overall performance on the Line Cancellation (Albert’s) Test in 12 of 15 sessions (Figure 10). Additionally, Participant 1 demonstrated improvement in crossing out more lines left of midline in six therapy sessions and no change in crossing out lines left of midline in five treatment sessions (Figure 11).

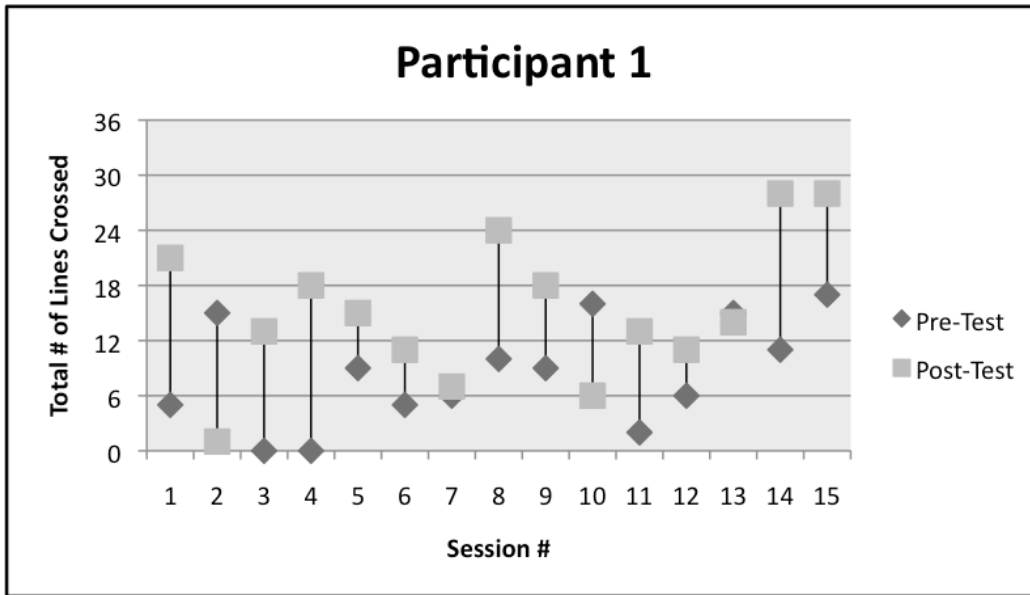


Figure 10 Session-By-Session Line Cancellation Test Scores for Participant 1.

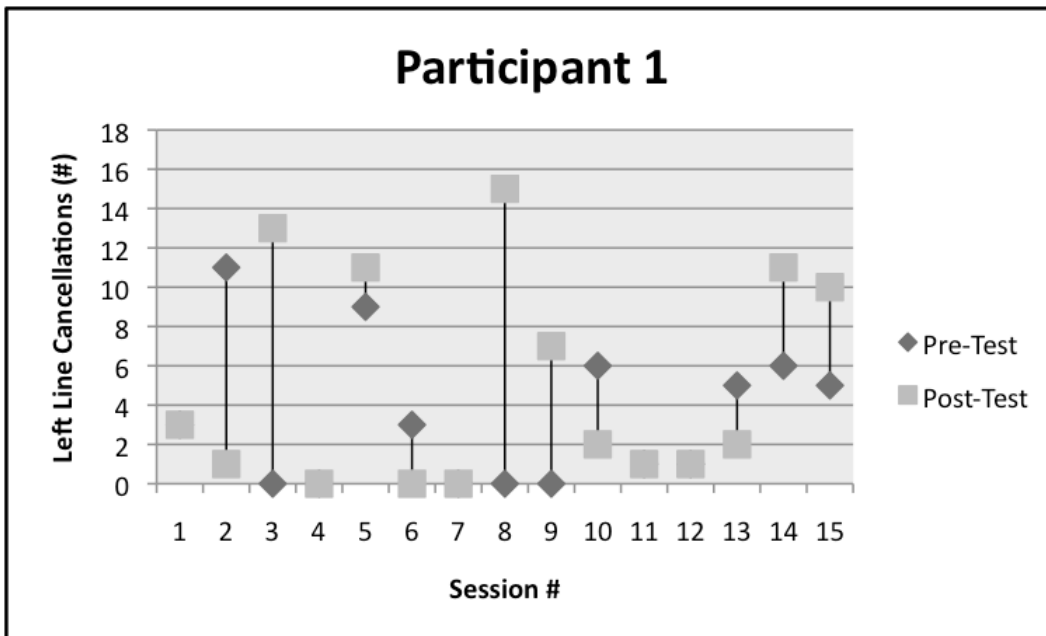


Figure 11 Session-By-Session LCT Left Line Cancellations for Participant 1.

Comparing Figures 10 and 11, the Line Cancellation Test (LCT) performance for Participant 1 declined in three sessions (treatments 2, 10, and 13), as they were unable to locate more items off to the left side of the page. On the other hand, Participant 1 found more lines overall in sessions 1, 4, 6, 7, 11, and 12, although did not find more lines to the left. This may

have indicated a possible increase in overall sustained attention despite showing no change in spatial attention. Furthermore, in treatment sessions 3, 5, 8, 9, 14, and 15, Participant 1 found more lines overall as well as lines to the left, demonstrating greater attention toward the left side of space.

Participant 2 demonstrated a short-term improvement in overall performance on the Line Cancellation (Albert's) Test in one session and a perfect score in the last three sessions (Figure 12).

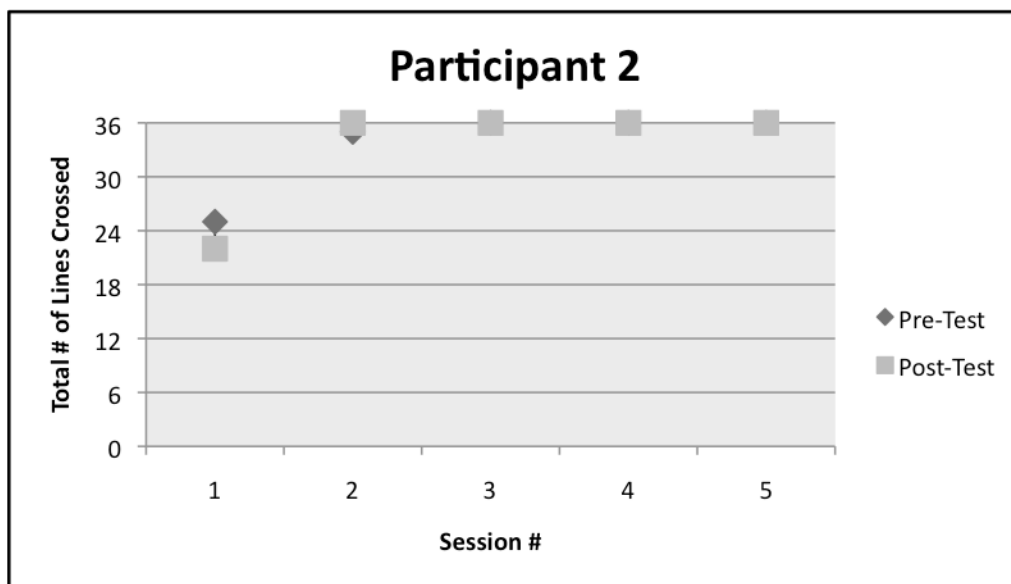


Figure 12 Session-By-Session Line Cancellation Test Scores for Participant 2.

On a similar scale, Participant 2 demonstrated an improvement in crossing out more lines left of midline in one therapy session. In the last three sessions, Participant 2 found all 18 lines left of midline during the pre- and post-tests (Figure 13). Participant 2 located fewer items off to the left side of the page during the post-test in session one. On the other hand, their overall performance increased in the second session, as they discovered one more line left of midline missed during the pre-test. Overall, Participant 2 had a perfect score (36 lines crossed out of a possible 36 lines) in sessions 3-5, no longer illustrating a presence of spatial neglect on the LCT.

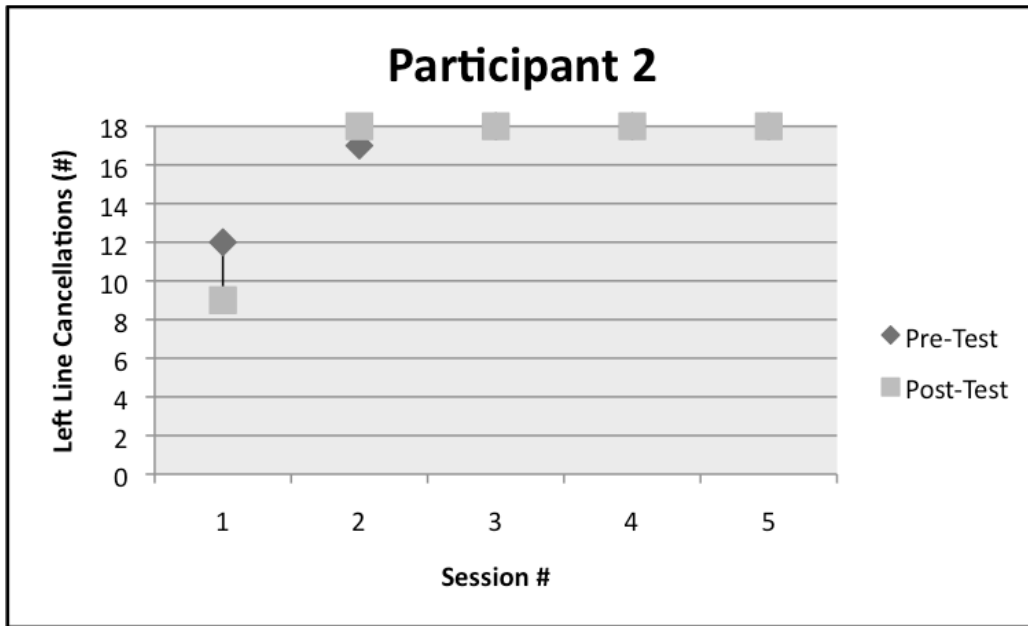


Figure 13 Session-By-Session LCT Left Line Cancellations for Participant 2.

Participant 3 demonstrated frequent improvements from pre-test to post-test in overall line cancellations, locating more lines to the left in six of the eight sessions (Figures 14 & 15). These changes indicated better attention toward the left side of space, thereby representing a short-term decrease in severity of spatial neglect.

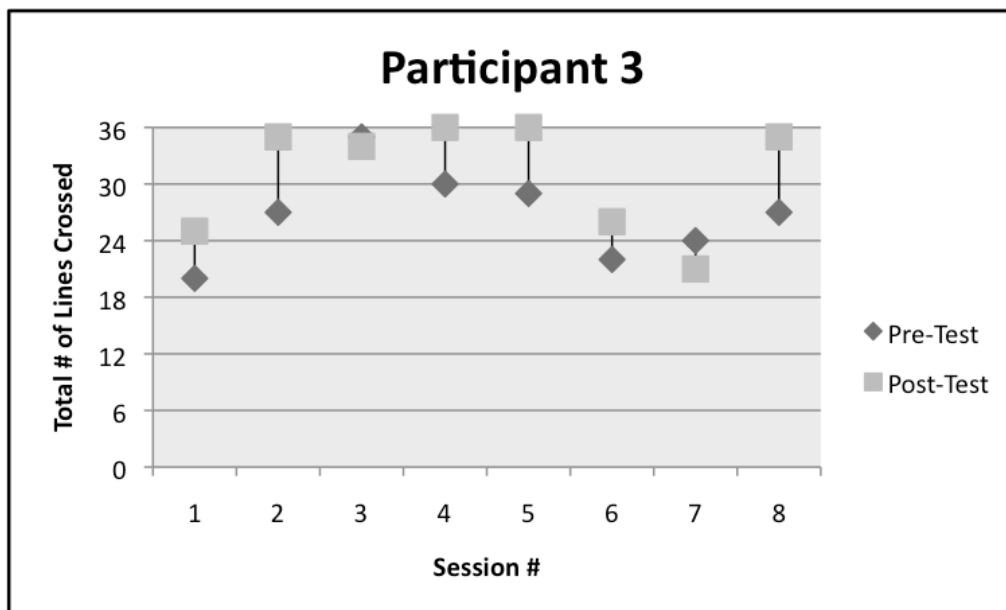


Figure 14 Session-By-Session Line Cancellation Test Scores for Participant 3.

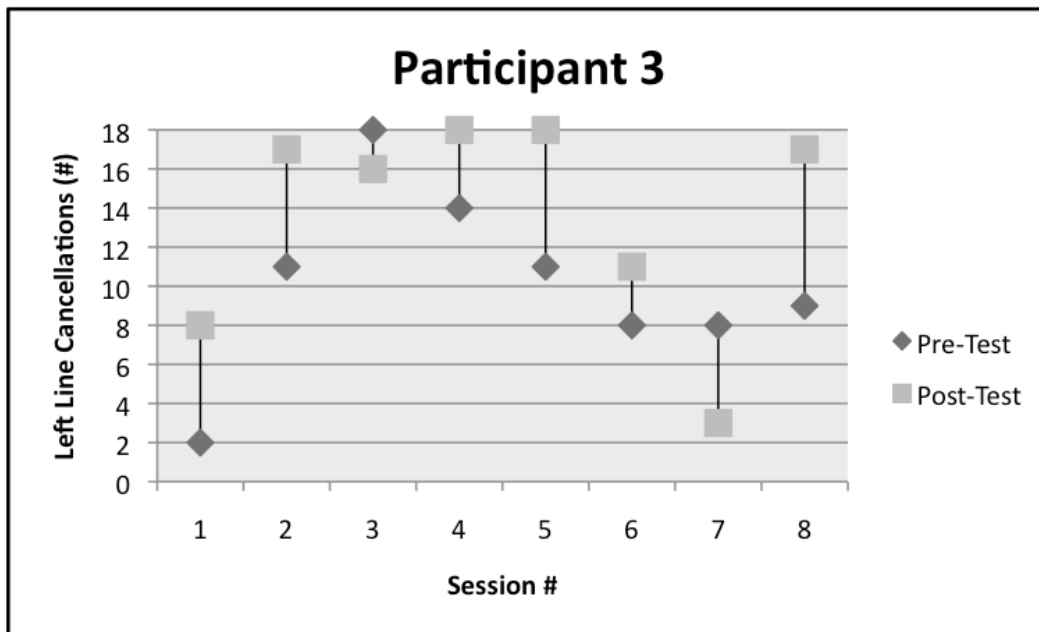


Figure 15 Session-By-Session LCT Left Line Cancellations for Participant 3.

Both Participants 1 and 3 located more lines on the page as well as those left of midline during the average post-test compared to the pre-test, while Participant 2 found about the same number of lines (Tables 2 & 3).

Table 2. Line Cancellation Test (Total Lines Crossed) Scores for Participants 1-3.

Participant	Pre-Test Mean (All Lines)	Post-Test Mean (All Lines)	Pre-Test SD	Post-Test SD
1	8.4	15.2	5.6	7.8
2	33.6	33.2	4.8	6.3
3	28.6	31.0	4.8	6.0

Table 3. Line Cancellation Test (Left Line Cancellation) Scores for Participants 1-3.

Participant	Pre-Test Mean (Left Lines)	Post-Test Mean (Left Lines)	Pre-Test SD	Post-Test SD
1	3.3	5.1	3.6	5.4
2	16.6	16.2	2.6	4.0
3	10.1	13.5	4.7	5.6

CHAPTER V: DISCUSSION

The purpose of this study was to determine the effect of active music making on spatial neglect in patients undergoing acute rehabilitation following a right-hemispheric stroke. The hypotheses of this study were that there would be a difference in severity of neglect on written assessments such as a Line Bisection Test (LBT) and Line Cancellation Test (LCT) following a music-based intervention and on the Kessler Foundation Neglect Assessment Process (KF-NAP™) upon hospital discharge. Results indicated that two of the three participants experienced a decrease in severity of neglect on the functional assessment, while one participant showed little to no change. On the first written assessment, the Line Bisection Test, one of the three participants showed a decrease in severity of neglect during average post-test procedures, another showed little to no change, and the third showed an increase in severity of neglect. On the second written assessment, the Line Cancellation Test, two of the three participants showed a greater exploration of the left side of space, while the remaining participant showed little to no change, as they continually scored 100% after the first two treatment sessions.

The KF-NAP™ was used to measure any changes in functional outcomes over the course of the inpatient physical rehabilitation stay. On the KF-NAP™, none of the participants showed any changes in the category of gaze orientation, while all demonstrated a 1-point decrease in collisions. On average, the combined participants experienced a 5-point decline in severity of neglect at discharge compared to admission. More specifically, two participants' severity decreased by 8-points, while the neglect for Participant 3 marginally increased by 1-point.

This incongruence between the first two participants and the last may be attributed to their differences in medical status. In particular, Participant 3 followed a unique hospital course,

as they were admitted for rehabilitation, discharged, and then re-admitted. After an initial evaluation and two treatment sessions, Participant 3 experienced a medical decline necessitating a transfer back to acute care to ensure medical stability. Upon return for rehabilitation, scores on all three measurements (KF-NAP™, Line Bisection, and Line Cancellation) showed an increase in severity of neglect compared to the first admission. As such, all data for this participant was considered to start upon re-admission to appropriately reflect any changes in medical and cognitive status. As a result, the change in medical status and extension of initial stroke may have contributed to their increase in severity of neglect as shown on the KF-NAP™. More specifically, the KF-NAP™ results for Participant 3 combined with written test performance may indicate a possible decline in intrapersonal neglect, but an improvement in extrapersonal neglect, possibly due to the stroke lesion extending into different areas of the brain than initially affected.

In general, performance on the Line Bisection Test varied between sessions and individual participants. For Participant 1, post-test deviation was more leftward ($M = -0.48$ cm), while markings were more to the right ($M = 0.46$ cm) for Participant 3. On the other hand, Participant 2's deviation slightly increased, although essentially remained the same ($M = 0.02$ cm). Given the varied performance on the assessment for all three participants, the single 20-cm Line Bisection Test used in this study may not be an appropriate way to measure severity of neglect. Other studies by Bodak and colleagues (2014) and Kang and Thaut (2019) report similar findings, with no significant improvements on the Line Bisection Test following protocols involving musical instruments.

Performance on the Line Cancellation Test was consistent for Participant 2, who scored 100% on all testing measures following the first two treatment sessions, thereby accounting for little change on this measure. This finding was similar to a study involving two patients with

chronic neglect, as Bodak and colleagues (2014) reported one individual in their study showed a large and sustained treatment effect on a cancellation test following one session using tone bars. Conversely, the remaining two participants showed a decrease in severity of neglect following the music therapy procedure. On average, Participant 1 discovered 6.8 more lines, while Participant 3 crossed through 2.4 more lines. Performance also improved in finding more lines in the left side of space, as Participant 1 discovered 1.8 more lines left of midline and Participant 3 found 3.4 more lines left of midline. The combined three participants experienced an approximately 8% improvement on the LCT from pre-test to post-test, with approximately a 9% improvement in finding lines left of midline. In general, participants demonstrated short-term improvements in several trials, although showed inconsistent performance within sessions as well as little to no carry-over from one session to the next. On the contrary, other studies report statistically significant improvements on the LCT immediately following treatment using musical instruments (Bodak et al., 2014; Kang & Thaut, 2019).

During sessions three and four, Participant 1 was given verbal reminders to mark out lines other than those crossed out at midline during the demonstration and initial instructions, but still did not find any lines on the page during either pre-test. This then happened again in session 11, when Participant 1 only found two lines during the pre-test. While unclear why this pattern usually occurred during the pre-test, it may have occurred for a variety of reasons, including the participant not hearing the instructions correctly or feeling distracted or fatigued at the start of the session. Something similar happened in one session with Participant 2, where they thought the instructions were to only mark through lines on the right side of the page during both the pre-test and post-test. At the end of the session, the participant expressed confusion for only marking through half of the lines when they had been asked to cross through all lines the day prior. As the

participant was in fact visually able to locate all lines, this data set was omitted from the study. Notably, Participant 3 always took full advantage of the full five-minute time limit to complete the Line Cancellation Test compared to the other two participants who did not use the full duration of time.

Other possible reasons accounting for some of the differences among participants include varying levels of musical training and experience as well as diverse musical preferences between individuals. This notion is supported in the literature, as other researchers thought varied performance on the LBT might be linked to differences in musical training (Lega et al., 2014). While music was tailored to each individual through age-appropriate or preferred melodies, some songs elicited a stronger response than others. For example, one participant expressed that a song used in therapy was a favorite, although music used the following day may not have been as well liked. This ideal song choice may have led to an increased level of interest or arousal, thereby having a larger effect on attention, a finding supported by Chen and colleagues (2013).

Additionally, some of the participants were limited by increased fatigue during therapy. These varying endurance levels even prevented some participants from completing the full protocol or post-test procedures in some sessions. This occurred in two sessions with Participant 1 and one session with Participant 3. During therapy, two of the participants required frequent or occasional rest breaks while one did not, thereby allowing for more therapeutic treatment time during some sessions compared to others. Individuals respond differently during stroke rehabilitation, and factors such as age, site of neurological lesion, baseline mental and physical health, and prior independence level can all impact the recovery process. On a similar note, one participant received more targeted therapy than others. More specifically, Participant 1 engaged in Prism Adaptation Therapy, a non-musical intervention for neglect, and was also seen for a co-

treatment session with Physical Therapy to address visual scanning using music during mobility and balance exercises. Environmental factors may have also played a role during the testing procedures for some participants. For example, in one session the colored square on the bell would not stay taped to the instrument, which Participant 3 commented was distracting.

Physical factors may have also played a role, as one participant had a high level of back pain, arthritis in their hands, feelings of nausea, or shortness of breath while completing written assessments. While considered medically stable, these physical ailments were noted to be distracting to the participant and may have impacted performance on the written measures. Physical features such as hand dominance may have also been a factor, as Participant 2 was left hand dominant, but used their right hand to complete the written assessments and musical exercises. This same participant often moved their pencil several times before making their final marking during the Line Bisection Test, possibly altering the results. Finally, the participants may have responded differently to treatment simply due to the heterogeneity of neglect between individuals (Pierce & Buxbaum, 2002).

Limitations

One of the primary limitations in this study was the small sample size ($N=3$) used to collect data. Furthermore, the three participants involved in this study were all recruited from a convenience sample at the same facility and are not be representative of the stroke population as a whole, as they were all the same gender and within four years of age. Despite this commonality, not all participants received the same intervention, as various protocol levels and different musical selections were matched with each individual. The therapy protocol was also not completed on a consistent schedule between participants. Instead of all participants receiving treatment the same number of days per week, some individuals may have experienced a gap in

treatment, due to external factors like medical holds from therapy, fatigue, or treatment breaks on the weekend. Additionally, there was no separate control group, as interventions could not ethically be reversed or withheld from patients with neglect. Environmental distractions may have also played a role in this study, as some participants were seen in a quiet testing room, while others were seen in a semi-private hospital room, which included various distractions, including but not limited to staff entering and exiting the room, family and visitors present, and roommate interruptions.

Due to the use of repeated measures in this study, participants may have experienced practice effects from completing the same written assessments each session. On the other hand, Bodak and colleagues (2014) disagreed with this notion, stating that neither of their neglect participants showed systematic improvement on written cancellation tests during a baseline period. Additionally, one study examining test-retest reliability showed stable performance with no significant practice effect on cancellation tests (Machner et al., 2012). While the Line Bisection Test was selected for its quick ease of administration, this test may not be the most appropriate way to measure neglect, as some studies report low test-retest reliability with the LBT (Machner et al., 2012). Generally, this may be attributed to a comorbidity of hemianopsia, as a larger deviation from midline on the LBT has been shown in individuals with lesions in parieto-occipital regions (Kang & Thaut, 2019). Participants in this study may also have been limited by decreased coordination in marking the center of the line, as lines crossed on the Line Cancellation Test were typically not marked through the midpoint. Additionally in terms of testing, different therapists were used to score different admission and discharge KF-NAP™ outcomes. Despite the standardized and objective instructional manual for the functional

assessment, one therapist may have subjectively scored a participant differently than another therapist.

Suggestions for Future Research

More replication studies are needed to grow the body of research for this protocol and those similar. A larger sample size involving a control group would allow for statistical power, as would a greater number of treatment sessions such as during outpatient therapy following inpatient rehabilitation. Treatment sessions could also run longer than 30 minutes in this setting, as appropriate for endurance. Removal of extraneous factors such as environmental distractions and other simultaneous interventions like Prism Adaptation Therapy would also help clarify any effects produced by music therapy and not confounded by other treatment modalities. Ideally, future studies would continue to include a functional assessment like the Catherine Bergego Scale administered through the KF-NAPTM, although conducted on a more frequent basis. This study amended the initial exclusion criteria of participants with visual or hearing impairments beyond glasses or hearing aids to allow for a greater subject pool during recruitment, although future studies should ensure participants do not have a comorbidity of hemianopsia, cataracts, or other sensory impairments that could impact written testing procedures. Finally, the use of familiar or preferred music is recommended during some or part of the treatment protocol, as this allows for a more pleasant therapy experience on behalf of the participants, thereby tailoring to psychosocial needs of patients while simultaneously treating symptoms of neglect. Given a more pleasant treatment experience, individuals with neglect are more likely to experience an increase in dopamine and feelings of reward, thereby increasing arousal and encouraging increased attention toward the neglected side of space.

Conclusion

The musical procedure in this study outlines a possible form of treatment for the rehabilitation of unilateral spatial neglect. Two of the three participants in this study demonstrated a change in severity in neglect on a Line Cancellation Test in several therapy trials, although performance was inconsistent between and within sessions. All participants did show a greater exploration of the left side of space during treatment sessions involving music, evidenced by the ability to appropriately produce sounds from instruments placed on the neglected side. The procedure outlined in this study was feasible to administer in an inpatient physical rehabilitation setting and could easily be incorporated into current therapy plans. Furthermore, the involvement of musical instruments may be more enjoyable to some patients than other existing treatment methods such as Prism Adaptation Therapy, which may cause feelings of dizziness or nausea. Overall, this study suggests that a musical procedure involving resonator bells or paddle drums may be a potential treatment for individuals with neglect, though future research involving a larger and more diverse sample size as well as a control group is warranted.

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