Music-Induced Speech and Language Rehabilitation

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Abstract and Keywords

This chapter examines the connection between music and speech, and points out areas of intersection relative to the mechanisms guiding their practice, application, and execution. This work also investigates the role of neurologic music therapy as a developmental, remedial, and rehabilitative protocol in the area of speech and language. In order to operationalize findings, the chapter is divided into sections by speech and language disorder: dysarthria, apraxia of speech, aphasia, fluency, sensory deficits, voice disorders, and dyslexia. Literature is provided hereafter outlining the premise for music prescription relative to the aforementioned areas, as well as areas of speech and language therapy wherein music discernibly exists as a fundamental construct in various therapeutic protocols; the practice of singing being a main area of concentration. The review provides an overview of related research and outlines areas in preliminary stages of investigation.

Keywords: speech and language disorders, speech and language therapy, rehabilitation, music, singing, neurologic music therapy

Introduction

There are anecdotal and clinical reports—some of which trace back hundreds of years—as to the fact that music, especially singing, renders increased speech fluency for individuals with profound speech deficits. Both short- and long-term music-based interventions exist which can address developmental, rehabilitative, and adaptive speech goals. A growing body of behavioral evidence prevails demonstrating the efficacy of music training on various speech and language impairments including: dyslexia, specific language impairment (SLI), aphasia, dysarthria, apraxia of speech, fluency disorders, voice disorders, and hearing loss. Despite the conglomerate of findings, it has remained largely elusive as to how music can elicit neural changes that help to mediate speech and language processes in the brain. In recent years however, a burgeoning volume of neuroimaging studies have begun to yield promising evidence with regards to the efficacy of the use of Neurologic Music Therapy (NMT) interventions for speech rehabilitation by demonstrating said neural reformations. For example, Wan and colleagues (Wan, Zheng, Marchina, Norton, & Schlaug, 2014) showed that intensive melodic intonation therapy (MIT) induced structural connectivity in the undamaged right hemisphere in patients with non-fluent chronic aphasia.

What aspect of music (e.g., pitch, rhythm, melody, dynamics) plays the pivotal role in the transference of music to speech ability? Although melody may seem like the most important feature, recent evidence suggests that rhythm plays a centrally critical role in the facilitation and recovery of speech, induced during music-based intervention (Fujii & Wan, 2014; Stahl, Kotz, Henseler, Turner, & Geyer, 2011). Behaviorally, rhythm performance predicts some linguistic abilities including grammar and phonological processing (Gordon et al., 2015). Neurologically, there is substantial overlap between rhythm and speech circuitries along the speech-motor network (Kotz, Schwartze, & Schmidt-Kassow, 2009; Kraus & Chandrasekaran, 2010). Namely, emerging research has proposed that the built-in temporal processes—necessary for both music and speech—are mediated by corticostriatal circuitries comprising the basal ganglia, the supplementary motor area (SMA), the premotor cortex, and the frontal operculum (Kotz & Schwartze, 2010). In particular, the basal ganglia serve as a central hub in analyzing patterns of temporal sequences of sensory or motoric events (Kotz & Schmidt-Kassow, 2015). Accordingly, there is a body of evidence indicating the functional role of the basal ganglia, ranging from beat perception and production (Grahn & Brett, 2009), to speech and language processing. Thus, patients with basal ganglia damage (e.g., Parkinson's disease, PD) show speech and language deficits as well as motor deficits (Friederici, Kotz, Werheid, Hein, & Von Cramon, 2003; Grahn & Brett, 2009; Kotz, Frisch, Von Cramon, & Friederici, 2003). As an example, PD patients are not able to detect temporal cues in speech (Farrugia et al., 2014; Kotz & Gunter, 2015), syntactic violation in language (Friederici et al., 2003; Kotz & Gunter, 2015), and fail to modulate their speech rate during speaking tasks (Skodda & Schlegel, 2008).

Such rhythm and timing deficits can stem from the mutation of genes coding a key neurotransmitter regulating temporal processes (Wiener, Lohoff, & Coslett, 2011; Wiener, Lee, Lohoff, & Coslett, 2014). DRD2 polymorphism can cause the reduction of dopamine2-receptors' density in the basal ganglia (Rowe et al., 1999), which can potentially affect timing and rhythmic processes. Accordingly, Wiener et al. (2014) have shown that polymorphism of the DRD2 gene can lead to poor temporal judgment. Similarly, Wong and colleagues (Wong, Ettlinger, & Zheng, 2013) reported poor performance on grammar sequencing. These two studies also related DRD2 polymorphism to the differential functional magnetic resonance imaging (fMRI) activity in the basal ganglia.

Intriguingly, patients with a dysfunctional basal ganglia benefit from external rhythmic cueing when performing speech and language tasks. For example, Kotz and Gunter (2015) demonstrated that a PD patient elicited P600 electroencephalography (EEG)—a hallmark of the syntactic processing in response to syntactically violated sentences after listening to music that had pronounced beat patterns (e.g., the even-metered musical form of march music). Correspondingly, in the developmental domain, children with SLI performed better on syntactic judgment tasks when primed by music with a regular beat pattern than by music with an irregular beat pattern (Przybylski et al., 2013), or by environmental sound lacking beat components entirely (Bedoin, Brisseau, Molinier, Roch, & Tillmann, 2016). This speaks to the temporal dynamic theory wherein internal temporal processing can be enhanced by external rhythm (Large, Herrera, & Velasco, 2015; Large & Jones, 1999). In summation, current findings suggest that there is a tight coupling between speech and music, and that rhythmic processes are mediated by dedicated neural and genetic mechanisms.

Neurologic Music Therapy is an evidence-based system of standardized clinical techniques which are based on scientific knowledge related to music perception and production, and the effects thereof, on non-musical brain and behavior function (Thaut & Hoemberg, 2014). In the speech and language domain, there are eight standardized techniques: Melodic Intonation Therapy (MIT), Musical Speech Stimulation (MUSTIM), Rhythmic Speech Cueing (RSC), Vocal Intonation Therapy (VIT), Oral Motor and Respiratory Exercises (OMREX), Therapeutic Singing (TS), Developmental Speech and Language Training Through Music (DSLM), and Symbolic Communication Training Through Music (SYCOM). This chapter will review common speech and language disorders, and existing research which support the use of NMT techniques in the development, recovery, and remediation of speech and language.

Dysarthria

Motor speech disorders (MSDs) can be defined as speech disorders resulting from neurologic impairments affecting the planning, programming, control, or execution of speech. MSDs include the dysarthrias and apraxia of speech (Duffy, 2005, p. 5). Dysarthria is a collective of disorders defined by a neuropathophysiologic disruption in the activation and control (e.g., strength, speed, range of motion, tone, coordination) of the muscles necessary for speech production. Dysarthria therefore, can affect the respiratory, phonatory, resonatory, articulatory, and prosodic aspects of speech. Several categories exist: flaccid, spastic, hypokinetic, hyperkinetic, ataxic, upper motor neuron, and mixed; all resulting from damage or disturbance in the upper or lower motor neurons, basal ganglia, or cerebellum (Darley, Aronson, & Brown, 1969; Duffy, 2005).

Singing and speech share the same proprioceptive feedback system. Guenther's Directions into Velocities of Articulators (DIVA) model describes a segmental theory of speech motor control which proposes that speech segments are coded by the central nervous system (CNS) as auditory-temporal and somatosensory-temporal goal regions, and that two controls drive a speech sound map: feedforward and feedback. The feedforward mechanism outlines how the CNS sends anticipatory pre-programmed instructions about movements by relying on past experiences in movement planning, execution, and error correction. The feedback mechanism provides scaffolding for how speech movement is controlled based on the sensory input the CNS receives, which may indicate deviation from the planned movement (Guenther, 2006; Guenther & Vladusich, 2012; Tourville & Guenther, 2011). In the domain of speech and language rehabilitation, the task of singing could be theorized as able to induce neuromotor retraining via the formation of new motor command relationships within the feedback mechanism, that stimulate learning within the feedforward mechanism, thereby causing the CNS to re-calibrate or reset its motor program for communication. In addition, since singing naturally lends itself to heightening various elements of speech production as an augmentative form of vocal loading, respiratory shaping, resonant voicing, exaggerated articulation, and prosodic phrasing, singing could also be theorized as able to modulate motor neuron activity; carrying with it implications for rehabilitation (Cohen, 1994; Natke, Donath, & Kalveram, 2003; Tonkinson, 1994). Hereafter lies a review of current singing-related voice therapy strategies prescribed to specific motor speech disordered populations and their outcomes. Elucidation of the practice of singing as a therapeutic science with reproducible effects is the main construct of the review.

There is a significant profusion of literature reporting positive outcomes for utilizing singing tasks as a means of voice therapy in dysarthric populations. In traumatic brain injury and stroke, singing-induced gains have been documented in areas related to maximum phonation time, intensity, speech rate, prosody, vocal range, and overall intelligibility (Baker, Wigram, & Gold, 2005; Cohen, 1988, 1992; Kim & Jo, 2013; Tamplin, 2008). Therapeutic outcomes using NMT speech techniques such as VIT, TS, and OMREX in Parkinson’s disease have also revealed significant improvements in the areas of hypomimia, vocal intensity, fundamental frequency, maximum phonation time, prosody, articulation, and better lung function test scores, overall (Caligiuri, 1989; Canavan, Evans, Foy, Langford, & Proctor, 2012; DeStewart, Willemse, Maassen, & Horstink, 2003; Di Benedetto et al., 2009; Elefant, Baker, Lotan, Lagesen, & Skeie, 2012; Haneishi, 2001; Stegemöller, Radig, Hibbing, Wingate, & Sapienza, 2017; Tanner, 2012; Tanner, Rammage, & Liu, 2016; Tautscher-Basnett, Tomantschger, Keglevic, & Freimuller, 2006). Accordingly, in earlier work by Bellaire, Yorkston, and Beukelman (1986), the modification of the breathing pattern of mildly dysarthric speakers resulted in the amelioration of prosodic repertoire. Similarly, in 1993, Cohen and Masse applied a singing intervention to persons with neurogenic communication disorders, symptomatic of multiple sclerosis, cerebral palsy, Parkinson’s disease, and cerebrovascular accident. Findings revealed improvements in intelligibility ratings, vocal intensity, and vocal range.

The significance of singing in human development has always had firm roots in our evolutionary inheritance: Charles Darwin theorized that Neanderthals originally communicated using a catalog of song-like expressions lacking in words or meaning (Darwin, 1872/1988). Furthermore, recent research provides description of a phenomenon known as infant-directed speech, or musical speech as being catalytic for preverbal communication and an important stage in language learning in the earliest stages of life (Fernald, 1989; Trainor, Clark, Huntley, & Adams, 1997). As such, singing’s current emergence (or re-emergence) as speech’s keen and remunerative partner, implies that the pairing has been evident all along, and that prescribing singing training to motor speech disordered populations is, therefore, reflective of a more refined understanding of where we came from.

Apraxia of Speech

Apraxia affects the sensorimotor programming, planning, or preparation (e.g., velum elevation, tongue placement) needed for directing movements that result in volitional speech production (Yorkston, Beukelman, Strand, & Hakel, 2010, p. 7). Messages from the brain to the mouth become disrupted, resulting in an inability to move the articulators to execute speech sounds correctly. Apraxia can range from mild to a complete loss of the ability to produce speech. The disorder exists in two forms: congenital (childhood apraxia of speech—CAS) and acquired (apraxia of speech—AOS). Furthermore, “although AOS can involve all speech subsystems, it is predominantly a disorder of articulation and prosody” (Ballard et al., 2015, p. 316). While still in its infancy, the most significant conglomerate of clinical evidence that points towards treating apraxia utilizes rhythm as the main cueing mechanism. In NMT, representative techniques include MIT and RSC, with some additional prescription of OMREX and TS.

In RSC "speech rate control via auditory rhythm is used to improve temporal characteristics such as fluency, articulatory rate, pause time, and intelligibility of speaking" (Mainka & Mallien, 2014, p. 150). Since 1988, several single-case studies have existed in the literature pointing to the positive effects of metronomic pacing treatment for the rehabilitation of apraxia of speech (Dworkin, Abkarian, & Johns, 1988; Wambaugh & Martinez, 2000). More recent research has developed. Brendal and Ziegler (2008) compared a metrical pacing treatment with an articulatory treatment on a sample of ten patients with post-stroke induced mild to severe aphasia. Post-therapy, the metrical stimulation treatment group exhibited improvements in articulatory and suprasegmental accuracy, while the articulatory treatment group displayed improvement in articulation alone. Using a metronomic rate control and hand tapping task within a single-subject baseline design on a patient with mild AOS, Mauszycki and Wambaugh's (2008) results indicated improvement in sound production accuracy and total utterance duration during repetition tasks. Aitken Dunham (2010) designed a single-subject study comparing the efficacy of a speech therapy treatment program with a speech and music therapy-combined treatment program. The music therapy protocol was established through the work of Kim and Tomaino (2008), and included elements of RSC, MIT, OMREX, and TS. Results revealed that while both treatment groups showed improvement post-therapy, the greatest treatment effect was found following the combined therapy protocol. Finally, using a single-subject design with a repeated practice versus repeated practice in tandem with a rate/rhythm control strategy on ten speakers with chronic AOS, Wambaugh and colleagues' results (Wambaugh, Nessler, Cameron, & Mauszycki, 2012) indicated articulation improvement in the repeated practice treatment with mild gains when rate/rhythm control tasks were added.

MIT "is a therapy technique that uses melodic and rhythmic elements of intoning (singing) phrases and words to assist in speech recovery for patients with aphasia" (Thaut, Thaut, & McIntosh, 2014, p. 140). Several studies have looked at the use of MIT with apraxia of speech populations; however, due to the small sample sizes and lack of consistent protocols, it is difficult to draw conclusions without further investigation and caution is recommended when interpreting the results. In 1975, Keith and Aronson reported a case of a 48-year-old woman who three years post-stroke presented with both aphasia and apraxia of speech. After several weeks of speech therapy, progress was muted, so a singing task was prescribed, which resulted in the patient's exhibition of the ability to sing and articulate words in song. While transfer to speech was not without mild aphasic and apraxic error; the presence of speech, and the effectiveness thereof, warranted acknowledgment and prompted further clinical investigation. Krauss and Galloway (1982) ran a study comparing a traditional speech therapy protocol to one that included MIT as a warm-up across a single-subject case study on two boys with CAS and additional developmental delays. Outcomes for both subjects indicated improvements in phrase length, noun retrieval, and verbal imitation. Furthermore, Helfrich-Miller (1984) provided a report on a population of three case studies involving children with apraxia of speech who were prescribed MIT over a period of one to four years. Gains were reported in the areas of phoneme acquisition, speech sequencing, and overall improvements in intelligibility rating. However, due to the fact that the patients were also receiving speech therapy during this time, the conclusion that MIT was the catalyst for outcome causation should be viewed with discretion. In 2011, Martikainen and Korpilahti compared the effectiveness of combining MIT with the Touch-Cue Method (TCM) in the single case of a 4-year-old girl with CAS. Findings revealed a decrease in speech sound errors along with an increase in sequencing abilities post MIT. This progression continued when TCM was added resulting in whole words being formed. The outcomes of all of the aforementioned work indicate the need for further study in this domain to improve the communicative efficiency of people afflicted by AOS and CAS. Both MIT and RSC are valuable compensatory facilitators of speech and language encoding and in tandem, speech and language production.

Aphasia

Aphasia is a communication disorder which can affect a person's use of expressive and receptive language, despite their cognitive ability. Aphasia is typically caused by acquired brain injuries, but can also present as a degenerative brain and nervous system disorder in persons with frontotemporal dementia. Applications of MIT and MUSTIM as used in NMT have primarily focused on non-fluent aphasia and primary progressive aphasia.

Broca's aphasia, also referred to as expressive or non-fluent aphasia, results from damage to the language network in the left frontal lobe of the brain, Brodmann's areas 44 and 45. Broca's aphasia is characterized by the complete loss of ability to produce meaningful speech or severely reduced speech output with limited short utterances. Vocabulary access is halted and laborious, with a lack of ability to organize and control linguistic content, which often consists of non-propositional speech. Speech can be perseverative, with disordered syntax, grammar, and structure. The person with expressive aphasia may understand speech relatively well and be able to read, but be limited in writing (The American Speech-Language-Hearing Association, 2017). For over a hundred years, it has been noted that people with aphasia frequently have the ability to sing familiar, overlearned songs, which are accessed through the unimpaired right hemisphere which is heavily involved in the emotional color and expression as well as rhythmic aspects of both singing and speech. It was not until the 1970s that researchers standardized it as a formalized treatment process for people with Broca's aphasia (Sparks, Helm, & Albert, 1974, Sparks & Holland, 1976). Since then, successful applications of the rhythmic and melodic intonation for aphasia have been seen across languages and cultures (Bonakdarpour, Eftekharzadeh, & Ashayeri, 2003; Cortese, Riganello, Arcuri, Pignataro, & Buglione, 2015; Haro-Martinez et al., 2017, Popovici, 1995).

Melodic Intonation Therapy (MIT) is a technique which uses a person with aphasia's unaffected ability to sing familiar songs, in order to teach them how to sing and eventually generate speech output of functional phrases through the use of the melodic and rhythmic elements of speech. Evidence has shown that by using the stepwise process of MIT, the brain is able to bypass damaged left-hemisphere networks and engage right-hemisphere language resources via the rerouting of speech pathways, therefore aiding in the restoration of propositional speech (Breier, Randle, Maher, & Papanicolaou, 2010; Schlaug, Marchina, & Norton, 2009). While many studies have focused on the use of MIT with acute aphasia, Van der Meulen and colleagues (Van der Meulen, van de Sandt-Koenderman, Heijenbrok-Kal, Visch-Brink, & Ribbers, 2012) saw significant improvements on verbal output task in subacute severe non-fluent aphasia patients between two and three months post-stroke.

While the ultimate goal when using MIT is to train propositional language, in order for people to communicate and express non-formulaic verbal output independently in their everyday life, it is also used to teach a specific set of formulaic or overlearned phrases which are relevant to the patient's life. The long-term goal is to improve propositional speech, and therefore speech and language assessments which are sensitive to both propositional and non-propositional speech should be used (Lim et al., 2013; Zumbansen, Peretz, & Hébert, 2014). Long-term, there is some evidence that suggests reactivation of left-hemisphere speech circuitry (Belin et al., 1996; Naeser & Helm-Estabrooks, 1985; Schlaug, Marchina, & Norton, 2008; Schlaug et al., 2009).

Although the body of research validating the use of MIT with aphasia is very large, there is still more to be understood. Many studies have emphasized melody as the key element driving the responses seen in patients when using MIT (Akanuma, Meguro, Satoh, Tashiro, & Itoh, 2016; Seger et al., 2013). While melody clearly plays an important role, more recent research has focused on the rhythmic priming and pacing which has been shown to engage auditory, prefrontal, and parietal regions in the right hemisphere (Boucher, Garcia, Fleurant, & Paradis, 2001; Stephan et al., 2002).

Fluency

Fluency refers to the aspects of speech output related to continuity, smoothness, rate, and effort. Most people have experienced brief speech disfluencies at some point in time in their lives. For instance, normal disfluency can happen when children are first learning to combine words and speak in short sentences, or when they are learning to read. However, when disfluencies become numerous to a point where they impede the ability to communicate, they may meet the diagnostic criteria for a fluency disorder such as stuttering or cluttering.

Stuttering, most commonly presents at childhood, but adult onset can also result due to a range of neurologic and neuropsychological conditions. While the exact cause of stuttering is not completely understood, there are many theories suggesting a range of genetic, neurological, psychological, and social linguistic links to the disorder. The Diagnostic and Statistical Manual of Mental Disorders, 5th edition (DSM-5; American Psychiatric Association, 2013), identifies primary symptoms for childhood-onset fluency disorder as repetition of sounds, syllables, or monosyllabic whole words; prolongation of single sounds; blocked silence or voicing during speech; and excessive physical tension in word production. Secondary behaviors may also include hesitation, interjection of sounds, loss of eye contact, and extraneous motor movements such as eye blinking.

Jokel and colleagues (Jokel, De Nil, & Sharpe, 2007) systematically assessed the speech characteristics of adults with neurogenic stuttering due to acquired brain injury. Their research resulted in six principal characteristics of stuttering, which are often referred to in the neurogenic stuttering literature:

1. Disfluencies occur equally on grammatical and substantive words.
2. Repetition, prolongation, and blocks occur in all positions of words.
3. There is a consistency of stuttering behavior across all speech tasks.
4. The speaker does not appear overly anxious about the stuttering behavior.
5. Secondary features are rarely observed.
6. An adaptation effect is not observed.

Cluttering, which also presents as a disruption in fluency and rate of speech, is characterized by rapid bursts of speech at an irregular speech rate. Typical disfluencies may include excessive whole word repetition, unfinished words, omitted syllables, and interjections. People who clutter often have limited self-awareness of their irregular speech, sloppy handwriting, poor attention, difficulties organizing thoughts, auditory processing disorders, and learning disabilities.

Several studies have suggested that stuttering is a disorder of motor timing, and may be related to the basal ganglia (Lebrun, 1998; Rosenberger, 1980; Victor & Ropper 2001; Wu et al., 1995). The SMA and basal ganglia play a significant role in providing internal timing cues to facilitate the initiation of even well-learned speech (Cunnington, Bradshaw, & Iansek, 1996). Rhythm has been used as an effective external timing cue to compensate for deficient internal cues from the basal ganglia and the SMA. This may explain why speaking to a metronome is one of the most effective ways to instantly create fluency for persons who stutter (Alm, 2004). This effect has been reported to be independent of speech rate, with significant reduction in stuttering seen even at very fast tempos (Van Ripper, 1982).

Research has also looked at singing to increase fluency in vocal output. Alm (2004) suggested that melody cannot exist without rhythm; therefore, when singing the brain has an internal representation of the intended timing for the initiation of each syllable, similar to how the metronome can provide external timing cues. A study by Healey and colleagues (Healey, Mallard, & Adams, 1976) compared singing familiar and unfamiliar lyrics to a familiar melody. While both conditions were associated with significant reductions in stuttering, the greatest increases were seen when singing familiar lyrics, possibly indicating that singing alone does not account for all of the decreases in stuttering that occur during singing. In 1979, Colcord and Adams compared reading versus singing altered lyrics to a familiar melody in order to increase fluency, voicing durations, and vocal sound pressure levels (SPL) in moderate to severe stutterers. Results revealed both a decrease in disfluency and an increase in voicing duration when singing to a familiar melody over reading. In addition, Glover and colleagues (Glover, Kalinowski, Rastatter, & Stuart, 1996) compared reading vs. self-generated singing at normal and fast tempos. Singing at both fast and normal rates was found to generate substantial reduction in stuttering over reading. Although the quality of singing varied significantly, this study suggested that stutterers also have the ability to internally create fluent speech output by imposing self-generated melodic structures when asked to sing.

Sensory Deficits

Although several attempts have been made to use music as a habilitative means for hearing restoration, there is only a scant of NMT research in the hearing loss and cochlear implant (CI) domain (Gfeller, 2016; Limb & Rubinstein, 2012). This is primarily due to the inherent difficulty of music perception in CI users—their ability to process spectrally complex musical sound is limited (Limb & Roy, 2014). Such impoverished music signals can be disturbing to some CI users, while others find it pleasant (Abdi, Khalessi, Khorsandi, & Gholami, 2001; Gfeller, Driscoll, Smith, & Scheperle, 2012). There are many parallels between both the structure and production of speech and music. Both can be considered sensorimotor behaviors that require a high level of control and dynamic interplay between several brain processes in order to select, organize, and articulate, in a time-sensitive manner. Kotz and Schwartze (2016) identified temporal processing and coordination as essential to effective speech production. As such, due to the inherent timing, rhythm, pattern, and melodic structures in both music and speech, music has the potential to simulate normal speech patterns, and therefore act as a training and retraining tool for people with fluency disorders.

Only a few studies have examined the effect of music training on CI hearing improvement with rigor for proper experimental designs and formal tests. This is due to logistical and practical challenges including heterogeneity in age, onset of the hearing loss, and duration of the CI among the participants. For example, past studies often relied upon teachers' or parents' evaluations as indicative of improved music skills and aptitude after music listening with no statistical analyses (Abdi et al., 2001; Rocca, 2012). Nevertheless, emerging evidence indicates that music training appears to elicit improved listening skills in the CI users. Chen et al. (2010) reported that pitch perception was positively correlated with music training period in twenty-seven CI children. Fu and colleagues (Fu, Galvin, Wang, & Wu, 2015) demonstrated that melodic contour identification ability was significantly improved after four weeks of a computerized music training program in fourteen congenitally deaf CI children. Of note is that within the this population, long-term music training not only leads to listening skills within the music domain, but it also transfers to speech and cognitive domains. For example, Rochette and colleagues (Rochette, Moussard, & Bigand,2014) showed that fourteen profoundly deaf children who received 1.5–4 years of music lessons outperformed the control CI group (i.e., no musical training) in phonetic discrimination tests, auditory scene analysis, and working memory tests.

At present, there is a dearth of CI studies examining the effect of music training at the neural level. In general, it is difficult to study the CI users using fMRI because of the ferromagnetic characteristics of the CI device. Instead, EEG has been used to study the neural activity associated with listening skills in the CI users. For example, Peterson et al. (2015) recorded the brain activity profiles of eleven adolescent CI users using EEG before and after a two-week music training period. Although they found a significant change in mismatch negativity (MMN) in response to deviations of timbre, intensity, and rhythm, they found no MMN difference in pitch deviation. The lack of neural changes in the pitch processing could have been due to the short intervention period. In addition to EEG, functional near-infrared spectroscopy (fNIRS) is another viable option to study CI populations (Saliba, Bortfeld, Levitin, & Oghalai, 2016). In fact, fNIRS has several advantages over fMRI including quietness, portability, and a naturalistic and participant-friendly environment. Although the application of fNIRS in the CI domain is still in its infancy, fNIRS allows for studying the neuroanatomical changes following music intervention training in CI users, and therefore remains attractive.

Voice Disorders

Voice disorders occur when there is a deficiency in vocal functioning affecting speech production. Symptoms may include: hoarse or breathy vocal quality; loss of voice; pitch breaks, inability to maintain typical pitch, or reduced pitch range; lack of vocal carrying power; reduced loudness range; a need to use greater vocal effort; running out of breath while talking; an unsteady voice, tension in the neck and shoulders, throat or neck pain, throat fatigue or tightness, pain upon swallowing; an increased need to cough or throat clear; and any form of discomfort in the chest, ears, or back of the neck (Kostyk & Putnam Rochet, 1998). Voice disorders can be manifested in a multitude of different ways and have multi-factorial etiologies. Stemple and colleagues (Stemple, Glaze, & Klaben, 2009, p. 55) classify disorders into four main causal areas: medically-related disorders and primary disorders (structural and neurogenic); personality-related disorders, sometimes referred to as psychogenic; and vocal misuse disorders, alternatively labeled functional.

Medically-related disorders refer to “medical or surgical interventions that directly cause voice disorders and medical or health conditions and treatments that may indirectly contribute to the development of voice disorders” (e.g., trauma, chronic illness, chronic disorder) (Stemple et al., 2009, p. 60). A sampling of singing-task induced voice therapy research outcomes are highlighted hereafter. Onofre and colleagues (Onofre, Ricz, Takeshita-Monaretti, Prado, & Aguiar-Ricz, 2013) provided report on the use of a singing training program prescribed to laryngectomy-wearing patients with tracheoesophageal voice prostheses that included both respiratory muscle strengthening and scalar vocalization tasks. Outcomes revealed improvement in the grade of dysphonia, roughness and breathiness as well as minor improvements in vocal extension during tracheoesophageal phonation. Using a randomized control trial, Hilton et al. (2013) prescribed singing exercises to a population of ninety-three patients in an effort to reduce symptoms of snoring and sleep apnea, and found that by improving the tone and strength of the pharyngeal muscles, the experimental group displayed a significantly reduced frequency of snoring. Lortie and colleagues (Lortie, Rivard, Thibeault, & Tremblay, 2017) described the augmentative effects of singing on the aging voice by looking at a population of seventy-two people with an age range of 20 to 93 years. Findings indicated that frequent singing moderates age-related effects on most acoustic parameters of the voice, especially related to pitch accuracy and amplitude levels. This is in keeping with similar findings by Sauder, Roy, Tanner, Houtz, and Smith (2010) and Ziegler Verdolini Abbott, Johns, Klein, and Hapner (2014) related to presbylaryngis, which lends itself to the burgeoning conglomerate of evidence related to the benefits of singing practice on the aging voice.

Primary disorders include "embryologic, physiologic, neurologic and anatomic disorders that have vocal changes as secondary symptoms of the primary disorder" (e.g., cleft palate, velopharyngeal insufficiency, hearing impairment, cerebral palsy) (Stemple et al., 2009, p. 65). Research in this area has been localized to a few select areas; one being spasmodic dysphonia (SD). SD causes symptoms of strained or effortful voice qualities due to adductor or abductor laryngospasm and while primary treatment prescription includes botox injections or resection of the recurrent laryngeal nerve to paralyze one of the folds, voice therapy treatment targets may include work related to soft and sustained phonatory onsets, or pitch and loudness modifications (The American Speech-Language-Hearing Association, 2017). Recent literature suggests that SD is a form of focal dystonia with dysfunction often reflected during speech tasks alone, leaving non-linguistic vegetative functions such as coughing, laughing, and singing unaffected by the disorder. Reduction in spasticity thereby, is the result of deviation from the normal mode of phonation, and singing has henceforth been promoted as an effective strategy to explore in therapy (Bloch, Hirano, & Gould, 1985). Therapeutic outcomes in populations with unilateral vocal fold paralysis have also been positive, with reported improvement related to reduced hoarseness and improved perception of voice impairment (Busto-Crespo et al., 2016). That said, acknowledgment of these results should be treated with caution as idiopathic vocal fold immobility has a history of spontaneous resolution. Finally, since professionally trained classical singers are said to carefully tune their velopharyngeal port to fine-tune their vocal timbre (Austin, 1997; Birch et al., 2002; Fowler & Morris, 2007; Sundberg et al., 2007; Tanner, Roy, Merrill, & Power, 2005; Yanagisawa, Estill, Mambrino, & Talkin, 1991), research investigating the effect of altered auditory feedback on the control of oral–nasal balance in song was completed by Santoni, de Boer, Thaut, and Bressmann (2018). Results indicated that all participants showed lower nasalance scores in response to both increased and decreased nasal signal level feedback, with no differences reported between trained singers and untrained non-singers. In a similar study, Jennings and Kuehn (2008), looking at the singing of sustained vowels, without the altered feedback condition, trained singers were shown to display lower nasalance scores than untrained singers. While the results of both studies may not be directly comparable, they do support the premise that more research is needed in this area in order to support the potential for the experimental implementation of singing-infused therapeutic protocols in populations with hypernasal resonance disorders.

Personality-related or psychogenic voice disorders come about due to psychological factors reflected via a disturbance of voice (e.g., puberphonia, conversion aphonia). In a study treating patients with puberphonia, Desai and Mishra infused singing modalities (humming and glottal phonatory onsets) into part of their voice therapy protocol and found that all patients (N = 30) were able to achieve appropriate pitch range post-therapy (Desai & Mishra, 2012). More research is needed in this area.

Vocal misuse disorders (e.g., muscle tension dysphonia, voice fatigue, ventricular phonation, phonotrauma) are typical of vocal abuse, often caused by poor muscle functioning or poor voicing behaviors. There is a lot of literature supporting the use of several standard voice therapy treatment protocols addressing vocal misuse with protocols somewhat analogous to tasks involved in singing—specifically the use of nasal consonants and humming, sustained phonation, pitch glides, and rhythmic vocal play: the Smith Accent Method (Smith & Thyme, 1976), Vocal Function Exercises (Stemple, Lee, D’Amico, & Pickup, 1994), Lessac-Madsen Resonant Voice Therapy (Verdolini-Marston, Burke, Lessac, Glaze, & Caldwell, 1995), Semi-Occluded Vocal Tract (Titze, 2006), and Phonatory Resistance Training Exercises (Ziegler & Hapner, 2013). Perceptual outcomes of Resonant Voice Therapy, for example, have included improvements in speech-level fundamental frequency and range of speaking intensity, as well as reductions in vocal roughness, strain, monotone, hard glottal attack, vocal fry, and overall vocal fatigue (Chen, Hsiao, Hsiao, Chung, & Chiang, 2007; Roy et al., 2003; Yiu & Ho, 2002; Verdolini-Marston et al., 1995). Alleviation of supraglottic activity (false vocal fold and anterior-posterior compression) has also been reported (Ogawa et. al, 2013).

Active singing as a treatment option in the world of voice therapy is in fact not a new concept. Boone, McFarlane, Von Berg, and Zraick (2010) explain a technique called Redirected Phonation, which is prescribed to patients having difficulty “finding” their voice due to functional dysphonia. The procedural mechanism of the technique is that the speech language pathologist “searches with the patient to find some kind of vegetative phonation (coughing, gargling [Boone, 1983], laughing, throat clearing) or some kind of intentional voicing (‘playing’ the comb or kazoo, humming, singing, trilling [Colton & Casper, 1996], or saying ‘um-hmm’ [Cooper, 1973])” (Boone et al., 2010, p. 230). Relative to singing, the protocol is focused on singing practice sentences (similar to the practice of chant-talking) with the goal of phasing out the singing with the newly redirected voicing procedure for speech—shaped by the improved respiration, phonation, and overall voice quality present in the singing condition. Outcomes have included increased ease and clarity of voice production, with less perturbation (Boone et al., 2010, p. 231).

A vast amount of clinical evidence also points to the benefit of using singing tasks as a means of respiratory therapy. Within the domain of chronic obstructive pulmonary disease (COPD), clusters of research have shown that singing voice therapy tasks (VIT, TS, OMREX) have resulted in improvements in single breath counting, breath support modes (clavicular vs. diaphragmatic), maximum intensity ratings, lung function tests (maximum expiratory pressure, forced expiratory volume, and forced vital capacity), as well as self-reported improvement in dyspnea ratings (Canga, Azoulay, Raskin, & Loewy, 2015; Engen, 2003; Jamaly et al., 2017; Lord et al., 2012; Skingley et al., 2014). In a study completed by Eley and Gorman (2010), thirty-three asthmatic participants were treated with either OMREX (males playing a didgeridoo) or VIT and TS (females taking singing lessons). Results for the men indicated significant improvements in lung function tests (peak expiratory flow, forced expiratory volume, and forced vital capacity), while the women's results revealed promising, but insignificant peak expiratory flow gains. There is also some preliminary evidence of the clinical benefit of a singing program in the cystic fibrosis population with one study pointing to amelioration reflected in lung function scores (maximum inspiratory pressure, maximum expiratory pressure) of eight hospitalized children post-treatment and during follow-up (Irons, Kenny, McElrea, & Chang, 2012). Finally, in a study conducted by Tamplin et al. (2013), a randomized control trial comparing the effectiveness of singing lessons (OMREX and TS) versus music appreciation and relaxation classes for twenty-four participants with quadriplegia was completed. Results indicated significant improvements in speech intensity as well as maximum phonation time for the singing group alone.

The breadth of this research exhibits an exciting trend towards the use of a singing-task as a viable and contemporary utensil for use in voice therapy practices.

Dyslexia

Rhythm-based intervention has been applied to developmental dyslexia, a prevalent reading disorder despite a person's normal cognitive abilities and IQ. For example, Thomson and colleagues (Thomson, Leong, & Goswami,2012) devised a novel rhythm training program for six weeks of intervention with eleven dyslexic children. The rhythm intervention program consisted of three different training regimens aimed at improving auditory temporal processing in a fun and engaging manner. They compared the efficacy of the rhythm intervention to a conventional phonetic training program that eleven other dyslexic children participated in. Both intervention programs yielded a comparable amount of improvement in phonological awareness compared to a third control group of eleven dyslexic children. Similarly, Bhide and colleagues (Bhide, Power, & Goswami, 2013) compared a rhythm intervention program consisting of nine different rhythm training sections (e.g., same/different rhythm discrimination, rise time discrimination, etc.) to a conventional intervention program that required children to match sound to spelling. Their findings indicated that the rhythm-based intervention was as effective as the conventional intervention method. Bonacina and colleagues (Bonacina, Cancer, Lanzi, Lorusso, & Antonietti, 2015) conducted an intervention study with fourteen dyslexic children who underwent a computerized rhythmic-reading training (RRT) every other week (a total of nine sessions). Compared to a control group (no training), children who received the RRT improved reading ability as evidenced by reduced reading speed and increased accuracy.

Flaugnacco et al. (2015) performed a randomized control trial wherein dyslexic children participated in either a music training program or a painting training program (in tandem with conventional daily treatment) for a period of seven months. The music training program was based on Kodaly and Orff pedagogy with significant focus given to the rhythmic and temporal aspects of the music. What they found was that the music group outperformed the control (i.e., painting) group in phonological awareness and reading skills. More recently, Habib et al. (2016) conducted a music-based intervention program with dyslexic and normal school-age children for three days (six hours per day). After the intervention, they found a significant improvement in phonological and syllabic encoding abilities in the dyslexic children. Most notably, performance after the intervention was comparable to that of normal children. In summation, both short- and long-term music-based intervention programs appear to be effective ways of treating dyslexia.

Conclusion

There are many parallels between both the structure and production of speech, language, and music. All can be considered sensorimotor behaviors that require a high level of control and dynamic interplay between several brain processes in order to select, organize, articulate, and implement in a time-sensitive manner. Because of the inherent timing, rhythm, pattern, and melodic structures in both music and speech, music has the potential to simulate normal speech patterns, and therefore act as a training and retraining tool for people with speech and language disorders.

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