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How Music Is Used to Facilitate Communication in Speech-Language and Music Therapy for Children with a Diagnosis of Autism Spectrum Disorder

Anna McGreevy

Murray State University Honors College

HONORS THESIS

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How Music Is Used to Facilitate Communication in Speech-Language and Music Therapy for Children with a Diagnosis of Autism Spectrum Disorder

Anna McGreevy
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Dr. Alison Brown, Professor
Communication Disorders Department

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_____
Dr. Warren Edminster, Executive Director
Honors College

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Author: Anna McGreevy

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(Dr. Alison Brown, Advisor) (Date)

_____ _____

(Megan Smetana, Committee Member) (Date)

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(Becky Jones, Committee Member) (Date)

How Music Is Used to Facilitate Communication in Speech-Language and Music Therapy for Children with a Diagnosis of Autism Spectrum Disorder

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of the requirements
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Anna McGreevy

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Abstract

The goal of this research was to determine how music is being used in speech and music therapy sessions for children with a diagnosis of autism spectrum disorder, to discover the most common targets of these therapy sessions, and to examine the anatomical and physiological constructs that support the inclusion of music. This study was a review of literature, and included research from a variety of articles, several written in the past 25 years. Overall, results showed that music-based speech interventions such as Melodic Based Communication Therapy and Developmental Speech and Language Training, as well as music therapy interventions, are used to target behavior, communication, social interaction, or attention and motor control. Most often, music is used to create more engagement between the speech therapist and client, or between the caregiver and the client. These increased interactions can lead to more social engagement and help children with autism diagnoses gain confidence and increase their motivation to be involved in the therapy session. This paper also analyzes neurological studies that underscore how music engages the frontal and temporal areas of the brain, as well as the neural pathways between these regions. This research, along with insight into the structure and function of an autistic brain, helps to explain and support the combination of music with more traditional speech therapy approaches when working with those on the autism spectrum. It also indicates a need to conduct further studies on how music can be used to support speech acquisition and functional communication growth, as there is a current lack of research in this area.

Keywords: Autism spectrum disorder, music integration, speech therapy, children, intervention

Contents

Introduction

Communication, whether verbal, nonverbal, or social, is essential in the lives of every child as they develop, learn, and grow. This ability to exchange information and ideas provides opportunities for social interaction and the formation of peer relationships, leads to greater independent functioning, and affects their overall quality of life. When there is a breakdown in any of the systems of communication, however, many areas of a child's life may be altered. Children, for example, could have difficulty expressing their feelings, understanding the perspectives of others, engaging in a conversation, using gestures, or speaking with appropriate prosody. These symptoms are, in fact, all common communication deficits of individuals with (ASD), according to the American Speech-Language-Hearing Association (ASHA) (n.d.a). Autism not only involves these deficits but also those related to restricted and repetitive behaviors and motor difficulties. Such impairments often provide additional barriers to communication, social interaction, and overall functioning. Indeed, the *Diagnostic and Statistical Manual of Mental Disorders*, 5th edition, states that individuals with autism have varying levels of difficulty in these realms based on the severity of the disorder in that particular individual. Level 1 encompasses people with ASD diagnoses that require support, whereas individuals in level 2 require "substantial support," and those in level 3 require "very substantial support" (American Psychiatric Association, 2022, p. 57). At any level, however, the way an individual can live their life is altered due to communication, interaction, and behavioral deficits.

Treating those with ASD diagnoses is within the scope of practice for speech-language pathologists because these clinicians have expertise in treating the aforementioned impairments present in autistic individuals. A wide variety of treatments, such as Applied Behavior Analysis (ABA), Cognitive Behavioral Therapy (CBT), and the SCERTS Model (ASHA, n.d.a), have

been employed by speech therapists in order to increase interaction and social language abilities, as well as provide strategies that help autistic individuals gain greater independence, cope with change, decrease distress, and better function in all spheres of life. Musical interventions in therapy, which are the focus of this paper, have also been used to help those with autism since the 1950s, but only in the last few decades has music been used to improve more than just engagement in the therapy session. Now, there is research that shows therapists including music in treatment to decrease undesirable behavior, improve independent functioning, increase communication, and promote social interaction (James et al., 2015). The goal is that these improvements take place not only during therapy sessions but also beyond – whether that means at home, in school, or throughout everyday living. Going forward, it is essential to understand the variety of different uses of music in speech therapy sessions, as well as the techniques being employed in music therapy, to improve behavior, communication, interaction, motor control, and attention. This paper, therefore, focused on analyzing both the musical interventions in speech therapy and the music therapy interventions described by past studies to draw conclusions on how music is being used to treat autistic individuals.

In the articles that were reviewed, a wide variety of musical activities and techniques were used to teach the targeted skills. These musical interventions ranged from unstructured activities like improvisation and active music making with instruments to more structured techniques involving repetitive drumming, intonation, and originally composed songs. In some sessions, the speech or music therapists used a client-led approach, whereas in others, they themselves directed the therapy or guided the caregivers to be more explicitly involved in the music making interaction. Moreover, these activities did not always include musical instruments or melody recordings. In Salomon-Gimmon and Elefant's study (2019), for instance, 16 vocal

interventions used in music therapy sessions for 4 children with low-functioning autism were listed. One of the most common techniques was "vocal resonance with changes," where the therapist "repeats the same melody and syllables but changes the tempo" (Salomon-Gimmon & Elefant, 2019, p. 182). Each of these instances highlights the vastly different ways that music is being employed in speech therapy and music therapy sessions for children on the spectrum.

In order to provide a more complete analysis of music usage in speech therapy sessions, this discussion will also incorporate the neurological reasons behind music integration. Firstly, many individuals with autism appear to have "superior musical abilities" (Wan et al., 2011, p. 1). Anatomical and physiological brain research has, in fact, shown that the right hemisphere in ASD is "relatively spared" (Sandiford et al., 2013, p. 1299), which means that areas of music such as rhythm and melody are potential areas of strength. These and other unique characteristics of music stimuli that are used in therapy may play an important role in improving communication in an autistic individual. Other capabilities appear to be preserved in many individuals with ASD diagnoses, such as the cortical circuits underlying reward processing (Caria, Venuti, & De Falco, 2011). Therefore, when a child with an ASD diagnosis has an affinity for music, and music is incorporated into a speech therapy session, his reward system is positively impacted, altering his behavior so that not only he is more engaged, but he is also more likely to participate in activities targeting some social or communication skill. Finally, neural research has exhibited that music has the potential to strengthen "connections between frontal and temporal [brain] regions bilaterally" (Wan & Schlaug, 2010, p. 797). These regions are essential to a child's speech and language abilities, so stronger connections between these areas are promising in terms of producing plastic changes in the young autistic brain and their resulting communication skills. Each of these anatomical and physiological findings relate to

how music has been shown to affect the autistic brain and help to explain the reasoning behind using music to target behavior, speech, language, social interaction, motor control, and attention in those with ASD.

By combining how music is currently being used to assist those with ASD with the neurology behind why music integration may be beneficial, individuals can then better understand the areas of music usage that may be lacking. Current research has only begun to explore, for example, the practice of using music to directly increase speech output by helping autistic children link sounds with articulatory actions (Wan et al., 2011). There is also a limited amount of research on using music to target attention and motor control, which are strongly interconnected with behavior and social communication skills. Further research should be conducted to more completely understand the "effects of rhythmic entrainment" on both attention and motor control, as this was the concept that helped form the basis of Janzen and Thaut's (2018, p. 9) argument to expand the role of music as an intervention for those with ASD.

Overall, the aim of this paper was to evaluate how music is being utilized to facilitate communication in speech and music therapy sessions for children with a diagnosis of autism spectrum disorder and to explain the anatomical and physiological constructs that support music's inclusion. Due to the prevalence of articles related to music therapy interventions that target speech and language therapy goals, in the future, there may be an opportunity for collaboration between speech and music therapists. With the music therapist's expertise, this collaboration could make certain that music was being used by SLPs in the best way possible so that functional language outcomes for those with ASD could improve. Future research can begin studying the results that these musical interventions in therapy sessions produce in specific ASD

populations, as well as continue to study the neurological basis behind music integration in speech therapy. Ultimately, the subsequent literature review will focus on the neurological research behind the inclusion of music to facilitate communication in speech and music therapy, as well as the description and analysis of how music is being included in therapy sessions for those with ASD.

Review of Literature

Definition and Symptoms

Autism spectrum disorder (ASD) is a complex neurodevelopmental disorder. Due to this altered brain functioning, those with ASD exhibit impaired communication, interaction, and behaviors in comparison to their same-aged, neurotypical peers. Having deficits in each of these three domains, according to the *Diagnostic and Statistical Manual of Mental Disorders*, 5th edition, is necessary for an autism diagnosis to be given (American Psychiatric Association, 2022). There is a distinct difference between those with ASD and those with social communication disorder, for example, which involves social communication and interaction issues without the repetitive behaviors of ASD. Additionally, it is important to note that the abilities of children with ASD also vary. Some children, for instance, may be nonverbal while others have “advanced conversation skills” (Centers for Disease Control and Prevention, 2022b, para. 2). Therefore, autism is classified as a spectrum disorder because of the wide variation in the type and severity of symptoms individuals may experience. These symptoms manifest in the early developmental period of a child’s life and persist throughout that person’s lifetime, differing largely “depending on the severity of the autistic condition, developmental level, chronological age, and possibly gender” (American Psychiatric Association, 2022, p. 60).

The common signs and symptoms of autism spectrum disorder can be broken into three main categories: social communication deficits, language and cognition deficits, and behavioral and emotional difficulties (ASHA, n.d.a). First, challenges in social communication can make it difficult to share focus with another person on a particular object or event. They can also result in frequent communication breakdowns during turn-taking in conversation. Individuals with ASD experience social cognition issues as well, as they often have difficulty distinguishing their own feelings and perspectives from others around them.

Second, children with ASD will have language and cognition impairments. These may include deficits in using and understanding nonverbal and verbal communication, atypical voice productions, inflexible play, inappropriate and unnecessary comments in conversation, challenges maintaining a conversation about a topic of another's interest, and echolalia, which is the repetition of words and phrases spoken by others. Third, individuals on the spectrum may exhibit unconventional behaviors or atypical emotional responses in various situations. They may be focused on the parts of an object (such as wheels of a toy car) rather than the whole object (the toy car). Other behaviors may include lining up toys in a certain order or playing with those toys in an identical way every time. Children with ASD can also develop "idiosyncratic strategies for self-regulation," which may include chewing on clothing, spinning, rocking, or hand flapping, among other behaviors (ASHA, n.d.a, Signs and Symptoms section). These strategies help autistic individuals feel as if they have more control of their emotions and can also work to block out certain overwhelming stimulation. Small deviations in routine or particular sensations, however, can still be difficult to undergo and can produce extreme emotional reactions.

In addition to these common symptoms, individuals with autism often are diagnosed with other health conditions or disorders, such as attention deficit hyperactivity disorder (ADHD), depression, anxiety, and epilepsy. Other co-occurring conditions may include eating disorders, sleep disorders, gastrointestinal issues, and a "lack of fear or more fear than expected" (Centers for Disease Control and Prevention, 2022a, Other Characteristics section). Children with ASD also likely experience delayed movement, language, and cognitive skills.

These delayed speech and language skills can often manifest in spoken language disorders, written language disorders, and speech sound disorders. A core language difficulty for children with ASD involves pragmatics, as children on the spectrum "show limited use of language in social context" (Mody & Belliveau, 2013, p. 159). This could result in challenges involving taking the perspective of another child or recognizing a peer's distressed mental state, for example. Structural language has also proved difficult for some children with ASD, mostly in terms of phonology and morphosyntax. Although these impairments are not universal across the entire ASD population, they are prevalent. Prosody, which includes patterns of rhythm and intonation in a person's speech, is another area that presents challenges for those with ASD. The prosody of autistic individuals is often described as "unusual" or "deviant;" this means that any variations in duration, intensity, or pitch are often atypical and rarely used to enhance communication (Schaeffer et al., 2023, p. 439). When impaired prosody occurs, such as abnormal intonation or stress, a conversation partner may misunderstand the autistic child's attitude or interpret the statement incorrectly due to hearing atypical emphasis. In any alteration of prosody, it becomes more difficult for a conversation partner to understand the autistic child's message. These speech and language impairments can contribute to the overall social communication deficits of individuals on the autism spectrum.

Role of the SLP

The speech-language pathologist (SLP) plays a key role as a member of an "interdisciplinary team" that is able to collaborate in order to screen, assess, and diagnose ASD (ASHA, n.d.a, Roles and Responsibilities section). SLPs can work together with these other professionals to design and implement a treatment plan to improve social communication of their client and modify behaviors so that person can learn how to function effectively in daily life. Other important members of this diagnostic team may include but are not limited to occupational therapists, teachers, social workers, psychologists, and physicians. Speech-language pathologists are an integral part of this collaboration because they can develop speech and language goals for their autistic clients that relate to social language and literacy. SLPs can also assess a client's need for an augmentative and alternative communication (AAC) device and provide training in the use of that device. Additionally, it is within the scope of practice for speech therapists to assess and treat any feeding issues, if there are any present. However, most clinicians, according to a recent research study that collected data from 258 clinicians in Ontario, Canada, "reported *always* or *often* targeting four skill development areas in intervention," including prelinguistic foundational social communication capacities, language, play, and pragmatics (Binns et al., 2022, p. 7). As indicated previously, these areas often are ones of great difficulty for those on the spectrum, so intervention by an SLP can often lead to positive outcomes and an overall improvement in social communication.

It is important to note a speech-language pathologist generally cannot independently diagnose someone with autism spectrum disorder, unless he or she has been explicitly "trained in the clinical criteria for ASD" and there is no interdisciplinary team available (ASHA, n.d.a, Roles and Responsibilities section). Even then, the SLP must have experience in diagnosing

developmental disorders, and still, they may not be qualified to diagnose ASD. Having an entire team is ideal because of the complex nature of the disorder and the need to differentiate ASD from any other medical conditions or disorders. Autism spectrum disorder also affects a variety of different functions in an individual, so expertise from a variety of disciplines is necessary. Therefore, having a group of skilled professionals work together is the best way to establish the highest quality of care for autistic individuals. Speech-language pathologists will likely often have an opportunity to be a part of this collaborative team, as children with suspected or diagnosed autism normally make up a large percentage of their caseload (Binns et al., 2022). SLPs can additionally be involved with autistic individuals beyond assessment and treatment, typically in the form of advocacy, administration, parent education, and research. Overall, the speech-language pathologist can play a crucial role in the life of an individual on the autism spectrum and provides an important perspective during a team's discussions about assessment and treatment plans.

Neurobiological Factors

Neurological Differences

Individuals with autism have many variations in the brain in terms of structure, function, and connectivity. These differences, along with a combination of other neurobiological, genetic, and environmental factors, are linked to the language and social communication deficits associated with autism. One of the most significant anatomical findings is the decreased white matter in autistic individual's brain when compared to their typically developing peers (Courchesne et al., 2001). This is concerning because white matter is responsible for "connect[ing] neurons in different brain regions into functional circuits" (Fields, 2010, p. 768). With less white matter, the higher chance of altered connectivity in the brain. When these

connections between regions such as the posterior inferior frontal gyrus and the posterior superior and middle temporal gyri are affected, language difficulties may ensue. Additionally, the white matter that *is* present in an autistic individual's brain often has an "abnormal microstructure" (Wan & Schlaug, 2010, p. 800). When the language regions of the frontal and temporal lobes contain this atypical white matter, deficits of language may result. Social communication and pragmatic difficulties in those with ASD also may arise due to differences in the brain's white matter. Researchers Maria Mody and John Belliveau (2013), for example, noted that diffusion tensor imaging found that those with autism exhibit lower fractional anisotropy, a measurement of the integrity of white matter, in the anterior cingulate, which plays a role in empathy, emotion, and making decisions, and the temporoparietal junction, which also relates to empathy and perspective taking. These discoveries shed light on just one of the factors that may be related to communication challenges that those with autism experience.

Other studies have found anatomical and physiological differences in the cerebellum and the motor system in autistic individuals compared to those who are typically developing. In fact, according to Janzen and Thaut (2018), the "abnormalities in the structure and function of the cerebellum are associated with impaired neurobehavioral function" (p. 7). Research by Bolduc and his colleagues (2012), for instance, highlighted that reduced vermis volume is linked to deficits in cognition, expressive language, and behavioral issues; these individuals are also more likely to score high on autism spectrum screenings. Moreover, vermal lobules VI-VII, which are often found to be smaller in autistic individuals, are connected to decreased "visuospatial exploration" and increased "stereotyped motor movements," a few of the distinct characteristics of those on the spectrum (Pierce & Courchesne, 2001, p. 655). These findings indicate that altered aspects of the cerebellum may help explain the deficits in communication and repetitive

behaviors, both key aspects of the autism diagnosis. Other studies note that in autistic individuals, there are “disconnections in sensorimotor and cognitive functions” (Sharda et al., 2018, p. 240), as well as disruptions in motor timing (Geretsegger et al., 2022), which result in social communication and interaction difficulties for those on the spectrum. The cerebellum plays a key role in this motor coordination and timing. Typically, this part of the brain helps to establish “sensory prediction errors,” allowing for “rapid adjustments in the motor output and refinement of future sensory predictions” (Janzen & Thaut, 2018, p. 7). Therefore, when there are abnormalities in the cerebellum, the prediction mechanism is impaired, causing slower, more inaccurate responses, as well as periodic movements. These functional differences contribute to many of the common symptoms that those on the autism spectrum experience daily.

In addition to the abnormalities described above, research has shown differences in the autistic brain’s network and connections, especially between the hemispheres. Toddlers in one neuroimaging study, for example, had “reduced or reversed laterality patterns” (Mody & Belliveau, 2013, p. 163). This is likely due to corpus callosum impairments, the two brain hemispheres functioning more independently of one another, and the “atypical right-hemisphere network” (Persichetti et al., 2022, p. 9045). It is important to note, however, that not all autistic subjects’ symptoms and characteristics can be explained by a model of brain disconnectivity. A more complete explanation is illustrated by the results of a study by Lai et al. (2012), which found reduced activation to speech stimulation in the “left inferior frontal gyrus and secondary auditory cortices in the left temporal lobe” in autistic subjects (p. 971). Their findings suggest that reduced activation of these areas during speech could be associated with the failure to receive language-specific information from impaired lower-processing regions instead of disconnection of the whole system. In another brain structure study, researchers “revealed a

rightward asymmetry of the pars opercularis and pars triangularis," which are parts of the inferior frontal gyrus (Mody & Belliveau, 2013, p. 161). In fact, when the left hemisphere fails in its language specialization role in autism, the result is this rightward asymmetry. This may also produce social language deficits in areas such as prosody by "crowding it out from its rightful place in the right hemisphere" (Mody & Belliveau, 2013, p. 163). Lastly, neuroimaging studies have shown altered minicolumns in the ASD brain. In autistic individuals, these structures are often thinner and more numerous, which essentially favors shorter connections (Mody & Belliveau, 2013).

Language and Music Pathways in Typical People

Language Processing. Language processing and production involve multiple regions of the brain that information must transfer between in order for the action to be complete and effective. The classical model of language organization focuses on Broca's area in the inferior frontal gyrus and Wernicke's area in the superior temporal gyrus. Whereas Broca's area is believed to have a central impact on "planning and executing speech and writing movements," Wernicke's area emphasis is on "analysis and identification of linguistic sensory stimuli" (Binder et al., 1997, p. 353). Further research, however, has found that although these areas are important for expressive and receptive language, other areas in the frontal, temporal, and parietal lobes of the brain also have a significant involvement with language. This network of regions typically has a "left lateralization," which means that language processes tend to be specialized to the left hemisphere of the brain as opposed to the right (Friederici, 2011, p. 1357). According to fMRI results, these additional brain regions that are activated during language processing tasks include the middle frontal gyrus and most of the inferior and superior frontal gyri in the frontal lobe; the superior temporal sulcus, middle temporal gyrus, and inferior temporal gyrus in the temporal

lobe region; the angular gyrus in the parietal lobe; portions of the anterior and posterior cingulate in the limbic system; and the right posterior cerebellum (Binder et al., 1997). Beyond these specific language areas, the motor and premotor regions are also important for language production and the sensory input systems (for both hearing and vision) are important for language perception (Friederici & Gierhan, 2012).

Although these brain regions all play a role in efficient language processing, the way that these regions are connected to each other is essential in order for the action to be complete. The two dorsal and two ventral pathways guarantee that there is a transfer of language information by connecting both the "prefrontal and temporal language-relevant regions" (Friederici & Gierhan, 2012, p. 250). The dorsal pathways support the processing of complex sentences and auditory-to-motor-mapping, which involves linking sounds to articulatory actions. One such dorsal pathway is the arcuate fasciculus (AF), which may also overlap with the superior longitudinal fascicle (SLF). According to Wan and Schlaug (2010), in addition to connecting the "frontal motor coordinating and planning centers with the posterior temporal comprehension and auditory feedback regions," the AF might link Broca's and Wernicke's area as well (p. 801). The ventral pathways, on the other hand, help further semantic and more basic syntactic processes. This pathway is composed of the extreme capsule (EmC) and uncinate fasciculus (UF) tracts, which are fiber bundles that connect parts of the temporal lobe to brain areas such as the inferior frontal gyrus and prefrontal cortex that play a major role in "mapping of sound onto meaning" (Wan & Schlaug, 2010, p. 802). This brief overview of brain areas and pathways that are involved in typical language production and processing highlights the complexity of these activities. It also draws attention to the fact that when even the slightest changes in the anatomy and physiology of

those regions occur, there could be major consequences, affecting that individual's ability to understand and express language.

Music Pathways. Music is a complex acoustic signal made up of many separate components, such as form, pitch, rhythm, melody, timbre, harmony, and dynamics. All these elements are woven together to create a pattern, which people perceive as music. The perception of the musical pattern is ruled by Gestalt laws of perception, which include organizational principles such as proximity, similarity, simplicity, common direction, and closure. The last two principles, for instance, are at work when individuals hear melodies as "moving in a common direction toward completion" (Lim, 2010, p. 4). Music processing has also been shown to have a modular structure, rather than a hierarchical one. Flohr (2010) describes this module theory, discussing how music engages multiple brain areas independently in a coordinated but not sequential activity. Based on this description, music experiences activate various submodules, such as timbre operators and rhythm operators, in regions throughout the brain. The regions that are commonly activated during such musical experiences are Broca's area, primary and secondary auditory cortices, the temporal cortex, and the primary motor cortex. There are additional areas activated during the processing of other specific components. For instance, with rhythm, the right anterior superior temporal gyrus (STG) and cerebellum play an important role, whereas with musical memory, the dorsolateral and inferior frontal areas are essential (Hernandez-Ruiz, 2019). Even lengthened musical training appears to involve different brain regions, producing "enhanced structure and function of the motor cortex, cerebellum, and corpus callosum" in musicians (Hernandez-Ruiz, 2019, p. 320). Essentially, experiencing and processing music involves many cognitive processes, which have been shown to be activated independently but in an interconnected manner.

Music's Potential in Intervention

According to previous research, musical abilities may be enhanced or relatively spared in individuals with autism. Researcher Hayoung Lim, for instance, states that "children with ASD recognize the different characteristics or organizations of musical patterns," and they are often able to produce well-organized musical patterns, even if they are rhythmically complex (Lim, 2010, p. 4). This information is significant, Lim notes, because perceiving music, speech, and language all require listeners to recognize patterns and group auditory information categorically. Speech and language also share several technical aspects with music, as they are structured (as evidenced by phonological, morphological, and syntactical rules), ritualized (as they involve fixed patterns of speech motor actions or language use), and to some degree metric (especially when purposefully producing rhythmic speech). When people with ASD have difficulties in speech and language areas of the brain but their musical abilities remain intact, it, therefore, makes sense that similar but "alternate mechanisms of speech processing may be recruited in individuals with ASD through singing" (Janzen & Thaut, 2018, p. 2). Also, children with ASD often acquire language through Gestalt processing, which means they will learn a "chunk" or memorized phrase first rather than an individual word. Musical interventions that involve Gestalt processing, therefore, have increased potential because they build off an autistic individual's intact processing ability.

Furthermore, the physiology of an autistic brain can help explain why several individuals with ASD have musical strengths. As an illustration of this concept, Sandiford et al. noted that individuals with autism typically have lower than normal activation of the left hemisphere. If the right hemisphere in ASD is "relatively spared," then it may be the case that "right hemisphere functions such as rhythm and melody can serve as areas of strength and sources of compensatory

activity" (Sandiford et al., 2013, p. 1299). This idea of music being "spared" is illuminated by a study where those with autism were "just as likely to pair fragments of major mode music with happy faces and fragments of minor mode music with sad faces as were age- and intelligence-matched controls" (Heaton, 2009, p. 1445). These results convey that children with ASD understand the emotional connotations of music, a fact that could later be helpful during treatment of social interaction and communication deficits.

Those with autism also frequently demonstrate expanded sensitivity to musical pitch and timbre. Enhanced pitch memory, specifically, may be a result of increased early attention to the "pattern-rich, highly structured domains" of music (Heaton, 2009, p. 1446), making the musical experience more rewarding and memorable. The idea of using music as a reward also has neurological foundations, as the "cortical and subcortical circuits underlying affect & reward in individuals with ASD" are preserved (Caria, Venuti, & De Falco, 2011, p. 2846). If music is used in a therapy setting, it has the potential to generate emotional responses and activate this mesolimbic reward system (Hernandez-Ruiz, 2019), which may, in turn, alter clients' behavior so they are more likely to make progress grasping the targeted skills during the session.

Musical interventions, in addition, engage a variety of connected brain regions, including the temporal lobe and the posterior inferior and middle frontal regions, as well as the putative mirror neuron system. In fact, research has found that while "functional fronto-temporal connectivity" is disrupted during spoken-word perception in autistic individuals, the same network is "preserved during sung-word processing" (Sharda et al., 2015, p. 174). Music may then create more long-range connections between less active regions of an autistic client's brain, involving tracts like the AF, the EmC, and the UF, which are all believed to be involved in language and speech processing (Wan & Schlaug, 2010). Finally, the corpus callosum is often

impaired in autistic individuals, causing the two brain hemispheres to function more independently of one another. Schlaug et al. (1995), however, noted in their research study that in professional classical musicians, the corpus callosum is strengthened when starting musical training before age 7. This highlights the potential positive impact of music on the brain, which is why it may be helpful during intervention, especially if it is early intervention, for those with ASD.

How Music is Being Used in Therapy for Children with an ASD Diagnosis

Behavior

As mentioned previously, the neurological research supports including music in therapy to positively alter client's behavior and engagement, as well as promotes language acquisition in those with ASD. This is primarily due to articles highlighting the preserved musical abilities and an intact reward system in the autistic brain, as well as research that shows music can help form more long-range connections between language areas of the brain. Before discussing what this can mean for future music usage in speech-language therapy, however, it is first necessary to review how music is already being used in therapy sessions. The following information includes research from the fields of both music and speech therapy, in order to provide a full account of the ways in which music is being used to target language and social communication goals for individuals with autism.

Currently, music is being utilized in therapy sessions with children on the autism spectrum in order to increase enjoyment and, therefore, improve behavior both during and beyond the sessions. For most individuals, and especially those with profound and multiple learning disabilities, music tends to have the ability to produce arousing and emotional results. In fact, musical activities in Rushton and Kossyvaki's (2022, p. 35) recent study were shown to

produce a “calming and relaxing” effect that decreased the anxieties of children with severe disabilities, according to caregivers of those children, allowing them to remain more engaged and concentrated. This article takes results from parent questionnaires and interviews, focusing on how musical experiences in the home influence child behavior. Although this research was not specifically related to therapy sessions, the authors did note that in order to produce musical experiences, parents used a large range of resources obtained from participating in music groups and classes. Other music therapy studies have highlighted a similar behavioral effect in autistic individuals specifically, noting that music enhanced clients’ concentration, which allowed for improved language abilities (Hoskins, 1988). Buday (1995) also found that “music’s positive effect on sign and speech imitation” was influenced by increased attention and enjoyment of the musical intervention (p. 199). Music, in these instances, is being used in music therapy sessions to motivate children with ASD with the hope that keeping them engaged will allow them to reach some other communication or social interaction goal. Speech intervention, too, uses music to attract because music is something that individuals with autism appear to “intrinsically enjoy” (Wan et al., 2011, p. 1). In these examples, music is not being used to directly improve language skills but rather to captivate, comfort, and excite the child during music and speech therapy.

Music is not only being used to motivate and engage autistic children but also to reinforce adjusted behaviors and address problematic ones. First, music has been purposefully used as a reinforcement in various music therapy sessions by giving individuals the opportunity to listen to and play instruments (Farmer, 2003) and in co-treatment by music and speech therapists when they sing rather than read the client a book (Geist et al., 2008). In both instances, music is seen as a reward, encouraging children to produce target behaviors. On the other hand, in a systematic review of music therapy for individuals with ASD, two of the twelve studies

(Pasiali, 2004; Boso et al., 2007, as cited in James et al., 2015, p. 42) targeted decreasing undesirable behaviors such as “aberrant vocalizations, rewinding/fast forwarding video tapes, rummaging in the kitchen, or psychomotor agitation.” Various musical activities were utilized, including listening to music, drumming, singing, and piano playing. In another study, “original music was composed using the text of the social story [that addressed a behavioral goal] as lyrics” (Brownell, 2002, p. 117). Next, individuals could listen to the song, play instruments to keep rhythm during the song, and eventually sing along. These instances use music to explicitly target decreasing certain behaviors instead of utilizing music to engage or reward so that other targets might be reached.

Additionally, therapists incorporate music into therapy sessions in order to improve the independent functioning of autistic children, especially in terms of behavior. To produce this result, parents and music therapists provide structure through music, which helps those with ASD cope in changing situations and strenuous environments. According to Rushton and Kossyvaki’s (2022) survey, music is often used in the homes of those with profound and multiple disabilities to “add routine and structure to the day,” signifying when activities are occurring during the daily routine (p. 35). A similar idea was applied in a music therapy approach specifically for children on the autism spectrum, when a greeting song that outlined steps of the morning routine was written for each child in the study (Kern et al., 2007b). This intervention was further modified for one participant, eliminating the step in the song where the child said goodbye to the caregiver, as this often caused the child to get more upset. In this instance, music is being used to modify the actions and behaviors of the children so that they will be more capable of functioning in a self-sufficient manner appropriate to the environment they are in.

Musical improvisation is a music therapeutic technique that provides a unique way to accomplish this goal, as it "integrates clear structures that provide [autistic children] with an anchor and safety, alongside great flexibility" (Salomon-Gimmon & Elefant, 2019, p. 175). This may allow children with ASD to learn how to better cope in daily life, which is significantly more complicated, confusing, and unpredictable. Such a technique contrasts to the song-based musical interventions that are used to detail the step by step processes of washing hands, going to the bathroom, cleaning up, and performing a morning greeting routine, as described earlier (Kern et al., 2007b). In either case, however, music is being utilized to alter the behavior of those with ASD so that they are more able to function independently.

Communication

Language. One of the ways that music is being incorporated into speech therapy sessions with children on the autism spectrum involves attempting to increase clients' communication. The studies examined in this section specifically use music to target language (rather than speech), which ASHA defines as the comprehension and use of a spoken, written, or signed symbol system (ASHA, n.d.b). For instance, Sandiford et al.'s (2013) study utilized Melodic Based Communication Therapy (MBCT), which is a music-based speech therapy technique, to increase imitative attempts and verbal attempts or productions of the 25 target words, which were chosen "based on high frequency words children typically use first," as all 12 individuals in the study were nonverbal children with autism (p. 1301). The language learning process involved a type of scaffolding, which required the child to first listen to a recording of the word set to a unique melody while the therapist showed the stimulus item. The following details the exact sequence of steps taken:

> Therapy then progressed from listening to a recording of the word set to melody, to hand over hand clapping of the rhythm, to unison clapping of the rhythm, to independent clapping of the rhythm, to independent clapping of the rhythm while singing to the recording with the clinician, to singing with just the clinician while clapping, to singing with just the clinician without clapping, to singing while the clinician mouthed the word silently, to singing the word independently, to answering the sung question, 'What is this?' with the melodic version of the expected target word, to answering the spoken question, 'What is this?' with the expected target word. (Sandiford et al., 2013, p. 1302-1303)

If these target words were learned, the therapist guided the children towards two-word phrases that use the initially-targeted words. This highlights that the goal of the treatment was to expand the children's knowledge and use of the spoken symbol system of the English language, rather than only helping them form the sounds that make up the words. This intervention is just one way music is being integrated into speech therapy sessions to increase autistic children's language skills.

Hayoung Lim (2010) describes another attempt to increase communication with a specific technique called Developmental Speech and Language Training through Music (DSLM), which is another music-based speech therapy intervention. This study involved 6 composed songs and pictures of the 36 target words. The words that were targeted, such as "help," "all gone," and "eat," were selected based on usage by typically developing children. Each song was composed in a way that would allow individuals with ASD to distinguish patterns in pitch, note duration, and rhythms so that although the target words were emphasized in each lyric, the "combination of musical elements and target words was [still] perceived as a whole

unit" (Lim, 2010, p. 11). Once composed, the songs were recorded by a music student to guitar accompaniment and shown to children during the sessions by video; pictures of the target words were also presented as they were sung. Additionally, it is important to note that the target words appeared at the end of each lyric, as both the pre and post tests prompted the children to produce the word based on hearing the first section of a phrase. This practice is particularly interesting, as past music therapy research has shown that it is frequently possible to get children with limited verbal ability to "supply the missing words to a song they know by suddenly stopping the song and accompaniment at points of 'maximal tension'" (Shore, 2002, p. 104). So, by presenting these songs in a music video to autistic individuals (where 25 were considered high functioning and 25 were considered low functioning) two times per day for three days, the children come to learn not only the melodies but also the words. Because these targeted words expressed things such as "early semantic functions," "agreement of affirmation," and "internal states," the individuals with ASD were able to expand their ability to communicate (Lim, 2010, p. 10). In this intervention, music is, therefore, being used to increase the verbal production of children with ASD and expand their language abilities.

Vocabulary growth appears to be a common target in the use of music-based interventions. Allen and Heaton (2010), for instance, outlined a technique based on associative learning that focused on helping people with ASD and alexithymia (which is characterized by a difficulty with identifying and expressing emotions) to use language to convey their feelings during musical and non-musical experiences based on previously learned associations between music and emotions. Researchers Lim and Draper (2011) also conducted an experiment with autistic participants who were either verbal or pre-verbal that involved incorporating music with the Applied Behavior Analysis Verbal Behavior (ABA VB) approach. Throughout the music

sessions, outcomes such as naming instruments, singing with books, and completing songs functioned as target verbal productions. The study sought to determine if the integration of music into this traditional training was effective for the production of the four ABA verbal operants, which include mand, tact, echoic, and intraverbal (Lim & Draper, 2011). Each of these operants relate to language production, as they include requesting, labeling, imitating, and conversing.

In addition to music being used in therapy sessions to increase spoken language abilities, it is also being used to improve nonverbal autistic individual's abilities to use their augmentative and alternative communication (AAC) devices and hand signs. In one article published in *Exceptional Parent*, for example, author Murphy (2010) describes how eight-year-old Josh attended a "Music, Movement, and More" therapeutic recreational group, where structured music activities were used to help children on the autism spectrum and those with developmental delays break communication barriers. Participating in the group allowed the child to improve his ability to use his DynaVox V speech communication device. The buttons on his device, in fact, were a "visual and auditory complement to familiar props and activities" in his music therapy group (Murphy, 2010, p. 37). The "GymBop" class he participated in also combined music education with physical, occupational, and speech therapies, providing Josh with many communication opportunities. In fact, during this class, the students were the ones that drove the "lesson by choosing what to do next when prompted with verbal and visual cues" (Murphy, 2010, p. 38). By having so many chances to make choices and participate, increased communication is more likely to occur. In another music therapy study, music was used to increase the number of hand signs correctly imitated (Buday, 1995). This also targets language by providing individuals with ASD more tools (in this case, hand signs rather than words or phrases) they can use to get a message across.

Speech. In addition to targeting language abilities, music has been used in an intervention called Auditory-Motor Mapping Training (AMMT) to facilitate speech output in those with a diagnosis of ASD. In a study by Wan et al. (2011), for example, six children between ages 5 and 9 with "no or minimal vocal output prior to treatment" attended these music-based speech therapy sessions 5 times a week over an 8-week period (p. 1). During therapy, 15 items were trained, and they were all high-frequency words and phrases such as "mommy" and "more please" that were relevant to the participants and could be beneficial to use in their daily lives. The technique itself involved the therapist introducing the target words by singing the words while tapping a set of electronic drums tuned to a fixed pitch. The child listens during this initial step but then eventually is led towards repeating the vocalization and movement and finally producing the word on his own. This practice of engaging "both hands in rhythmic motor activity" while simultaneously producing the speech sounds helps to "facilitate auditory–motor mapping" (Wan & Schlaug, 2010, p. 803). The goal is then that the production of untrained words in these participants will also increase, since AMMT has helped them to associate sounds with "oral articulatory and motor actions" (Wan et al., 2011, p. 2).

This treatment overall seeks to teach autistic children how to approximate and produce speech sounds when provided with a model to imitate. Because all children were nonverbal and significantly language delayed, the fact that they learned how to "generate several words and phrases" over the course of the study means that their expressive *language* capabilities increased. The intervention itself, however, was primarily targeting *speech*, as the children were taught how to vocalize sounds and pronounce certain words. This is why AMMT is included in the speech section of this literature review. The therapy technique is, in fact, very motor-based, as the goal of the treatment was "acquisition of speech sounds and word approximations" (Wan et al., 2011,

p. 1) through music usage and motor activity. This motor activity "engages a sensorimotor network that controls orofacial and articulatory movements in speech" (Wan & Schlaug, 2010, p. 803). Therefore, although the training does involve trying to increase nonverbal children's communication skills, the immediate aim is to improve the children's ability to vocalize and produce word approximations, which creates a foundation for potentially future speech and language therapy. Overall, there is a lack of research in this particular area, as most musical interventions have been focused on engaging the child and promoting social interaction, rather than building the articulatory abilities of speech.

Social Interaction

A large portion of the studies using music to help those with a diagnosis of autism spectrum disorder are focused on improving or promoting social interaction. Using music in this way stems from caregiver or therapist concerns with autistic children's "lack of interactions" in the classroom and with their difficulty relating to peers (Geist et al., 2008, p. 313). An important goal, therefore, is increasing basic social communication skills, such as eye contact, joint attention, turn-taking, and initiating interactions. One specific music therapy study that focused on expanding peer interaction and participation for those with ASD involved adapting a playground so that it included a music hut with drums, other percussion instruments, and a CD player. The teachers were then trained to follow a "sequence of five steps: (a) entering the Music Hut with the child and at least one peer buddy; (b) initiating play, including both children on their level; (c) singing the unique song and playing the instruments in the Music Hut; (d) modeling the content of the song [...]; and (e) continuing to play in the Music Hut for 10 minutes at a time" (Kern & Aldridge, 2006, p. 279). The second intervention condition was peer-mediated rather than teacher mediated, where the goal was independent interaction in the music

hut between the autistic child and his peer. In another study in 2014, autistic individuals received music therapy intervention that consisted of structured group musical experiences where "participants shared an instrument" to promote cooperative play (LaGasse, 2014, p. 262). Both experiments included music in therapy in order to foster peer interaction during a shared musical experience.

Eye contact was also an important learned skill that was targeted with musical intervention, although it can be controversial. In the "Music, Movement, and More" therapeutic recreational group mentioned earlier, the children were able to "practice making eye contact while exchanging greetings" as the therapist sang "Little Sir Echo" in "classic call-and-response style" (Murphy, 2010, p. 37). By incorporating music into a therapy group such as this one, children can repeatedly rehearse this social skill due to the repetitive and imitative nature of the song. Improvisational music therapy, which typically involves less structure and more opportunities for the child to make choices, is another common way therapists are utilizing music to improve social interaction skills. In one music therapy research study, pre-school children with ASD went through 12 weekly improvisation sessions with goals of improvement in eye contact frequency and duration, which included any instance where the child looked at the therapist "while playing, manipulating, holding, touching toys, or instruments, or being engaged with the therapist in any way," as well as joint visual attention (Kim et al., 2008, p. 1761). Therefore, although targeting eye contact is disputed, using music as these researchers did could be applied to learning and practicing other nonverbal communication skills such as gestures, body language, and facial expressions. These studies, in fact, highlight how music is being used for its repetitive or engaging qualities to promote social interaction.

In addition to eye contact, turn taking is another common skill that therapists are targeting when they include music in their therapy sessions, as it is an important part of interactions with family, friends, and teachers. For instance, one therapist interacted with a child on the spectrum through singing songs and playing the guitar. The music therapy itself was focused on turn taking play with three toys, and at the end of the intervention period, the frequency of social responsive behaviors (eye contact, imitation, and turn taking) was calculated (Finnigan & Starr, 2010). Turn taking was also used in Vaiouli and Andreou's (2022) experiment with family-centered music therapy intervention. During these sessions, there was a period for parent-child music interactions and a period for therapist-parent-child music interactions. In both periods, the therapist encouraged the parents to be involved in turn taking, or "back-and-forth play" (p. 545). The process began with imitating the child's actions and then moved towards responding to the child's actions. The parents were taught to concentrate on the rhythm of the turn taking during the session. In this sense, music is again being used because it provides a unique context in which autistic children may be more likely to grasp the targeted social skills.

Moreover, music is included in therapy sessions in order to help children greet peers and adults. In the music and speech therapy co-treatment study by Geist et al. (2008), for example, one child with severe communication impairments participated in sessions led by a music therapist that targeted "greetings and increased engagement" during classroom activities (p. 314). It is important to note that this therapist collaborated with a speech-language pathologist as a part of the co-treatment model proposed by the researchers. During this co-treatment, one 3-minute "Hello" song gave the student 10 chances to practice a greeting by pressing "hello" on a voice output device at the appropriate times. Another music therapy study by Kern et al. (2007b) tested two individuals with autism spectrum disorder; the therapy supported peer interaction and an

increase in greetings, as individual songs were composed that outlined the steps of the "morning greeting/entry routine" in their classrooms (p. 1264). The goal was that the songs could be used to make separating from the caregivers easier and less stressful for the children. Here, although there was a behavior component to the targeted end result, the primary target was improving the social interaction of the greeting.

Because music has "relational aspects," it is also being used to help foster relationships between the child and their peers, their therapist, and their caregivers (Geretsegger et al., 2022, p. 21). In a survey, for example, parents of children with profound and multiple learning disabilities "described the ways in which music 'helped the relationship' [...], facilitated 'moments of connection' [...], provided opportunities for communicating and was something they could 'all get involved in' [...]" (Rushton & Kossyvaki, 2022, p. 37). Essentially, listening to and making music at home strengthened the relationship between parent and child. A similar idea is being used with autistic individuals in actual therapy sessions for the purpose of "fostering the ability to experience, maintain, and eventually enjoy interpersonal relations" (Salomon-Gimmon & Elefant, 2019, p. 184). Often the interventions used involve providing the autistic child with opportunities to make choices and begin contact with an adult. A therapist using Improvisational Music Therapy (IMT) targets the goal by "musically, vocally, and emotionally attun[ing] to the client's vocalizations and behaviors" during these periods of choice-making that parallel the interaction between mother and infant (Salomon-Gimmon & Elefant, 2019, p. 176). Therefore, music in this instance is being used to help individuals with ASD increase their social interaction by promoting the formation of relationships.

There is a wide variety of studies that focus on family-centered intervention, which often targets social interaction by building a stronger relationship with the parent or caregiver.

Thompson, Mcferran, and Gold (2014), for example, discuss an approach where parents are urged to participate actively in home-based music therapy sessions and to collaborate with the therapist in songs, improvisation, and "movement to music" (p. 843). Creating these engaging episodes between parents and their autistic children helps produce "mutual enjoyment and feelings of togetherness" (Rushton & Kossyvaki, 2022, p. 38). Having these shared musical experiences, therefore, helps form relationships and produces more moments of social interaction, which also gives those with ASD more opportunities to practice turn-taking and joint attention skills, which are the foundations of language. Other studies indicate the importance of parent involvement during and between the music therapy sessions. Parents are "experts" on their children and can help therapists or teachers understand their child's preferences, dislikes, strengths, and weaknesses, making the sessions or lessons more productive (Shore, 2002, p. 100). When parents or caregivers provide this type of information in addition to being active participants during therapy, more interactive patterns of musical play ensue. This was the goal of Vaiouli and Andreou's (2022) recent study, where a 40-minute intervention session was divided into two parts: parent-child improvised music making and therapist-parent-child music interactions, where the music therapist introduced a relevant music activity and modeled participation. Each of these family-centered interventions focused on the objective of increasing connections and growing the bond between parent and child.

Lastly, there was one music therapy study that concentrated on the encoding and decoding of happiness, sadness, anger, and fear. In the experiment, one condition involved improvised piano music that referenced a certain emotion while the therapist was providing verbal instruction for that specific emotion. In another phase of the study, therapists taught the "selected emotion by singing specially composed songs about the emotion" (Katagiri, 2009, p.

15). Both conditions had the goal of improving the emotional expression and understanding of the 12 participants, who were autistic individuals with a mean age of 11.5 years. If this skill is gained, it could in turn affect social interaction. Being able to communicate emotions and also comprehend the emotions of others may help build empathy and perspective taking, leading to moments of "emotional synchronicity" (Kim, 2006, p. 130), "reciprocal emotions" between parent and child (Thompson, 2012, p. 170), and more "spontaneous social engagement" by the client (Stephens, 2008, p. 645). Although there is not much research on the ways in which music is used to teach emotional understanding to those with ASD, the study by Katagiri (2009) does elucidate two possible avenues of incorporating music to achieve this goal. Additionally, this, in combination with the other studies discussed in this section, reveals there is a plethora of information regarding the various types of intervention that are used to promote social interaction and improve relationships between those with autism spectrum disorder and their peers, therapists, and caregivers.

Attention and Motor Control

Although most of the research up until this point has focused on incorporating music into therapy sessions in order to improve behavior, communication, and social interaction, there is a fourth area that is starting to gain more traction. For example, in one article, researchers Janzen and Thaut (2018) work to expand the clinical scope of practice by suggesting music-based training that targets attention and motor control. They are promoting this shift in thinking because of new research that provides evidence that says "impaired motor functions in ASD are strong predictors of core social, communicative, and behavioral features of autism" (Janzen & Thaut, 2018, p. 6). Moreover, difficulties in attention can lead to having issues with turn-taking in conversation or in other social communication. When these ideas are combined with research

evidence, it becomes clear that motor control and attention impairments are both strongly "implicated in the healthy neurodevelopment of socio-communication skills," according to Janzen and Thaut (2018, p. 1). By targeting these motor and attention systems during intervention, therapists may be able to better improve outcomes for those on the spectrum. One way to target such systems is by using Musical Attention Control Training, a music therapy technique that was used with 9 high-functioning adolescents with neurodevelopmental delays by Pasiali, LaGasse, and Penn (2014). The reason they chose this goal was because children with ASD commonly have trouble filtering out irrelevant stimuli (selective attention) and switching between information in the environment (attentional control/switching).

Specifically, the MACT sessions included drumming/rhythm exercises, structured/unstructured improvisation, singing chants, and using body percussion, among other musical activities. The intervention incorporated these musical experiences in a way that required sustained attention, selective attention, and attentional control/switching. To target sustained attention, children were required to "focus their attention on a changing music stimulus," such as when the researcher modeled "rhythm patterns the students had to echo," whereas for selective attention, the children "had to focus on single musical cues while ignoring other stimuli" (Pasiali et al., 2014, p. 344). An example of this intervention included the researcher modeling a musical pattern the student had to continue playing on their instrument when the researcher eventually switched to free improvisation. Lastly, to target attentional control/switching attention, the children were given opportunities to participate in complex musical experiences, such as "chanting while doing body percussion," that required them to pay attention to two auditory sources at the same time (Pasiali et al., 2014, p. 345). Ultimately, this new research discusses a change in the way music might be used in speech therapy sessions for

those with a diagnosis of autism spectrum disorder. It is important to note that joint attention, a skill that was mentioned in the social interaction section of this paper, was not included in this area because of the highly relational focus of joint attention, which links it more intricately with social interaction. The attentional targets described here also differ from what was described in the behavior segment because those therapists' goals were to motivate their clients to pay attention and remain engaged in the session in order to help them achieve another communication or social interaction target. Overall, MACT aims to use music to explicitly target sustained attention, selective attention, and attentional control/switching attention so that those with ASD can exhibit improved attention not only in the session but beyond.

One way to target motor skills while also including music comes from a speech intervention that has been discussed previously: Auditory-Motor Mapping Training (AMMT). The technique centers on the therapist singing a word while tapping a pair of drums tuned to the corresponding pitches of the singing. This highly-structured intervention begins with the children listening and later with them participating by attempting a vocalization and tapping the drums to "facilitate bimanual sound-motor mapping" (Wan et al., 2011, p. 3). The auditory rhythmic cues in this training can essentially entrain motor responses, which allows therapists to use rhythm to "prime the motor system and re-program the execution of a motor pattern" (Janzen & Thaut, 2018, p. 9). Therefore, it is clear that in this treatment, music is being used to not only target speech sounds but also to activate "frontoparietal motor-related areas" (Wan et al., 2011, p. 2). These are the areas that are engaged during a motor action and also when viewing or listening to others complete that same action. Overall, MACT and AMMT both utilize music to help target attention and/or motor skills, based on the idea that making progress in these areas during early

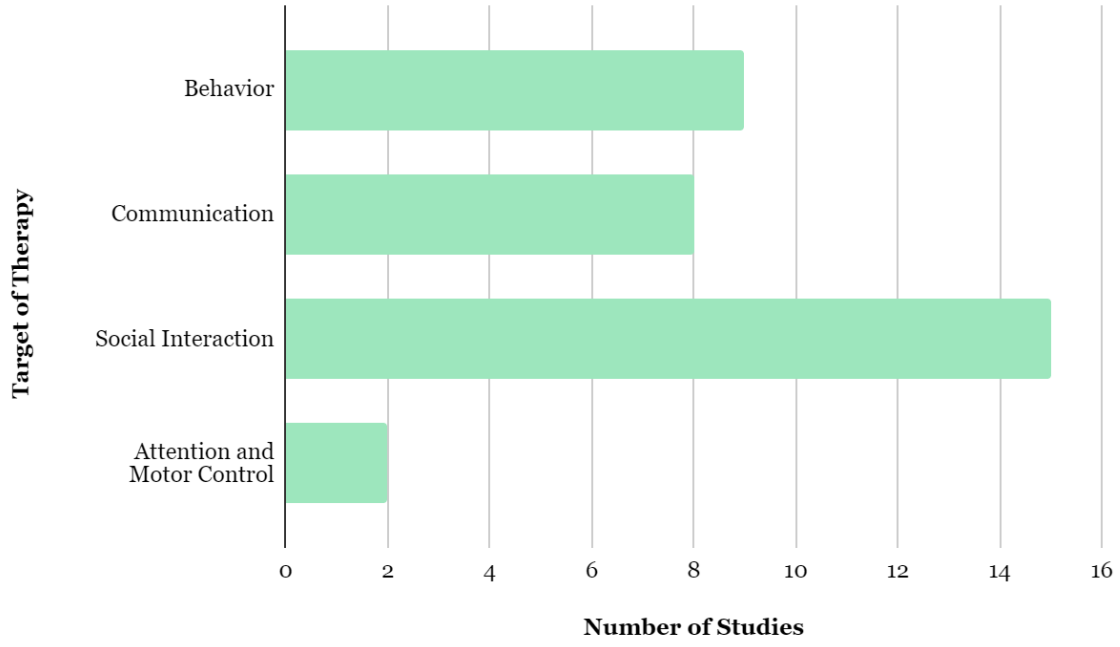
development can help those with ASD make improvements in behavior, communication, and social interaction.

Results

Very few studies have used music in therapy for its inherent structure or for its ability to strengthen language areas and increase connections throughout the brain (Wan & Schlaug, 2010). Rather, the research focused on using music to improve social interaction, as it provided an experience autistic individuals could bond over with caregivers, peers, or the therapist. Most often, music was used to grab the attention of the clients and keep them engaged and excited so that the therapists could improve behavior during the session or target some other skill. This comes from the idea that music activates the mesolimbic reward system (Hernandez-Ruiz, 2019). To view the number of studies included under each targeted skill, see Figure 1. Also, this review reveals that there has been much more research on music therapy techniques for those with ASD than on music integration in speech therapy sessions. For example, systematic reviews by James et al. (2015) and Geretsegger et al. (2022) provided a wealth of information about music therapy interventions that were used to target behavior, communication, interaction, attention, and motor control skills. There have also been, however, a few studies, such as Lim's (2010) study on DSLM and Sandiford et al.'s (2013) study on MBCT, that have directly compared speech and language training with music to more traditional speech and language therapy. Including articles with both music therapy and speech therapy focuses was necessary to provide a full snapshot of the current ways music is being used to target skills that an SLP would be targeting while working with someone on the autism spectrum.

Figure 1

What Skills Music is Being Used to Target in Individuals with ASD



Note. This chart illustrates how many studies on music or speech therapy interventions were included in each category.

This study primarily focused on describing and analyzing how music is used in speech and music therapy sessions for children with autism spectrum disorder, as well as identifying the anatomical and physiological constructs that support the inclusion of music in speech-language therapy sessions. The articles that were reviewed included studies with a wide range of participants, both in terms of age and level of functioning. Some were nonverbal, such as the 5 to 9 year olds in the AMMT study by Wan et al. (2011), the 3 to 6 year olds in the family-centered music therapy intervention in Vaiouli and Andreou's study (2022), and 8-year-old Josh in the article by Patti Murphy (2010). Other participants were preverbal or verbal but low-functioning, such as half of the 3 to 5 year olds in Lim's DSLM study (2010), whereas others were high-functioning autistic individuals, such as the 13 to 20 year olds in Pasiali et al.'s MACT study (2014) and the other half of the 3 to 5-year-old children in Lim's study (2010). In each of these

studies, the participants were limited to children and adolescents, which means that the results that follow are not applicable across populations of autistic individuals, especially those past the young adult age.

Overall, there has been a wide variety of musical interventions studied and presented in the current literature. Some of the interventions that have been tested are music therapy techniques that target behavior, communication, social interaction, motor control, or attention. The fact that these interventions are explicitly targeting these skills and abilities indicates that it may be within an SLP's scope of practice to utilize some of these same interventions, as long as they receive any additional training that may be recommended or required. In MACT, for example, 9 participants completed 6 weeks of Musical Attention Control Training, which involved a variety of different musical experiences like structured drumming, where the participants had to follow "verbal and nonverbal cuing for mirroring patterns, changing dynamics, improvising or performing specific patterns" that were assigned by the therapist (Pasiali et al., 2014, p. 344). In every session, these musical tasks were used to promote sustained attention, selective attention, and attentional control/switching attention. Other interventions examined were specifically related to speech and language therapy, although some still included input or treatment by a certified musical therapist. These interventions include DSLM, MBCT, AMMT, as well as the GymBop class that 8-year-old Josh participated in, as it combined music education with speech, occupation, and physical therapies.

In each of these interventions, music was used to help ASD clients improve in one of four central categories: behavior, communication, social interaction, or attention and motor control. To accomplish these goals, a wide variety of musical procedures and structures were used. Improvisational therapy, where the therapist and client work together to spontaneously produce

sounds or music, was one technique therapists used to "attract and engage the child" in order to improve behavior and keep their attention during the session (Salomon-Gimmon & Elefant, 2019, p. 175). The technique was also utilized to improve social interaction skills, such as turn taking and joint attention, and foundational language by dividing the improvisation session in half. The first half was client-led, which means the therapist supported and followed the child's lead during musical play. The second half was clinician-led, which meant the therapist "introduced modeling and turn-taking activities," while continuing to encourage the child to create sounds and music in the moment (James et al., 2015, p. 50). Overall, improvisation gives autistic children a chance to create new vocalizations and produce a variety of pitches and rhythms, which allows them to experience themselves as "the creator of [their] own actions" and paves the way for them to "grasp the presence of the 'other' and address him" (Salomon-Gimmon & Elefant, 2019, p. 184).

In contrast to musical improvisation, other interventions relied on structured musical tasks. Melodic Based Communication Therapy, for example, involved pre-recorded melodies specific to the target words and clapping of each rhythm. There was a clearly defined list of steps for the therapist to guide their client through in order to go from listening to the recording of the word set to melody to singing and later speaking the target word in answer to a question (Sandiford et al., 2013). Similarly, with Auditory-Motor Mapping Training, therapists lead a child from listening to eventual production of the target word on their own. Rather than listening to a recording, however, children are taught to sing the words on two pitches while tapping the tuned drums in front of them (Wan et al., 2011). Hence, although the musical experiences were different in MBCT and AMMT, each provided a structured way of incorporating music into sessions to help improve the communication of individuals who are on the spectrum.

Often, these musical experiences involve originally-composed songs that were related to the behavior or communication being targeted. In the study on Developmental Speech and Language Training, for instance, the investigator composed six songs, each in a "distinctly different style," where each lyric ended with one of the 36 target words (Lim, 2010, p. 11). In this instance, even though the sessions were speech and language based, a music therapist developed the songs. A similar study "consisted of singing the verbal instruction" during music ABA VB training; the music therapist arranged "musical elements within the songs" in a developmentally appropriate way and included target words or phrases in each song lyric (Lim & Draper, 2011, pp. 537-538). Original songs or songs with altered lyrics were also utilized in a study that sought to help autistic individuals learn self-care tasks such as hand-washing, toileting, and cleaning up (Kern et al., 2007a). Although the first two studies targeted language and the last targeted behavior, all three articles highlight how musical structure is being used in therapy sessions for those with ASD.

Frequently, music was used in therapy that was focused on relationships, either between the client and their peers, the clinician, or their caregivers. In each of these cases, social interaction was the overarching target of the session. Shore (2002) especially emphasized the importance of caregiver involvement in regards to reaching this goal, stating that "lessons give them another way to relate to their child" (p. 100). Not only that, but by including the caregiver or parent in weekly sessions, therapists can give them the tools to do more work with the child in between sessions, creating a stronger likelihood that the interaction skills the child is learning in therapy will carry over at home, school, and other social environments. This idea of the therapist having a "co-leading role" with the caregivers appears in other studies as well, such as Vaiouli and Andreou's (2022, p. 543) research, where the therapist models "ways to expand and assign

communicative meaning on the child's actions" during therapy. Modeling, as mentioned here, also is a common way for music to be integrated into therapy sessions, both in an improvised setting like this one and also in a more structured, intensive setting such as AMMT, where autistic individuals learned how to vocalize speech sounds when repeatedly provided with a model. Overall, this review of the current literature indicates that there is a wide variety of ways music is being incorporated into therapy sessions, all in order to improve behavior, speech, language, social interaction, attention, and/or motor skills of those with ASD.

It is essential to clarify the type of communicative tasks that music is being used for in these speech and music therapy sessions. In a few of these interventions, music is employed so that autistic individuals can simply practice a word, phrase, behavior, or social interaction skill. Such was the case in the Music, Movement, and More therapy group, where children with ASD participated in a call-and-response song that allowed them to "practice making eye contact while exchanging greetings" (Murphy, 2010, p. 37). Here, the communicative task was decontextualized, as music was utilized simply to engage the children and give them a chance to rehearse practiced greetings with eye contact. In other studies, however, music was used in a functional way. Children learned words and phrases, such as "all done," "look," and "again," that allowed them to communicate their needs and wants. In Lim's (2010) Developmental Speech and Language Training Through Music, songs were specifically designed to target these chosen words that, once learned, would allow children with ASD to "express early semantic functions," request assistance or affection, and describe a common environment (p. 10). In this sense, music is being used for its inherent properties to teach autistic individuals how to functionally communicate and navigate in daily interactions.

Another significant result of this research was the analysis of the neurological basis behind music's inclusion in therapy for autistic individuals. To understand the following reasoning, it is important to understand that language is processed in the left hemisphere. In fact, the primary support for the integration of music in therapy comes from the knowledge that the left hemispheric language abilities tend to suffer in those with ASD, whereas the right hemisphere of autistic individuals tends to be spared, and musical abilities of those individuals are often preserved. Therefore, right hemisphere functions such as melody, rhythm, and pitch have the potential to be areas of strength for those with autism, especially when it comes to processing and producing language. Additionally, the dopaminergic mesolimbic system, or the reward system, is often preserved in those with ASD. This system is composed of brain structures like the prefrontal cortex, amygdala, and hippocampus that are "responsible for mediating the physiological and cognitive processing of reward," a natural process where the brain associates stimuli with a positive outcome (Lewis et al., 2021, p. 57). This reward network can then affect attentional networks, making it more likely that someone remains engaged in the experience at hand. As a result, when music is incorporated into therapy sessions, the mesolimbic system is often activated, keeping autistic individuals captivated by the musical activity so that the therapist can target behavior or attention.

Finally, musical interventions have potential to help improve the skills of those with ASD because music engages the mirror neuron system (MNS) and the frontal and temporal regions of the brain, as well as the tracts between those regions. For someone with autism, these systems, regions, and tracts are often dysfunctional, abnormal, and asymmetrical. Many studies have proposed that these are the differences in an autistic individual's brain that may "underlie the communication deficits in ASD" (Wan et al, 2011, p. 2). Because music has been shown to alter

the “responses in the MNS,” activate the “inferior frontal regions” during both music perception and active music tasks, and increase the fiber number and volume of the AF, it is possible that music does indeed have the potential to strengthen areas and connections throughout the autistic brain (Wan & Schlaug, 2010, p. 803). This, in turn, may produce a positive impact on the individual’s communication and social interaction skills.

Discussion

Roles and Responsibilities

The aim of this study was to investigate how music was being incorporated into music and speech therapy sessions that targeted speech and language therapy goals for autistic children. It also sought to determine what anatomical and physiological constructs support the inclusion of music in therapeutic interventions for those with autism spectrum disorder. First, treating autistic individuals is within a speech-language pathologist’s scope of practice. According to ASHA, one of the SLP’s responsibilities when working with autistic individuals involves developing and targeting “speech and language goals focused on social language and literacy, and assisting the student with self-regulatory and social interactive functions” so they are able to better function in everyday life and more fully participate in mainstream curriculum (ASHA, n.d.a, Roles and Responsibilities section). In this review, it was found that music was used in therapy sessions to target 4 central categories of skills: behavior, communication, social interaction, and attention and motor control skills. Each of these categories fall into the realm above that describes what a speech-language pathologist can treat. Some may argue that the attention and motor control skills category does not explicitly relate to speech-language pathology goals. This, in fact, is a relatively new way of incorporating music into therapy sessions for those on the spectrum. SLPs should be interested in supporting development in this category because attention is intricately

related to an individual's ability to take part in social communication, so when there are deficits, that individual's ability to "attend, engage, reciprocate, and learn" are all significantly affected (Janzen & Thaut, 2018, p. 7). Targeting motor control is also within an SLP's scope of practice because an individual with ASD needs to be able to have control over their motor movements, not only for behavior and interaction purposes, but also for speech. The research in this area tends to focus on auditory-motor tasks, such as those found in AMMT. This therapeutic intervention uses motor movements of the hands as well as the musical component of pitch. Then it goes one step further, matching both of those with motor actions of the articulators so that children with ASD are eventually able to produce the target words. Overall, the interventions discussed in this paper are relevant to those in the field of speech-language pathology because of the skills they are targeting.

Connections to Music Therapy

It is important to note that although most of these interventions are musical tasks that are being incorporated into speech and language therapy, others are music therapy techniques that simply target the same skills (behavior, communication, social interaction, attention/motor control) that an SLP might also be treating in an individual with ASD. This means that many of these interventions require the specialty of a music therapist, as they have the "skills and clinical training" needed to create "developmentally appropriate music-based experiences" that target the skills an autistic child needs to gain (Pasiali et al., 2014, p. 338). Because of the neurological research that shows music's potential to help those with autism, it makes sense that musical therapists, with their expertise in music, should be more frequently involved in treating those with autism. In fact, common aims of music therapy for young children generally include producing "changes in a child's behavior" and facilitating "development of his/her

communication, social/emotional, sensori-motor, and/or cognitive skills" (American Music Therapy Association, Inc., n.d., p. 1). An autistic individual often needs assistance in one or multiple of these areas. Many of these skill areas can also typically be targeted by SLPs. The difference is that music therapists rely on musical experiences as the main "forces of change" to help promote health and increased quality of life in their clients (Geretsegger et al., 2022, p. 9).

If it is possible, co-treatment by both a music and speech therapist may be a beneficial way to help autistic individuals achieve their communication and interaction goals. Co-treatment involves both therapists assessing the child and discussing the best treatment plan based on the assessment results. During treatment, musical strategies such as breathing and vocalization exercises, song articulation experiences, and vocabulary and concept development singing, may be incorporated in speech therapy sessions (Geist, et al., 2008). Additionally, the music therapist might support speech therapy goals in their individual music therapy sessions, providing the student with more opportunities to learn and practice the targeted skills. Essentially, encouraging collaboration between speech and music therapists may be a powerful way to help improve an autistic individual's ability to function in everyday life beyond the therapy session.

Additionally, the idea of a music therapist assessing an autistic individual's affinity for music as well as their participation in and enjoyment of certain musical activities may be significant when deciding on a plan for treatment. In fact, "tailoring the intervention to the specific needs of the person" (Geretsegger et al., 2022, p. 2) may be key in creating more productive both music and speech therapy sessions. Performing an assessment that tests the child's involvement in various musical activities (such as listening to musical recordings, active music making with instruments, singing songs) could provide the therapists with the knowledge they need to choose how to best incorporate music in the session and make the therapy more

individualized. Parents may also be able to provide information about their children's preferences, dislikes, strengths, and weaknesses, giving therapists another opportunity to understand how the child best learns and makes progress. It is also plausible that children who display a "motivation to exhibit more communicative behaviors when music is present," as opposed to when it is not, may be more likely to benefit from the inclusion of music in speech and language therapy sessions (Geist et al., 2008, p. 315). This is important information for a speech therapist to take into consideration, especially when working with those on the spectrum. Indeed, every ASD client is unique, with a certain level of severity, different symptoms, and various co-occurring conditions, which should all be considered when SLPs create plans for treatment.

Current Music Usage and the Supporting Neurological Research

Although it is important for ASD clients to have treatment plans and interventions tailored to them as an individual, the use of certain musical interventions is becoming more common in the treatment of ASD. For this reason, it is important for SLPs to not only understand what the current practices involving music are but also the neuroscience that supports them. As described in the prior section, there is a wide range of musical interventions that are being researched or utilized in therapy sessions with those on the autism spectrum disorder. Some of the common ways to incorporate music, for example, include active music making, newly composed songs, and structured, rhythmic training exercises. Therefore, music can be incorporated into therapy sessions through specific techniques, such as DSLM, AMMT, MACT, ABA VB with music, and MBCT, or through more adjustable methods involving improvisation or simple music activities. In either case, these musical interventions are most often used to target behavior, communication, social interaction, or attention and motor control.

Neurological research has shown evidence for why exposure to music and involvement in musical activities during therapy may help those with autism spectrum disorder better learn the targeted skills mentioned above. This research is relevant in the field of speech-language pathology, as it discusses how language and music systems in the brain overlap, indicating that musical interaction techniques may be able to be used to improve social and communicative behavior in autistic children. Further investigation has highlighted that in an autistic individual, there are certain typically functioning areas of the brain, usually in the right hemisphere, which often results in music abilities being spared. This information, in combination with the inherent structure of music, is a significant part of why musical interventions have so much potential to help those with ASD reach therapy goals and learn target skills. Many of the interventions discussed in this review, in fact, were created with a focus on certain components of music. Rhythm, for example, was used in AMMT to prime the "sensori-motor network that controls orofacial and articulatory movements in speech" so that target words or phrases could be produced (Wan et al., 2011, p. 6). Other brain imaging research shows how music also activates an autistic individual's intact reward system, producing pleasure in autistic children and potentially altering their behavior and/or attention so they gain more during the therapy session. Finally, including music in therapy increases "synchronized activation of widespread networks in the brain" (Janzen & Thaut, 2018, p. 8). Specifically, intonation has been found to "engage a bilateral network between frontal and temporal regions" of the brain, which overlaps with language pathways like the AF and UF tracts (Wan et al., 2011, p. 6). Overall, this research is relevant to an SLP, as it explains how the structure and function of the autistic brain can be affected by music's inclusion in speech therapy interventions. Additionally, it is important to understand that actually very few of the studies in this review have used music for its inherent

qualities or for its ability to engage language regions and pathways in the brain. Instead, therapists tend to utilize music for its ability to activate the reward system, producing pleasure in the client and keeping them captivated. Therefore, the field of speech-language pathology may not yet be using music to its fullest potential.

Significance to the Field of Speech-Language Pathology

It is important for speech-language pathologists to learn more about how and why music is being used to target an autistic individual's primary symptoms because the number of children being diagnosed with autism is increasing. According to the CDC, 1 in 36 children (over 2.7% of 8-year-old children) were diagnosed with ASD in 2020, whereas only 1 in 44 were diagnosed in 2018 (Centers for Disease Control and Prevention, 2023). The research surrounding autism spectrum disorder and the interventions used to help individuals with this disorder function is also ever changing and expanding, so it is important for speech therapists to understand the latest techniques and the neurological research that supports them. As evidenced by the previous literature review, utilizing music in therapy encompasses a wide range of specific techniques and interventions that aim to treat those with ASD. Most commonly, music is being used to target behavior, communication, and social interaction, as well as attention and motor control. Although many of these interventions use recorded songs or activities like drumming, a few highlight the importance of using the voice itself as a musical instrument. This concept is especially important for an SLP to comprehend, as the research has shown that by incorporating music in the session through vocal exercises and improvisation, skills "related to vocal communication" may be "channeled more easily into real-life situations" (Salomon-Gimmon & Elefant, 2019, p. 188). In total, this review contains information about these vocal interventions

as well as the other musical interventions currently being used to help those with ASD, which are important for the speech pathology community to know and understand.

Moreover, this review is significant because it sorts the current musical interventions into categories of target skills: behavior, communication, social interaction, and attention and motor control. This allows for a discussion about the purpose of each therapeutic intervention and shows how different musical techniques are being used to accomplish similar goals, in order to help those on the spectrum better function in their everyday lives. Despite this initial division into 4 main groups, many of the interventions target multiple skills and can, therefore, fall into multiple categories. In the review by James et al. (2015), for example, a greeting song was sung during the morning routine of the children in the study. This intervention primarily supported the social interaction target by teaching the autistic children how to engage in greeting their peers. However, this intervention also became a way to increase the children's independent functioning during the step-by-step routine, attempting to improve behavior of the children when they separated from caregivers. Multiple areas were targeted in another study centered on encoding and decoding emotions. One goal was to improve emotional expression, which could be included in the categories of behavior and/or communication skills. However, the main target was social interaction, as having an understanding of empathy as well as the ability to show and communicate their true emotions without getting upset will allow for more functional interaction. Because these musical interventions tend to overlap in what they are targeting, when choosing how to incorporate music in their therapy practices, SLPs will likely have a wide variety of treatment options available that fit their client's goals.

Parent Involvement

Another final consideration involves parent involvement in speech therapy sessions. From the articles reviewed, there were several, especially those targeting social interaction, that mentioned the importance of including parents or caregivers in both the assessment and treatment processes. Conducting parent interviews, for example, can be helpful when determining if and how the child responds to music, providing the therapist with valuable details when they are planning treatment. During the musical intervention, parents can also be included, which gives them a chance to participate in engaging episodes of music making with their children; this can strengthen the parent-child relationship and encourage social interaction. In addition, when parents take part in therapy sessions where music is involved, they can learn from the therapist when they model how to facilitate the music-making process. Parents can take this knowledge with them and use it at home between sessions, giving their children more opportunities to practice skills learned in multiple settings and contexts. Bringing family into the session works toward empowering the "child and the family to thrive together within their cultural environment" (Vaiouli & Andreou, 2022, p. 537). Geretsegger et al.'s (2022) research also provides support for this idea, as it elucidates that currently, music therapy has the potential to improve social interaction and nonverbal communication *during* the intervention. However, when family members are then trained in these music-based techniques that allow for increased social engagement, the children's skills may be more likely to carry over to other aspects of their lives. Overall, this information can help SLPs decide if and how they might want to incorporate parent involvement with musical interventions.

Conclusion

Overview of Findings

To conclude, the initial findings of this study signify that music is being utilized in speech therapy sessions to target behavior, communication, social interaction, attention, and motor control skills for those on the autism spectrum. According to neurological research, music integration in speech therapy appears to be a promising approach, as music has certain properties that activate regions and pathways of the brain that are essential for communication. This paper paves the way for a continuation of research in this field, allowing individuals to better understand current musical interventions and also the neurological reasoning behind the inclusion of music.

Recommendations for Future Research

The next step for research into music and speech therapy would be to implement some of these intervention techniques with a more specific population but larger sample size in order to provide solid evidence and greater applicability of findings. One possible route for future research in terms of focusing on a specific population could involve choosing participants in the 3 to 4-year-old age range, as evidence suggests that the developing brain, as opposed to the adult brain, will be more reactive to experiences, indicating that plastic changes in the brain are age-dependent (Kolb & Gibb, 2011). It will also be important to be aware of all the different types of musical interventions, such as improvisation and AMMT. Future researchers may decide to study the effect of one of these techniques on a target, like language or social interaction. It would also be beneficial to not only measure the effect of music inclusion during the session but also its effect on the child at home or even school. Essentially, the next studies should help to determine if music integration in speech therapy is actually benefiting the communication skills of a certain population of those with ASD.

Additionally, an important question to consider is whether music integration is feasible and acceptable, and if it improves quality of life for the individuals involved. Researchers may also want to determine if the results after musical intervention are preferable to results after traditional speech-language therapy, or if both sets of results are similar to each other. This review, in fact, indicates a current lack of research in the area of music in speech therapy, as more studies focused on specific music therapy techniques for autistic individuals. Even in the articles that highlighted music-based speech and language interventions, a music therapist was often involved in the planning of or even execution of treatment. Following studies should investigate further ways to include music in speech therapy sessions and explore whether co-treatment of autistic individuals by music and speech therapists is possible. Although this review does not discuss these topics in detail, it does illuminate the potential value of music and speech therapy collaboration. By putting the expertise of both therapists together, music could be better utilized for producing functional communication outcomes. Subsequent research should be done to determine how exactly this collaboration would work.

Finally, additional research should be conducted to expand the potential use of music to support language development and speech acquisition because although the neurological research authenticates their inclusion, very few of the musical interventions being used now focus on targeting functional communication growth. In terms of language, Lim's (2010) article used music to help increase functional language of autistic individuals by creating a musical intervention that primarily relied on Gestalt processing, which is the primary language acquisition process used by those with ASD. For speech, the idea of rhythmic entrainment, where sounds are associated with actions of the articulators, should be further investigated, as AMMT is the only intervention in this review that uses this concept to help reprogram the

execution of a speech motor pattern. This research from Wan and her colleagues (2011), therefore, has started the discussion about a new way to use music in speech therapy sessions for individuals with ASD, one that should be studied further to determine if targeting this type of goal will benefit autistic children. The connection between music and emotion could also be further explored, as previous studies by Heaton (2009) and Katagiri (2009) produced results that show how music is used to target autistic individuals' abilities to encode and decode emotional expressions. Additional research is needed to determine how music usage in therapy can enhance emotional understanding and teach those with ASD to be comfortable expressing their own feelings and more aware of the feelings of others. This idea could be important for targeting both social interaction and communication skills of autistic individuals.

Limitations

One limitation of this study was the wide range of participants from all of the articles reviewed. The children, in fact, ranged from age 3 to age 20. Some were nonverbal, whereas others were preverbal or verbal, which means that the participants in these studies had varying levels of communication abilities. The small sample size within some of the articles may have been another limitation of the study, indicating that many of these techniques and interventions are only starting to be explored and are not yet widely used. Salomon-Gimmon and Elefant's (2019) study, for instance, focused on 4 children receiving improvisational music therapy. Other researchers, like Geist et al. (2008) and Shore (2002) centered their studies on individuals, describing the musical approaches used in their unique treatment.

This review of research has revealed that very few of the current musical interventions actually utilize music because of its intrinsic properties or its overlap with the language pathways in the brain. Instead, the articles more often highlighted the use of music for increasing

engagement, which is why it would be necessary for the client to have some sort of affinity for music. Janzen and Thaut (2018) were among the first researchers to call for an expansion in music's role in intervention for those on the autism spectrum. Their argument for musical interventions to target attention and motor control comes from the fact that music is "inherently temporal and sequential" (Janzen & Thaut, 2018, p. 9), which allows individuals to "induce a beat from the sensory input and then use that information to predict future events within a metrical framework" (Honing, Bouwer, & Háden, 2014, p. 309), consequently directing the individual's attention towards that moment. Overall, these findings indicate a need for further research, especially in the areas of using music to improve motor control and attention, as well as functional communication abilities.

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