Music and Medicine
5(3) 145-149

DOI: 10.1177/1943862113489995
mmd.sagepub.com
SAGE

Musical Instrument Modifications for Individuals With Neurodevelopmental Disabilities

Yuezhou Yu, BA[1], Warren M. Shadd, BA[1], Kelly A. Kleifges[1], Linda A. Myers, MD[1], and Phillip L. Pearl, MD[1]

Abstract

Music therapy is a systematic intervention that can benefit individuals with neurobehavioral disorders. The use of musical instruments is a central component of many clinical music therapy practices, and recent technological modifications to instruments have enhanced their accessibility and versatility as a therapeutic medium. A novel case example of a modified piano and examples from literature are presented to illustrate the potential applications of technological advances in musical instruments. These advances include the integration of computers, communication technology, and Internet connectivity in the creation of a more powerful and flexible platform for therapy. Sound amplification and surround sound systems, voice recognition software, eye-tracking and gesture-tracking command technology, magnifying lens technology, and Braille keyboards can aid individuals with sensory (eg, hearing or vision) or motor deficits. Such modifications have the potential to transform music therapy and education for children with neurodevelopmental disabilities including autism.

Keywords

music therapy, musical instrument modifications, autism, neurodevelopmental disabilities

Introduction

Music therapy as a systematic intervention can benefit individuals with neurodevelopmental disabilities, that is, impairments in the developing nervous system. These are represented by deficits in the development of cognitive, social, motor, and sensory skills as seen in diagnoses including autism spectrum disorder (ASD), primary sensory defects (eg, blindness, deafness), and neurological dysfunction secondary to a variety of causes including congenital anomalies, hypoxia–ischemia, trauma, genetic–metabolic errors, neuromuscular diseases, and other central and peripheral nervous system disorders. Interventions utilizing music and the playing of music have been used to address social, communicative, motor, emotional, and behavioral issues in these populations.

In recent years, the development of technological modifications to musical instruments has contributed to the accessibility and effectiveness of music therapy. This article provides an overview of music therapy and musical instrument use in patients with neurodevelopmental disabilities and discusses the contribution of recent technologies and instrument adaptations. These adaptations range from physically modified instruments to the integration of computers, assistive devices, web connectivity, interactive software, and enhanced audio systems. A novel case example of a modified piano and examples from the literature are presented to illustrate.

Music Therapy

Methods of music therapy are varied and usually individualized to each patient but can be generally defined as systematic interventions that may include group or one-on-one sessions, song listening, imitation, verbal reflection or discussion of music, and improvisational or structured playing of musical instruments.[1] As early as the 1960s, pioneers including Nordoff and Robbins, Saperston, Alvin, and Stevens and Clark explored how such applications of music could be used to address core clinical deficits in patients with autism.[2] These core deficits include qualitative impairments in verbal and nonverbal communication, social and emotional reciprocity, and behavior (eg, marked by repetitive or stereotypic actions, obsessive behavior, or unusual responses to sensory stimuli).

It was ventured that music could not only be an effective platform but perhaps also uniquely be effective in treating these individuals. Nordoff and Robbins, for example, proposed that

[1]Department of Neurology, Children's National Medical Center, Washington, DC, USA

Corresponding Author:
Phillip L. Pearl, Department of Neurology, Children's National Medical Center, 111 Michigan Ave NW, Washington, DC, 20010, USA.
Email: ppearl@childrensnational.org

music could be considered a nonthreatening, preverbal medium and, therefore, more likely to engage children with communicative or social disorders such as ASDs.[3,4] This idea was addressed in later decades by researchers, including Thaut, who found that musical responsiveness (unlike speech and language) was indeed intact or even enhanced in individuals with autism compared to normally developing peers.[5] Contemporaries of Nordoff and Robbins also pointed to the natural suitability of music as a medium for self-expression, communication, and interaction and as a means of addressing behavioral issues through structured engagement.[6-8]

As the practice of music therapy has become more widely established in recent decades, the potential for these applications has been explored both in clinical and research settings. Although the focus has primarily centered on children with autism, the suitability of music therapy for treating other neurodevelopmental disorders has also been addressed.[9-14] Specific goals of music therapy in these patient groups can include teaching social behaviors (eg, establishing eye contact, turn taking, joint attention); encouraging empathy through shared experience; improving focus and attentiveness; increasing emotional, verbal, and gestural self-expression; decreasing or redirecting agitation; and improving mood.[15]

Preliminary evidence for the ability of music therapy to improve social skills, language/communication, mood, behavior, and cognitive function in individuals with neurodevelopmental disorders has been evaluated in current literature. A 2006 Cochrane Collaboration meta-analysis of 3 randomized controlled trials (RCTs) found significant improvement in verbal and gestural communicative skills in child participants with autism ($n = 20$).[16] Improvements in behavior, however, were not significant. Results were measured following 1 week of music therapy and compared to a "placebo" of social therapy not using music (standard mean difference [SMD] = 0.5; 0.22-0.79 at 95% confidence interval [CI]; for gestural communicative skills and SMD = 0.36; 0.15-0.57 at 95% CI; for verbal communicative skills). An additional (2010) RCT ($N = 50$) concluded that speech training incorporating music was effective in improving speech production in autistic children and was preferable to nonmusic training methods in low-functioning individuals.[17] Further experimental trials focusing on autism have been reviewed in a narrative form by Simpson and Keen, with mixed results,[18] and in a meta-analysis by Whipple, showing significant benefit across 9 studies.[19]

A broader literature review in a 2012 *Journal of Music Therapy* issue found that 11 (of 32) experimental music therapy studies published between 1999 and 2009 reported effective results, and an additional 15 (of 32) studies reported partially effective results. A wider range of disabilities including sensory (hearing, vision) and motor impairments, as well as autism and other developmental disorders, were represented among these studies. Social skills were among the most common dependent variables showing improvement in participants (in 81% of studies that found effective or partially effective results), followed by academic performance (19%).[9] In individuals with traumatic brain injury, evidence for successful improvement in motor impairment has been minimal and limited primarily to improvements in gait.[11-13] There are also reports of clinically significant improvements in mood and self-esteem following music therapy in patients with neurodegenerative disorders and posttraumatic neurological injuries.[11,20]

Musical Instruments in Music Therapy

Active music therapy techniques involving the playing of musical instruments are popular modalities in clinical practice and research and can include structured or improvisational playing sessions facilitated by a therapist. For individuals with social or communicative deficiencies such as ASDs, the use of an instrument can be especially effective. As music therapists including Alvin and Warwick have posited, children with autism may resist interpersonal interactions and prefer to focus on inanimate objects.[8] In this context, instruments can serve as a nonthreatening medium that may facilitate greater engagement and communication. The visual and tactile features of an instrument, as well as the consistency and structure it provides, may also spark interest and help to sustain attention.[21]

Researchers Kissinger and Worley,[22] for example, experimented with the use of a harp to catalyze communication and social interaction in therapy sessions with 2 children having autism. The qualitative case study found that the visual and auditory elements of a harp, including color-coded strings and wide range of tones and textures, were able to capture and sustain the children's attention. After the instrument's introduction, the 2 children not only became interested and possessive of the object but also became more socially engaged. The children acknowledged the presence of the researcher and participated in interactive activities through the harp as a medium. Increased vocalization (though not verbalization) and nonverbal behavior, including significantly more frequent smiles, eye contact, and hand gestures, were also noted. Interestingly, the children did not participate in activities or acknowledge the researcher when the harp was not present.[22]

Breaking such patterns of isolation is fundamental to addressing social and communicative deficits,[23] and in this capacity musical instruments may serve as a bridge between a patient's personal, nonverbal world and his or her social environment. As Kissinger and Worley[22] noted, an instrument can also have the unique ability to engage children with autism through stimulation of the senses (touch, hearing, and vision) and through the consistency and predictability that it provides. In these capacities, instruments become much more than simply a tool for music making but also a medium for targeted therapy.

The use of instruments as a medium of music therapy for individuals with neurodevelopmental disabilities has been enhanced by adaptive instrument modifications and the integration of new technologies including computers, assistive software, and devices. A literature review reveals examples including (1) unique instrument mounting systems that improve accessibility, such as neck holders for wind instruments and adapted handles for drums and other percussion instruments,[24] (2) sound amplification or vibroacoustic technology to accommodate hearing

Figure 1. Prototype piano modified for neurodevelopmental disabilities—7′2″ Semi-Concert Grand. Enhancements visible in the figure include 4 liquid crystal display (LCD) touch screens (with 3 embedded and 1 stand-alone monitor) for interaction with the onboard computer and software, a mouse (and alphanumeric keyboard stowed beneath the keys), a fourth pedal for page turning, video camera to facilitate remote communication, embedded speakers above the keys facing the player, and electronic data ports beneath the upper keys that allow the piano to interface with additional tools and systems.

impairment,[25] (3) the integration of audio/video recording devices to document therapy sessions or record music,[26] (4) the use of synthesizers and musical instrument digital interface (MIDI) controllers to generate customizable sounds through electronic instruments or computers,[27] (5) computer applications such as video, audio, or interactive software to teach social, language,[28] or music skills,[24] and (6) the use of electronic "switches" that can be activated to trigger desired sounds. Such devices are particularly useful for individuals limited by motor impairments but also offer an alternate means of communication for nonverbal or poorly communicative patients.[29,30] Switches can be physical or computerized and recently have even utilized body movements (hand, eye, and facial movements) to trigger sounds.[31,32]

A modified piano (Figure 1) incorporates multiple technological modifications simultaneously by combining a traditional piano with computers, Internet connectivity, and assistive devices

Table 1. Musical Instrument Modifications for Individuals With Neurodevelopmental Disabilities.

Onboard computer with interactive (touch-screen) monitors
Remote teaching network with video cameras
Onboard self-teaching software
Video and electronic capturing of hand and pedal movement for recording, playback, and instructional use
Surround sound immersion technology
Sound-matching vibratory input
Voice command software
Gesture-interactive technology
Eye-tracking and eye movement-controlled command technology
Page-turning pedal
Magnifying lens software
Braille keyboard

(Table 1) that are currently being utilized in the practice of music therapy and that can benefit patients with neurodevelopmental disorders in the areas of social and communicative deficiencies as well as sensory and motor deficits. Modalities addressing social and communicative deficiencies include onboard computers equipped with (1) remote communication and audio/video capture technology, (2) music teaching software, and (3) movement-responsive and voice-responsive command technology. Thus, the piano is equipped with Internet connectivity, videoconferencing software, multiple cameras and a microphone, allowing distance learning and therapy. Using the piano station, participants and therapists can see, hear, and work together remotely. This may be particularly beneficial in the case of children who are inhibited or become anxious in the typical teaching environment of another person in their proximate space. Internet-based sessions can also facilitate therapy when in-person meetings may not be logistically possible.

The combination of a traditional piano with the added power and customizability of a personal computer makes for a highly versatile tool. Onboard computers can be used to play back any chosen video or audio as a component of therapy, and a range of communication devices (USB, MIDI, disc drives, video graphics array [VGA], digital video interface [DVI], high-definition multimedia interface [HDMI], Ethernet, and wireless Internet connectivity) allow easy interface with other technologies and smooth integration into the existing music therapy practices.

Onboard computers can also be used to deliver music tutorial software. Teaching software is fully interactive via multiple touch screens as well as a mouse and a keyboard and can provide real-time feedback to guide practice. Although this presumes relatively high intellectual and motor capabilities, patients in music therapy sessions can independently use the onboard teaching software to learn piano at various levels of proficiency. Video cameras and sensors placed in the instrument and above the keys and pedals can detect and record movement for playback or instruction and provide immediate feedback regarding intonation and rhythm. These modalities may be particularly applicable to high-functioning individuals with neurodevelopmental disorders or to patients with more

severe social or communication deficits who may not be responsive to direct instruction from a therapist but can learn to perform tasks and play independently in a structured therapy setting.

The piano is furthermore responsive to voice commands, hand gestures (eg, swipes, waves, pointing, etc), and even eye movements (including gazing, dwelling, and blinking). Similar to the switch devices often used by therapists and researchers, the piano can capture and translate hand and eye movements using video cameras and onboard software to provide real-time control. These tools could be used, for example, to control sound playback (eg, play/stop, volume control, fast-forward/rewind); operate synthesizers, MIDI, and other pre-recorded sounds; operate software (eg, tutorials, composing); and turn pages or dictate sheet music, among other functions.

Voice-and gesture-command technology can allow individuals with vision or motor impairments to operate an instrument with greater ease and control. Such devices, however, can not only enhance music making but also be used as alternative modes of communication with individuals with social or communication disorders. Gesture-command technologies, like the existing switch technologies (triggered sounds), may be incorporated by music therapists to facilitate alternative means of self-expression, encourage interaction, and improve social and communication skills in nonverbal or poorly communicative patients.

For individuals with hearing impairment, a modified piano bench with surround speakers and a subwoofer built into the center of the seat, as well as speakers built into the body of the piano, can amplify the sound produced by the instrument and conduct it throughout the musician's body. This improves the ability of individuals with hearing deficits to experience music. Amplification and full-body sound conduction through vibration allow individuals to "feel" sound and may provide particularly educational and emotional experiences for children with sensory impairments (hearing or vision), who may otherwise have limited access to instruments or music.[33,34]

Modifications for musicians with vision or motor deficits also include magnifying lens software for enhancing sheet music and displays and Braille alphanumeric keyboards that improve the ease of use of the instruments and onboard computer systems. Additional assistive technology includes automated grand top sticks that allow for otherwise heavy and unwieldy piano tops to be moved remotely; this is to aid individuals with motor impairments. The addition of a fourth page-turning pedal to a piano improves the ease of use by allowing musicians to manipulate the pages of electronic sheet music hands free. Automatic page turning, which does not require any manual control at all, is also an available function and can synchronize to a player's performance speed. Paper sheet music can be adapted for use with digital page-turning systems and imported as editable virtual images through scanners that interface with modified musical instruments.

The modifications outlined previously enhance traditional acoustic instruments with electronic and assistive tools that allow individuals with neurodevelopmental disorders to engage more fully with the art of making music and receive maximum benefit from music therapies. Patients who stand to benefit most from these technological advances include individuals with social, visual, or hearing deficits. As technology becomes increasingly incorporated into clinical music therapy practices, these modifications and their methods of use may serve as a prototype and foreshadow future trends in therapy and instrument design.

Conclusion

Music therapy techniques can meet the individual at his or her developmental level, helping to advance social and communication skills. The role of technology in music therapies for children with neurodevelopmental disabilities is growing rapidly, as is the role of technology in music therapy overall.[27,35] A 2012 survey of music therapists with 624 respondents throughout the United States, Australia, Canada, and the United Kingdom found that 71% (n = 443) of respondents have used technology before in a clinical setting, that 51% (n = 361) employ technology currently and that the most frequent use of music technology in therapy was with patients with developmental disabilities.[27]

Novel instrument modifications and technological applications offer new opportunities, experiences, and benefits. These include onboard video capability, self-teaching software, immersive audio sound systems, voice and gesture-command technology, and highly interactive computer systems accessible to many students with neurodevelopmental disabilities. Use of a teaching network to provide off-site remote instruction is targeted toward individuals with ASD. Voice recognition with command features, magnifying lens software, Braille keyboard, and surround sound are designed for students with vision loss. Provision of vibratory sensory stimuli is effective for individuals with hearing loss.

Authors' Note

This article does not endorse any specific music product or company.

Declaration of Conflicting Interests

The author(s) declared the following potential conflicts of interest with respect to the research, authorship, and/or publication of this article: Warren M. Shadd is a manufacturer of pianos modified for developmental disabilities and is the inventor of the prototype instrument shown in the manuscript figure.

Funding

The author(s) received no financial support for the research, authorship, and/or publication of this article.

References

1. Gold C, Wigram T, Voracek M. Predictors of change in music therapy with children and adolescents: the role of therapeutic techniques. *Psychol Psychother*. 2007;80(pt 4):577-589.
2. Reschke-Hernandez A. History of music therapy treatment interventions for children with autism. *J Music Ther*. 2011;48(2):169-207.
3. Nordoff P, Robbins C. Improvised music as therapy for autistic children. In: Gaston ET, ed. *Music in Therapy*. New York, NY: Macmillan Publishing Company; 1968:191-193.

4. Nordoff P, Robbins C. Music therapy and personality change in autistic children. *J Am Inst Homeopath*. 1964;57:305-310.
5. Thaut M. Measuring musical responsiveness in autistic children: a comparative analysis of improvised musical tone sequences of autistic, normal, and mentally retarded individuals. *J Autism Dev Disord*. 1988;18(4):561-571.
6. Saperston B. The use of music in establishing communication with an autistic mentally retarded child. *J Music Ther*. 1973; 10(4):184-188.
7. Stevens E, Clark F. Music therapy in the treatment of autistic children. *J Music Ther*. 1969;6:98-104.
8. Alvin J, Warwick A. *Music Therapy for the Autistic Child*. 2nd ed. Oxford, England: Oxford University Press; 1991.
9. Brown L, Jellison J. Music research with children and youth with disabilities and typically developing peers: a systematic review. *J Music Ther*. 2012;49(3):335-364.
10. Miller VH. Practical applications of computer and MIDI technologies for people with physical and cognitive disabilities. Paper presented at: Mid-Atlantic Region of the American Music Therapy Association Conference; March 2010; Pittsburgh, PA.
11. Schmid W, Aldridge D. Active music therapy in the treatment of multiple sclerosis patients: a matched control study. *J Music Ther*. 2004;41(3):225-240.
12. Bradt J, Magee WL, Dileo C. Music therapy for acquired brain injury. *Cochrane Libr*. 2010;7:CD006787. doi:10.1002/14651858. CD006787.pub2..
13. Kwak EE. Effect of rhythmic auditory stimulation on gait performance in children with spastic cerebral palsy. *J Music Ther*. 2007; 44(3):198-216.
14. Magee W, Baker F, Daveson B. Music therapy methods with children, adolescents, and adults with severe neurobehavioral disorders due to brain injury. *Music Ther Perspect*. 2011;29(1):5-13.
15. Bruscia KE. *Defining Music Therapy*. 2nd ed. Gilsum, NH: Barcelona Publishers; 1998.
16. Gold C, Wigram T, Elefant C. Music therapy for autistic spectrum disorder. *Cochrane Database Syst Rev*. 2006;19(2):CD004381
17. Lim H. Effect of developmental speech and language training through music on speech production in children with autism spectrum disorders. *J Music Ther*. 2010;47(1):2-26.
18. Simpson K, Keen D. Music interventions for children with autism: narrative review of the literature. *J Autism Dev Disord*. 2011;41(11):1507-1514.
19. Whipple J. Music intervention for children and adolescents with autism: a meta-analysis. *J Music Ther*. 2004;41(2):90-106.
20. Magee WL, Baker F, Daveson B. Music therapy methods with children, adolescents, and adults with severe neurobehavioral disorders due to brain injury. *Music Ther Perspect*. 2011;29(1):5-13.
21. Khetrapal N. Why does music therapy help in autism. *Empir Musicol Rev*. 2009;4(1):3-14.
22. Kissinger L, Worley D. Using the harp as a communication channel with children with autism. *Int J Spec Educ*. 2008;23(3):149-156.
23. Thaut M. A music therapy treatment model for autistic children. *Music Ther Perspect*. 1984;1(4):7-13.
24. Crowe J, Robin R. Implications of technology in music therapy practice and research for music therapy education: a review of the literature. *J Music Ther*. 2004;41(4):282-320.
25. Brodsky W, Sloboda JA. Clinical trial of a music generated vibrotactile therapeutic environment for musicians: main effects and outcome differences between therapy subgroups. *J Music Ther*. 1997;34(1):2-32.
26. Magee WL, Bertolami M, Kubicek L, et al. Using music technology in music therapy with populations across the life span in medical and educational programs. *Music Med*. 2011;3(3):146-153.
27. Hahna N, Hadley S, Miller V, Bonaventura M. Music technology usage in music therapy: a survey of practice. *Arts Psychother*. 2012;39(5):456-464.
28. Goldsmith T, Leblanc L. Use of technology in interventions for children with autism. *J Early Intensive Behav Interv*. 2004;1(2): 166-178.
29. Benveniste S, Jouvelot P, Michel R. Wii game technology for music therapy: a first experiment with children suffering from behavioral disorders. Presented at: CCIS'08 IADIS Game and Entertainment Technologies Conference; July 2008; Amsterdam, the Netherlands.
30. Magee W, Burland K. An exploratory study of the use of electronic music technologies in clinical music therapy. *Nord J Music Ther*. 2008;17(2):124-141.
31. Tam C, Schwellnus H, Eaton C, Hamdani Y, Lamont A, Chau T. Movement-to-music computer technology: a developmental play experience for children with severe physical disabilities. *Occup Ther Int*. 2007;14(2):99-112.
32. Eduardo M, Magee WL, Wilson J. Brain-computer music interfacing (bcmi): from basic research to the real world of special needs. *Music Med*. 2011;3(3):134-140.
33. Darrow AA, Schunk H. Music therapy for learners who are deaf/ hard-of-hearing. In: Wilson B, ed. *Models of Music Therapy Intervention in School Settings: From Institutions to Inclusion*. Silver Spring, MD: American Music Therapy Association; 2002:200-223.
34. Cormier L. *Music Therapy for Handicapped Children: Deaf-Blind*. Washington, DC: National Association for Music Therapy; 1982.
35. Magee WL. Electronic technologies in clinical music therapy: a survey of practice and attitudes. *Technol Disabil*. 2006;18(3):139-146.

Author Biographies

Yuezhou Yu, BA, is a clinical research assistant in the department of neurology at Children's National Medical Center, Washington, DC, USA.

Warren M. Shadd, BA, is a musician, piano technician, and owner of Shadd Pianos, Inc.

Kelly A. Kleifges is studying neuroscience and biochemical engineering at Tulane University, New Orleans, LA, USA.

Linda A. Myers, MD, is an anesthesiologist in private practice in the Washington, DC, area.

Phillip L. Pearl, MD, is Chief of Neurology at Children's National Medical Center and Professor of Neurology, Pediatrics, and Music at The George Washington University School of Medicine and Columbian College of Arts and Sciences in Washington, DC, USA.