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Music, Intelligence, and the Neurocognitive Effects of Childhood Cancer Treatment

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Abstract

Improved childhood cancer survival rates are associated with increasing numbers of patients with neurocognitive impairment. Detrimental cancer treatment effects include declines in IQ, attention, executive function, processing speed, memory, visuospatial, and visuomotor skills, reducing patients' quality of life and the potential to achieve key life milestones. Music training can improve intelligence, attention, and memory as well as provide a medium for interaction, coping, stress reduction, and improved self-esteem. Given the crossover between the domains impaired by childhood cancer treatment, and improved through music training, there is potential for music-based interventions to minimize detrimental treatment effects. This article reviews the neurocognitive effects of childhood cancer and its treatment, provides a theoretical rationale for offering children with cancer music-based interventions, and suggests strategies that carers may use to extend their intellectual potential and quality of life.

Keywords

music, intelligence, child, neoplasms

Advances in the treatment of childhood cancer have improved the 5-year survivorship from 59.9% in 1975 to more than 82.7% in 2004.[1] However, with 50% to 60% of survivors at risk of adverse neurocognitive effects related to the treatment or disease, interventions to limit negative effects are important.[2] Similarly, interventions to improve children's quality of life are also imperative as they can experience disrupted development associated with anxiety, isolation, embarrassment,[3,4] unfamiliar and possibly frightening hospital care, harsh, sometimes painful treatments,[3] regular checkups, and ongoing uncertainty.[5] Given the important role that music plays in children's lives, especially when diagnosed with cancer,[6] and the relationship between music, neural development,[7] and improved intelligence,[8] it is surprising that no research on music and cognitive remediation in oncology exists. Nonetheless, music therapy positively affects young cancer inpatients' mood,[9,10] engagement,[11] coping,[12] and play activity.[13] This article reviews how cancer and its treatment can affect children's neurodevelopment and cognition, examines the potential for music-based interventions to minimize cognitive impairments, and suggests how professional and family carers may ameliorate cancer's neurocognitive and psychosocial effects in children.

Childhood Cancer and Neurocognitive Impairment

The incidence of childhood cancer is increasing, with 12 060 American children younger than 15 years expected to be diagnosed in 2012.[1,14] Approximately one-third are diagnosed with leukemias, most commonly acute lymphocytic leukemia, and one-fifth are diagnosed with central nervous system (CNS) tumors. Treatment for these cancers involves therapies, including cranial radiation therapy (CRT), chemotherapy, and surgery, which can cause neurocognitive impairment. The scope of impairment varies from subclinical to severe.[15] Solid tumors can also directly impact upon adjacent structures impairing function.[15]

Cranial radiation therapy is particularly associated with declines in IQ and attention.[16] The effects are more severe the younger the patient is. Mulhern et al found that patients treated under the age of 5 had an average IQ of 72, while those treated between the ages of 6 and 11 had an average IQ of 93. The decline in IQ following CRT is also dose dependent, with larger doses causing greater declines.[17] Chemotherapy can cause

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Table 1. Neurocognitive Effects of Childhood Cancer Treatment.[15,21]

Neurocognitive Deficit	Characteristics
Attention	Common (up to 100% of brain tumor and 40% of patients with ALL posttreatment)
	Impaired ability to switch attention between tasks
	Impaired ability to sustain attention
Executive function	Impaired ability to plan and organize
	Difficulty with problem-solving tasks
Processing speed	Impaired speed and efficiency of information processing
Memory	Compounded by deficits in attention and executive function
	Impaired ability to store new information
	Impaired ability to retrieve stored information
Visuospatial/visuomotor	Difficulty with tasks such as writing and map interpretation
	Impairments coordination and fine motor control

Abbreviation: ALL, acute lymphocytic leukemia.

adverse neurocognitive effects but is less harmful than CRT.[18] However, chemotherapy (methotrexate) and CRT can also act synergistically, causing more harm in young children when given concurrently and leading to IQ declines of 25 to 29 points greater in girls younger than 5 years compared with those who received methotrexate preirradiation.[19] The damage caused by chemotherapy and CRT is located principally in the white matter, with volume loss thought to be due to vascular impairment.[18] This white matter consists of axons insulated by a myelin sheath produced by oligodendrocytes and continues to develop into a person's 20s, with the myelination of the frontal lobes completing this process.[20]

The neurocognitive effects of childhood cancer treatment include deficits in attention, executive function, processing speed, memory, and visuospatial and visuomotor skills. Further details outlined by Nathan et al[15] and Butler and Haser[21] are given in Table 1. Several treatment strategies have been employed in an attempt to minimize late neurocognitive effects in childhood cancer survivors, including reducing the radiation dosage in CRT, fractionating CRT (using repeated smaller doses), conforming CRT (reducing radiation exposure to normal tissue), and substituting CRT with chemotherapy and posttreatment interventions including pharmacological therapies and cognitive remediation programs.[21,22]

Butler and colleagues[23] devised a 3-part cognitive remediation program for childhood cancer survivors, which focused on brain injury rehabilitation, including attention training exercises; educational psychology, including metacognitive strategies assisting participants to prepare, monitor, and evaluate performance; and clinical psychology approaches to promote positive frames of mind. An evaluation study found modest improvements in academic achievement and parent-reported attention; however, the program was unlikely to return the children to their prior functional capacity.[23] Methylphenidate hydrochloride, used in the treatment of attention-deficit hyperactivity disorder, has also improved attention and processing speed in some childhood cancer survivors, with better responses in males and older, more intelligent patients.[22,24]

The decline in intellectual function, as time since treatment progresses, is "usually related to a reduced rate of skill acquisition rather than a loss of previously learned information"[15] and can be explained by the impacts of decreased attention and memory on the uptake of new information and skills. Patients of lower socioeconomic status also generally have poorer outcomes, possibly related to their parents' and schools' lesser abilities to meet the children's additional academic needs.[15]

The Relevance of Research on Music Training, the Brain, and Intelligence for Children With Cancer

Since the "discovery" of the Mozart effect in 1993, there has been considerable interest in how passive music listening can enhance intelligence in children.[25] The brief (10-15 minutes) improvement in spatial task performance found when listening to Mozart's Sonata for 2 Pianos (K448) has since been attributed to arousal and mood effects on task performance and found to be noncomposer specific.[26,27] Beneficial effects of music lessons on intelligence are evident and include improvements in IQ, memory, language, spatial, mathematical, and nonverbal performance.[28] A review of research by Hallam[29] found that music training was positively associated with improvements in perceptual and language skills, literacy, numeracy, and intellect. Only 3 trials examining causal relationships were found. In a randomized controlled trial of 144 6-year-old children, those who had 36 weeks of music training at the Royal Conservatory of Music in Toronto showed a mean improvement of 2.7 IQ points greater than the controls (control mean improvement 4.3, standard deviation [SD] = 7.3; music group mean improvement 7.0, SD 8.6).[8] Elsewhere, 2 years of an extended music curriculum led to improvements in children's visual and auditory memory significantly greater than a no music curriculum control group.[30] Another trial compared children who received 20 one-hour sessions of music listening activities (which included training in rhythm, pitch, melody, and vocal tasks) with children who received a visual arts skill development program. Verbal intelligence scores significantly improved in the music group (more than 90%

showed improvements), whereas there was no improvement in the visual arts group.[31] The music listening group also showed improvement in executive function, with corresponding changes in event-related potential analysis before and after the music listening program in the P2 component, thereby providing evidence of music-induced brain plasticity. All of these findings demonstrate a transfer of skills derived from music training to other domains of intelligence.

Music training's effects upon intelligence are dose dependent and long lasting, with Schellenberg postulating that the improvements in intelligence could be due to the ''schooling'' that accompanies music training, including the involvement of focused attention, concentration, memorization, reading, and fine motor skills.[26] Music training can also induce structural changes in the brain. Neuroplasticity refers to the brain's ability to adapt to environmental influences and insults, and this is greatest during early childhood.[32] Magnetic resonance imaging studies revealed larger cortical areas devoted to the left little finger in violinists and increased gray matter in professional keyboard players compared to amateurs.[33,34] The corpus callosum is also larger in musicians compared to nonmusicians; however, this occurs only when music training begins before 7 years of age.[35] The notion of a birth to 7-year-old critical period with regard to neurocognitive changes derived from music training is further supported by evidence showing that perfect pitch was only found in musicians who commenced training before the age of seven. These musicians showed changes in their right planum temporale.[36,37] Also, a sample of 5- to 7-year-olds, who practiced music for more than 2 hours a week for 29 months, had an increase in the proportional size of corpus callosum area 3, potentially due to increased myelination and axon size or the formation of collateral or transcallosal fibers.[38]

The research examining music training's effects on the brain and learning suggests that, in ''normal'' children, music training has the potential to improve intellectual function, with those who have the greatest involvement showing the most improvement. Given the crossover of some of the neuropsychological domains that music training strengthens and childhood cancer treatment negatively affects (including IQ, memory, visual spatial skills, and potentially executive function), there clearly is potential for music-based interventions to help alleviate some of the neurocognitive effects of cancer treatment.

Ameliorating Neurocognitive Effects Through Music

Varied music training, activity based, and communication strategies, informed by research and theoretical evidence, are suggested for the maintenance and amelioration of cognitive abilities in children with cancer. Health and family carers and educators need to tailor strategies according to the children's abilities, and neuropsychological assessments may inform realistic therapeutic and educational aims. Music training, music therapy, and associated strategies are ideal for children of almost any age, as they are accessible, often enjoyable, and can encourage the use and development of complex skills involving simultaneous perception of sensory modalities, even when lacking in energy and bedbound.[6] Table 2 offers suggestions for how parents and health professionals can use music to assist children neurocognitively affected by cancer based on the available work of music therapists, radiation therapists, and music educators. There is no evidence, however, that music training directly counters the generalized white matter loss associated with CNS cancer therapy and therefore cognitive improvements may be mediated though separate processes.

Quantitative research examining the effect of music-based strategies on cognition would need to address design issues that include minimizing recall bias when ascertaining prior musical learning; structured interventions that children are likely to complete, given the cancer-related circumstances (eg, fatigue); blinding of outcome assessors to treatment group allocation; and trial-size calculations that take account of the increased likelihood of both contamination of the control group by seeking music lessons and dropout from both groups. Furthermore, withholding music-based training and care from control groups in pediatric cancer studies is arguably unethical. Perhaps it is more appropriate and meaningful to provide musical care to children with cancer informed by therapists' rich practice wisdom,[6,48] qualitative data about patients' and carers' experiences,[6] and translation of findings from related contexts such as brain injury rehabilitation.[18]

Conclusion

Survivors of childhood cancers are less likely than their siblings to be employed or married and are at a greater risk of chronic disease and poor academic achievement.[50] Ameliorative strategies should be offered to maximize patients' cognitive capacities and quality of life. Indeed many of the benefits that patients and survivors derive from music therapy, music training, and related activities are social, psychological, and life enriching.[6,12,48] Arguably, this is enough to warrant substantive investment in music-based strategies for young patients with cancer and cancer survivors. The likely cognitive benefits from music-related training and activity, through attention, motivational, and intellectual effects, render music-based care an imperative for children with cancer. Two authors of this article are music therapists, a profession that receives university training in child development, human psychobiological functioning, neural correlates of music, performance skills, and therapeutic applications of music. It is suggested that this profession has much to offer children neurocognitively affected by cancer through direct service delivery or as consultants to families, teachers, and other health carers wanting to help children reach their potential through music. Other health carers and educationalists also clearly have much to offer this field (see Table 2), and it is hoped all involved in pediatric oncology further explore, share, and hopefully research ways in which music-based care can improve the neuropsychobiological and social lives of young patients with cancer.

Table 2. Suggested Music and Communication Strategies for Children Neurocognitively Affected by Cancer to Potentially Improve Cognition and Quality of Life.

Music and Communication Strategies	What the Strategies Offer
Encourage the child's musical play. Enable young children to exercise their natural tendency to explore sounds and play with instruments.[32] Develop their creativity through encouraging their improvisation on tuned and untuned instruments. As they get older, offer music lessons. Familiar melodic fragments may also be learned for enjoyment, for example, the opening repetitive riff of "Smoke on the Water"[39] or "Beat It."[40]	The earlier the child begins music education the greater its effect on neural development.[21] Music and speech share some processing systems; therefore, music experiences can enhance language perception and, in turn, reading.[29]
Play with music together. Use music to enrich a child's life, especially when familiar active games are not possible because of the illness. Play with vocalizing sounds together. Mirror back infants' babbling, and offer different "babbling" sounds for them to respond to. Invite children to make up new words for familiar songs. For example, "Twinkle, Twinkle Little Star," "Mary Had a Little Lamb" (for preschoolers), "Kookaburra Sits on the Old Gum Tree,"[41] "You Are My Sunshine,"[42] or popular music (top 30 hits) relevant to the child's musical tastes. Play musical games and do the actions for songs when possible, for example, "Heads, Shoulders, Knees, and Toes," "Incy Wincy Spider," "I'm a Little Teapot,"[43] "Hokey Pokey," "If You're Happy and You Know It," "Where Is Thumbkin?," "Dingle Dangle Scarecrow," and "Open, Shut, Them," or "Tony Chestnut" for older children.	Sharing music together can promote child and family coping with arduous cancer experiences[6] and, arguably, support the child's development of curiosity and capacity for learning. When children and families imitate and extend each other's tones, rhythms, melodies, vocalizations, and gestures, the child can feel heard and supported. The child's music making can also be a nonverbal expression, which is especially important when the child finds it difficult to verbalize how he or she feels.
Promote development and educational goals through music. Include music in learning tasks, such as singing the days of the week ("There Are Seven Days"), alphabets ("The Alphabet Song"), and the multiple times tables. Encourage regular music practice if having lessons. Integrate music into cognitive remediation strategies.	Music is a mnemonic, motivator, and energizer and can make otherwise arduous learning tasks fun. Skills developed in music education and practice, including focused attention, concentration, memorization, reading, and fine motor skills, may transfer to the development of other intellectual tasks.[29]
Use electronic music technologies. There are many developmentally appropriate music programs (commonly called music apps) accessible on handheld devices (phones and tablet computers), including touch-sensitive musical instruments (eg, harp, guitars, piano) and music-making applications (ie, GarageBand), which allow children to compose music. These are available through online commercial application and music sites.	Music-based technology can be familiar and provide interesting and novel interactive mediums. It can therefore help children to cope with unfamiliar and difficult treatment environments. Through being a vehicle to engage withdrawn and anxious children, music technology can sometimes promote the child's interest in music-based methods for educational and therapeutic goals as described previously.
Communicate in ways that help to compensate for children's vulnerable cognitive capacities while helping to enable the child's sense of achievement. For example, a child may be able to answer a question better if it requires a yes/no or multiple-choice answer, or through being given extra time to decide. Do not mistake attention problems for daydreaming but help a child to be "distracted back" to the point. Be prepared to repeat instructions.	To maximize cognitive development, a child needs to comprehend instructional tasks. Furthermore, given music education's effect on neural[36] and cognitive development,[29] and that language and music neural pathways are separate,[44] it follows that carers have a greater capacity to meaningfully connect with and remediate children with cognitive impairment when using both music and language compared with music or language alone.
Music therapy methods and music-based techniques can address therapeutic goals. For example, therapeutic song writing, music lessons, and improvisation; music-based relaxation techniques; music-based play therapy[6,45-47]; and involvement in audiovisual music-based educative audio productions about cancer treatment.[48]	Stress reduction provides a good context for learning. Young children may not have the developmental or emotional capacity to verbalize difficulties related to cancer experiences and so may particularly benefit from nonverbal forms of expression. Music-based methods may improve children's self-esteem, mood, and coping. For example, children can display musical talents acquired and song compositions created during treatment when returning to school. Involvement in a personalized audiovisual product, created during radiation treatment, has also reduced school bullying of a pediatric patient with cancer.[48] A radiation therapist's clinical audiovisual intervention also enabled music or a music therapist to support very young children in enclosed radiation therapy bunkers, ceasing the need for anesthesia.[49]

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