Article

The effects of music training on dyslexia: A selected literature review

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Abstract

This article reviews research on the neurological bases of dyslexia, examines the effects of music training on dyslexia, and investigates interrelationships between music, the brain, and dyslexia. Recent results in studies on the neurobiology of dyslexia lend credence to the effects of music training on dyslexia. This article may be of interest to teachers and researchers in the areas of Special Education and Music, and those who wish to better understand dyslexia.

In recent years, dyslexia causes and remediation have been an active area of research in the education literature. This article reviews research on the neurological bases of dyslexia, examines the effects of music training on dyslexia, and investigates interrelationships between music, the brain, and dyslexia. Results in studies on the neurobiology of dyslexia lend credence to the effects of music training on dyslexia. I have selected studies on the effects of music training on dyslexia examining rhythmic timing skills, rapid auditory processing skills, auditory stream biasing, and noise exclusion. These areas of study parallel various causal theories of dyslexia.

The Dyslexia Debate

Developmental dyslexia is a learning disability characterized by difficulty in acquiring reading, writing, and spelling skills despite sufficient intelligence, education, and social circumstances (Katzir, 2009; Overy, 2003; Ramus, 2003). Approximately 3–5% of all children and adolescents are diagnosed with dyslexia (Ouimet & Balaban, 2010; Ramus, 2003; Ziegler, Pech-Georgel, George & Lorenzi, 2009). Dyslexia is considered neurobiological in origin (Chandrasekaran & Kraus, 2010; Forgeard et al., 2008).

There is an ongoing debate as to whether dyslexia is due to a phonological deficit, a sensorimotor dysfunction, or a combination of the two. Phonological research finds that children with dyslexia have difficulty processing speech sounds, i.e., distinguishing similar phonemes (e.g., /p/ and /b/), and segmenting words into phonemes (p-a-t), and syllables (pat-tern) (Forgeard et al., 2008). Sensorimotor theory sees dyslexia as an auditory impairment, a magnocellular visual deficit, or a cerebellar/motor dysfunction (Ramus, 2003). In the auditory system, a proposed temporal processing deficit occurs during rapid processing and naming; a similar deficit in the visual system is thought to occur in magnocells (White et al., 2006). The magnocellular system controls three skills that relate to reading ability: visual search, control of eye movement, and direction of visual attention (Démonet, Taylor, & Chaix, 2004). The magnocellular theory has expanded to involve a discussion of magnocells that could affect auditory and cerebellar dysfunction (White et al., 2006). Cerebellar impairment is thought to affect balance, automaticity, and motor and timing skills. As part of the magnocellular theory, reading would be impacted by a visual deficit through a lack of automaticity, and phonological skills would be influenced by weak articulatory ability (White et al., 2006). In addition to reading problems, many children with dyslexia also have sensory difficulties in visual, auditory, and tactile areas, and problems with motor control and balance in situations requiring attention (Démonet, Taylor, & Chaix, 2004; Ramus, 2004). However, empirical evidence does not support the link between articulation and phonological and literacy skills, and motor deficits appear to affect only 30–50% of individuals with dyslexia (Ramus, 2003).

The existence of subtypes of children with dyslexia is another possibility: neuropsychological research has found discrete groups of children with dyslexia distinguished either by phonological processing or naming-speed deficits (Katzir, 2009). While neuroscience research has provided some answers to the dyslexia debate, there is no definitive solution to date.

The Mozart Effect

The Mozart Effect, a phenomenon based on a University of California study (Rausher, Shaw & Ky, 1994) resulted in a common perception that *music makes you smarter*. However, research has since indicated that the Mozart Effect was not attributable to Mozart, but to elevated mood and arousal levels promoted by lively music in a major key, which in turn promoted capability on a spatial test (Thompson, Schellenberg, & Husain, 2004). Rausher, Shaw, and Ky (1994) investigated the short-term effects of listening to music. While several studies have endeavoured to replicate these findings, most research since has focused instead on the longer-term effects of music training on cognition and perception.

Research interest in music regarding dyslexia is related to the relationship between music training and increased brain development and plasticity (e.g., Ozdemir, Norton, & Schlaug, 2006; Schlaug et al., 2009; Schlaug, Altenmüller, & Thaut, 2010; Trainor, Shahin, & Roberts, 2009). Studies using magnetic resonance imaging (MRI) have found more developed brain structures in musicians than non-musicians. The activation of similar brain structures in music and language processing has stimulated investigation into transfer effects, in which learning in one area reinforces another.

Studies on the effects of music training on dyslexia include examination of rhythmic timing skills (Overy, 2003), rapid auditory processing skills (Forgeard et al., 2008), auditory stream biasing (Ouimet & Balaban, 2010), and noise exclusion (Chandrasekaran & Kraus, 2010).

Dyslexia and Music Training

Rhythmic Timing Skills

In a series of studies examining timing deficits, Overy (2003) suggested that common problems in the areas of language and motor skills in children with dyslexia could be supported through group music lessons. A timing deficit, or temporal processing deficit, is a type of auditory impairment that is said to occur during the processing of rapidly changing stimuli. For example, the phonemes /ba/ and /da/ differ only in formant transitions during the first 40 milliseconds, thus a temporal deficit would result in impaired discrimination and consequential phonological and literacy deficits (White et al., 2006).

Overy (2003) postulated that improved rhythmic timing skills could enhance speech perception, reading proficiency, and motor control. She provided a 15-week music intervention, based on a Kodály approach, for children with dyslexia; games, movement and songs were used that increased in developmental difficulty over time. The program consisted of three 20-minute sessions per week. Nine boys with dyslexia (average age 8.8 years) were assessed with the WORD tests of single word reading and spelling, tests from the Phonological Abilities Test and the Dyslexia Early Screening Test, and musical timing and pitch tests. Statistically significant gains were seen in phonological ($p < .01$), spelling ($p < .05$), rhythm copying ($p < 0.05$), and rapid auditory processing skills ($p < .05$), but not reading skills. Limitations of the study included the lack of a causal relationship between the development of music and literacy skills, and the possible transfer effects, both between singing to phonological skills and reading music to reading text.

Overy (2003) hypothesized that a longer intervention period might result in improved reading skills. However, gains in reading skills in other dyslexia studies are inconsistent. In an overview of dyslexia remediation, Démonet, Taylor, and Chaix (2004) noted that commonly used phonological-based methods led to improvement in phonological capacities, but that "generalisations of remedial effects to reading are inconsistent; success varies depending on individual differences and predictive factors are still to be elucidated" (p. 1457).

The timing deficit hypothesis of dyslexia has received criticism. These deficits appear to exist only in a subset of individuals with dyslexia (Ramus, 2003). Despite these limitations, Overy

(2003) saw improved phonological, spelling, rhythm copying, and rapid auditory processing skills in all of her study participants, rather than a subset; the intervention was largely successful.

Rapid Auditory Processing Skills

In other research on music and dyslexia, Forgeard et al. (2008) examined rapid auditory processing skills. The Forgeard team noted that fMRI studies indicated that speech and non-speech rapid information processing occurred in the same left-hemisphere brain region, and inferred that music, or non-speech, might support phonological, or speech skills. They considered the core deficit in dyslexia to be phonological, with an underlying auditory processing issue.

Forgeard et al. analyzed the effects of music training on phonological and reading skills in children with and without dyslexia. Five children diagnosed with dyslexia with no instrumental music background were compared with five children with normal reading skills and one or more years of instrumental training, and five normal reading children with no instrumental training who served as the control group. Children in the three groups were matched on age, gender, nonverbal reasoning (Raven's Progressive Matrices), and socioeconomic status, ascertained by parental report of highest level of education. All children were tested on the Woodcock Picture-Vocabulary, Letter-Word Identification and Word Attack subtests; the Auditory Analysis Test; and a test of Melodic/Rhythmic Discrimination devised by the researchers. The results of language-related outcomes showed no significant differences between groups in age, socioeconomic status, Picture-Vocabulary and Raven's scores. However, on the Woodcock tests, the music and control groups had significantly higher scores than the group with dyslexia on all three tests (all $p < .01$). Musical discrimination ability in normal-reading children was found to predict phonological and reading skills, and children with music training did better on these tasks than the controls. The controls, in turn, did better on these tasks than the children with dyslexia (all $p < .01$). Musical discrimination in children with dyslexia also "predicted phonological awareness, which in turn predicted reading abilities" (Forgeard et al., 2008, p. 388). Limitations to this study include the small sample size (15 children in all), the lack of detail about the children's music training (type of training, exact duration), and the fact that the music training showed correlation, not causation, in the phonological and reading results.

While the Overy (2003) study found improved spelling, phonological, and auditory skills, but not reading skills in children with dyslexia and music training, the Forgeard et al. (2008) results indicated that music discrimination in children with dyslexia and music training predicted both phonological skills and reading abilities. However, the group of children with dyslexia and music training in the Forgeard et al. study did not outperform the control group without music training, despite their music background.

Auditory Stream Biasing

In another study examining musical experience in children with dyslexia, Ouimet and Balaban (2010) explored a global aspect of auditory temporal processing called auditory stream biasing. Auditory streaming is a perceptual effect that occurs when high and low pure tones are rapidly alternated and seem to split into two different streams of tones, one high and one low. The biasing effect in auditory streaming is thought to evidence the same mechanism that allows one to hear a voice in a crowded room. Therefore, the ability to bias, or split two tones into one would facilitate hearing in a noisy environment. Research has shown that children with dyslexia have difficulty processing short or rapidly varying sounds, with consequences in impaired phonological and literacy skills (White et al., 2006).

Ouimet and Balaban (2010) explored auditory stream biasing in 21 children and adolescents with dyslexia (mean age 11.3), 21 control children and adolescents (mean age 11.4) and 11 control adults (ages 21–51). The children with dyslexia and control children had comparable reading comprehension grade levels, but those with dyslexia recognized significantly fewer words and scored lower than controls on word reading. The researchers acknowledged that children with dyslexia are known to have high levels of reading comprehension despite slow word-recognition skills. Grade levels in reading comprehension and word reading were determined by the Reading Ability Screening Test. To ascertain musical training, participants were asked about the number of years of instrumental or choir experience they had. Most of the control children had music experience (95%), compared to 33% of the children with dyslexia. It was not possible to find a comparable group of controls without music training, due to the pervasive nature of music in regular classes in the study location.

The procedure for testing the participants on auditory stream biasing involved their listening to an *induction,* or introductory sequence of a repeating tone followed by a two-tone sequence. After the induction sequence and a variable delay, participants would detect either *continuous* sound (splitting or streaming) or *new groups* (two tones), and report this by circling one of two representational figures on a sheet of paper. Participants listened to and identified tones in four blocks of 17 randomized trials.

The results revealed that the group of children with dyslexia had significantly fewer streamed responses than the control groups of children and adults. This finding supported the association between dyslexia and auditory processing difficulty. There was no significant difference between the responses of the two control groups. The musically trained dyslexic children had a higher proportion of streamed responses than the dyslexic children and no music training. However, the dyslexic music group had significantly lower proportions of streamed responses than the control children with music training.

Limitations of this study include the small sample size and the fact that music training and length of training were over-represented in the control group. Another limitation was that the type and intensity of the children's musical training was not delineated; experience singing in a class choir or learning an instrument through private lessons was considered to be the same. Ouimet and Balaban (2010) concluded that music training resulted in more auditory stream biasing, reflecting better auditory processing in children with dyslexia. Auditory stream biasing is considered a component of noise exclusion, the subject of the next study.

Noise Exclusion

Noise exclusion comprises extracting information, suppressing unimportant details, storing information, ignoring noise, and using linguistic context to provide information lost in noise. Musicians have enhanced ability in these areas, while children with learning disabilities typically have deficits (Chandrasekaran & Kraus, 2010). In a study on noise exclusion in children with dyslexia and other language-based learning disorders, Chandrasekaran and Kraus considered the benefits of music as an auditory training approach. They reviewed the literature on music training benefits in auditory processing of music and speech. Compared to non-musicians, musicians have demonstrated better verbal memory; better sensory representation of pitch, timing, and timbre; better stream segregation; better working memory and executive skills; and better attention.

Chandrasekaran and Kraus (2010) reported that visual and auditory deficits in children with dyslexia are exacerbated in environments with noise. Visual contrast thresholds in children with dyslexia are usually similar to those in other children, but in noise, these thresholds are elevated. Children with dyslexia also have difficulty with speech perception in noisy environments. This appears to be due to their inability to use previous experience (e.g., the sound of a voice in a quiet setting) to improve auditory representation (e.g., the same voice in a noisy setting). Chandrasekaran and Kraus noted that musicians have better brainstem representation of speech in noise than non-musicians. They proposed that music training might improve literacy through enhanced noise-exclusion ability, moderated by enhanced attention, stream segregation, sensory representation of sound, and auditory working memory.

One limitation of this study is the assumption that improved noise-exclusion ability will lead to improved literacy skills. As seen in the Overy (2003) study and the Démonet, Taylor, and Chaix review, in dyslexia, generalizations of remedial effects to reading are inconsistent.

Music, the Brain, and Dyslexia

Noise exclusion in dyslexia is a recent research focus. Ramus and Szenkovits (2008) outlined the prevailing central components of the phonological deficit, ascertained over the past 30 years: weak phonological awareness (e.g. in phoneme deletion tasks), poor verbal short-term memory (e.g. in non-word repetition), and slow lexical retrieval (e.g. in rapid naming). They postulated that one or more of these components could be responsible for weak verbal skills in dyslexia. The first component involves attention to and manipulation of information—a central executive processor. The second involves short-term storage and cycling between input and output—a phonological loop. The third involves the retrieval of phonological representations from long-term memory. According to these researchers, the most widely accepted current hypothesis of dyslexia considers phonological representations to be degraded; they are noisier or have a lower resolution than they should. Ramus and Szenkovits conducted cognitive assessments of university students with dyslexia and controls using motor, visual, auditory and phonological tasks. They found that phonological representations appeared to be normal; the issue in dyslexia was phonological access, i.e., access to short-term memory, the phonological loop, and long-term memory. They concluded that individuals with dyslexia have intact auditory and visual representations, but have difficulty accessing representations “under certain conditions involving storage in short-term memory, speeded or repeated retrievals, extraction from noise, and other task difficulty factors” (p. 139). A limitation of these findings is that university students may have better phonological representations than children due to compensation or recovery; the researchers suggested replication of the assessments on children.

Ramus and Szenkovits (2008) hypothesized that additional auditory or visual deficits would also represent access issues; the range of deficits would parallel the extent of cortical dysfunctions. Ramus (2004) posited cortical abnormalities to explain the wide range of possible deficits in dyslexia. Cell migration anomalies have been observed in dyslexic brains. This is accompanied by mild disorganization of adjacent cortical layers. Ramus postulated that variations in cortical abnormalities could produce variations in phonological deficits.

This etiology of dyslexia supports the use of music training to reinforce the acquisition of literacy skills through alternate neural pathways. Schlaug et al. (2009) found significant structural changes in the brain as a result of early intensive music training. Active music training leads to more brain plasticity than listening to music, as it is multisensory (Trainor, Shahin, & Roberts, 2009). This reinforces Overy's (2003) conclusion that rhythm and singing games improve spelling, phonological, and auditory skills in children with dyslexia. The Forgeard et al. discovery that music training predicts music discrimination, phonological skills, and reading abilities in children with dyslexia is also pertinent. Music processing relies on a bihemispheric network. Language processing shares some of the same neural substrates. This indicates a shared system for motor preparation and execution, and sensory feedback control (Ozdemir, Norton, & Schlaug, 2006). Given the shared neural correlates, the Forgeard et al. research connecting music training to reading is credible.

If phonological representations in children with dyslexia are degraded, and degraded representations are due to weak phonological awareness, poor verbal short-term memory, and slow lexical retrieval, then Chandrasekaran and Kraus' (2010) proposal is significant. Music training may enhance noise-exclusion ability, attention, stream segregation, sensory representation of sound, and auditory working memory. Ouimet and Balaban's (2010) findings that music training results in more auditory stream biasing and better auditory processing capability are also relevant. These findings are substantiated by structural MRI reports showing that musicians, compared with non-musicians, have differences in gray matter in auditory, motor, and visual brain regions.

Conclusions

This article began with an overview of the conventional theories on the etiology of dyslexia: phonological, sensorimotor, and mixed. It ended with a less conventional, but thought-provoking theory: individuals with dyslexia have intact auditory and visual representations, but have difficulty accessing representations because of phonological noise due to weak phonological awareness, poor verbal short-term memory, and slow lexical retrieval. Additional auditory or visual deficits also represent access issues; the deficits parallel the extent of cortical dysfunction caused by cell migration anomalies (Ramus & Szenkovits, 2008). In the four studies on the effects of music training on children with dyslexia, findings included improved spelling, phonological, and auditory skills (Overy, 2003); a correlation between music training, music discrimination, phonological skills, and reading abilities (Forgeard et al., 2008); more auditory stream biasing, and resulting better auditory processing capability (Ouimet & Balaban, 2010); and postulated enhanced noise-exclusion ability, attention, stream segregation, sensory representation of sound, and auditory working memory (Chandrasekaran & Kraus, 2010). While some of these results are hypothetical, they are based on neuroimaging studies of musicians and non-musicians, anatomical data on dyslexic brains, and research on music processing in the general population.

Given the results of the reviewed studies, it seems apparent that music training can support weak phonological awareness, poor verbal short-term memory, and slow lexical retrieval due to its multisensory nature and its effect on brain plasticity and shared neural pathways. Thus, while the Mozart Effect's contention that *music makes you smarter* may be overstated, the effects of music training on dyslexia may be understated. Further research on the Ramus and Szenkovits (2008) theory with children instead of adult participants may substantiate this model, and more research using music as an intervention for larger samples of children with dyslexia may corroborate the four studies reviewed in this article.

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