Dyslexia in the Music Classroom: A Review of Literature

James L. Reifinger Jr.

Southern Illinois University Carbondale

published in

(2019) *Update: Applications of Research in Music Education.* doi:10.1177/8755123319831736

Abstract

Developmental dyslexia, or specific reading disorder, is a reading impairment characterized by persistent difficulty in word recognition, decoding, and spelling skills in children despite having average or above academic performance in other areas. To increase an understanding of the nature of dyslexia and its relationship to music, this article first discusses the process of typical reading development and how researchers believe this process is impaired for individuals with dyslexia. Dyslexia identification and interventions are then explained. Next, research that shows how music skills may differ for students with dyslexia is presented. Experimental studies have shown that music training has been an effective way to improve reading skills in children with dyslexia. To understand why musical training might improve reading ability, the Precise Auditory Timing Hypothesis proposed by Tierney and Kraus (2014) is discussed, along with implications for music education.

Keywords: auditory skills, dyslexia, music intervention, reading development, rhythmic skills

Dyslexia in the Music Classroom: A Review of Literature

Most children develop proficiency in reading to a level at which they are able to read even unfamiliar words and nonsense words by third grade (Shaywitz, 2003). For some children, however, learning to read is a struggle despite having average or above academic performance in other areas. Developmental dyslexia has been defined as a reading impairment characterized by persistent difficulty in acquiring skills in word recognition, decoding, and spelling that is not attributable to low intelligence, lack of access to educational opportunities, uncorrected visual or hearing impairment, or mental or neurological disorders (Goswami, 2011). It has been estimated to affect approximately 7% of children across cultures (Goswami, Power, Lalier, & Facoetti, 2014). Dyslexia has been listed as an alternative term for a "specific learning disorder . . . with impairment in reading" in the *Diagnostic and Statistical Manual of Mental Disorders*; the terms dyslexia and specific reading disorder are now used interchangeably (American Psychiatric Association, 2013, pp. 66–67). In the same way that reading skill is measured on a continuum and changes over time, reading impairment occurs in varying degrees of severity and should not be considered static. Because music educators are likely to work with students with dyslexia at some point, **t**his article reviews literature that explains the nature of dyslexia and the typical characteristics and abilities of students with dyslexia, information that can be helpful when planning and implementing instruction. Research is also presented that has shown music training plays an important role in supporting reading development for all children, and especially for children with dyslexia. Based on these finding, guidance is provided for addressing specific aspects of music instruction that may be most important to consider when helping students with dyslexia learn and participate in music in a range of settings, from elementary general music to middle or high school ensembles.

Neuroimaging research has revealed that dyslexia has a biological basis. It has been associated with atypical structure and connectivity of various brain areas that are used in reading (Démonet, Taylor & Chaix, 2004; Hoeft et al., 2006; Williams, Juranek, Cirino, & Fletcher, 2018). Dyslexia is also believed to be hereditary, as it has been reported to occur in approximately 40–60% of children who have a parent with dyslexia (Shaywitz, Shaywitz, Fletcher, & Escobar, 1990). Brain peculiarities found in children and adults with dyslexia have also been found in pre-reading children who were at risk for dyslexia because of family history. Because these brain characteristics were evident prior to the beginning of reading instruction, they have been attributed to heredity and not to experiences or lack thereof (Raschle, Chang, & Gaab, 2011).

Reading Development

Prior to reading instruction, young children learn to understand and speak language naturally through experiences, and they need to become aware that words are made up of a series of distinct phonemes, a concept referred to as phonemic awareness (for a review, see Pressley & Allington, 2015). For example, the one-syllable word cat is made up of three sounds: /c-/a/-/t/. To develop and improve phonemic awareness, children learn to blend, segment, and manipulate phonemes from the beginning, middle, and ends of syllables. When children are fluent with hearing and manipulating the smallest units of speech, they are ready to associate them with printed letters as they learn to read and spell. Phonemic awareness is both a prerequisite for and a consequence of learning to read.

Reading attainment requires both word decoding and overall comprehension. In individuals with dyslexia, ability to comprehend appears to be intact, but is impeded by the inability to decode and identify certain words (Shaywitz, 2003). When reading a passage and

answering comprehension questions, a student can use context clues to glean the meaning of words that he or she is unable to decode. As a result, a student with dyslexia will tend to have better performance on measures of comprehension and worse performance on decoding isolated words. Hence, assessing a student's ability to decode individual words in isolation may be the most appropriate way to evaluate a student for dyslexia.

What Causes Reading Impairment?

Theories of the basic reasons why learning is impaired for individuals with dyslexia have included those based on visual processing, speech processing, and cognitive or rapid auditory processing speed deficits. Tallal (1980) proposed an influential hypothesis for a cause of dyslexia, referred to as the temporal order perception theory of dyslexia. The theory proposes that dyslexia stems from an auditory processing deficit, more specifically, an impairment in the ability to hear and process acoustical aspects of sounds that unfold very rapidly. The theory was supported by an experiment in which children ages 8 to 12 with and without reading impairment listened to a series of two tones, one high and one low, and had to determine their order. When the tones were separated by a 400 milliseconds (ms) gap, all participants performed similarly; but when the tones were separated by a gap of only 60 ms or less, the children with reading impairment were significantly poorer than normal readers in their ability to determine the sequence of the tones. The use of nonverbal aural material as opposed to speech material helped to establish that the performance impairment was the result of deficiencies in general auditory processing ability and not a lack of skill with phonics. Performance on this tone order task strongly correlated with the students' ability to decode nonsense words, a test of skill in applying sounds (phonemes) to letters (graphemes). In a follow-up paper to explain why impairment in discriminating two short tones might be related to impairment in learning to read, Tallal (2004)

pointed out that hearing the difference between /ba/ and /da/ can only be achieved by distinguishing the contrast that occurs within the initial 40 ms of the sound. She suggested that the 40 ms during which the rapid acoustic changes occur is the critical time window that is necessary for an individual to be able to track temporal order across ongoing speech.

While consensus is building among researchers that dyslexia stems from difficulties with phonological processing as hypothesized by Tallal, diverse theories of the underpinnings of dyslexia continue to be explored, including the idea that there may be subtypes of dyslexia associated with different types of deficits (Vellution, Fletcher, Snowling, & Scanlon, 2004; Ramus & Ahissar, 2012). Many different cognitive processes are involved in learning to read and temporal processing deficit cannot account for all cases of dyslexia. Along with her original hypothesis, Tallal (1980) addressed this by pointing out that the reading impaired population should not be viewed as homogeneous in terms of the nature of deficiencies.

Research studies have consistently identified three areas related to phonology in which performance is impaired for individuals with dyslexia: phonological awareness, verbal short-term and working memory, and rapid automatized naming. Verbal short-term and working memory involves the ability to mentally hold and process information, beyond just perceiving it. Rapid automatized naming involves the automaticity with which an individual is able to convert visual information to speech sounds, a cognitive process that occurs in early reading development. It is assessed by having the individual view pictures of familiar items or colors and orally name them as rapidly as possible (Vellution et al., 2004).

Perception and Processing of Speech

An analysis of the acoustical properties of speech sounds will help to explain how speech perception may differ in individuals with dyslexia. Speech sounds include harmonics, similar to

how musical pitches contain overtones. The harmonics of speech sounds are referred to as formants because they encompass a range, or band of frequencies in which each harmonic resonates (Schnupp, Nelken, & King, 2011). Different speech sounds are distinguished, in part, by which formants are more pronounced than others. For example, /o/ versus /a/ is distinguished by the differences in loudness, or intensity, of certain formants without affecting the overall pitch. This is similar to how, in music, different strengths of overtones affect the timbre of musical sounds without changing the pitch. Speech sounds include both vowel sounds and consonants. Vowels have a sustained state, albeit brief, during which the formats are not changing. Consonants are made up of very rapid changes in formants, referred to as formant transitions. Individuals with dyslexia have difficulty processing rapid formant transitions (Tallal, 2012).

To provide an illustration of rapid formant transitions in speech sounds, Tierney and Kraus (2013a) presented an analysis of a sample utterance of the speech sound /da/ spoken at a pitch around G2. The voiced portion begins after a 5 ms lag between the initiation of the sound in the larynx and the burst of sound. During the 5 to 50 ms before the sound stabilizes on the vowel, the formants that make up the consonant move. The first formant rises from G4 to F#5 (400 to 720 Hz), the second and third formants fall from G#6 to D#6 (1700 to 1240 Hz) and from E7 to D#7 (2580 to 2500 Hz) respectively. Thus, the speech sound has two time windows: the very rapid formant transition period of the consonant (about 1/20th of a second), and the steady-state period of the vowel. Using a slightly different perspective, Goswami (2011) and colleagues referred to the transition occurring at the beginning of a speech sounds as rise time, the time from the sound beginning to the point at which it reaches full volume, similar to what musicians refer to as attack in music. For example, rise time is faster with /ba/ than with /wa/. An individual's

difficulty with hearing rapidly occurring changes in speech sound would result in degraded aural images of the phonemes. This would later result in difficulty with associating the phonemes with their graphemes when learning to read.

Dyslexia Identification and Intervention

Most children with reading impairment can acquire proficiency in reading if they are identified early and receive remedial reading instruction based on their individual needs (Shaywitz, 2003; Torgesen, 2000). Unfortunately, dyslexia often is not diagnosed prior to second grade, the point at which it is obvious that a child is falling behind in reading and spelling (Goswami et al., 2014; Ozernov-Palchik & Gaab, 2016). Paradoxically, interventions have been found to be most effective when implemented while the child is in kindergarten and first grade, a critical time when neural reorganization might be achieved with greater efficiency (Torgesen, 2000; Wanzek & Vaughn, 2007), and before the child has lost the opportunity to read thousands of words compared to peers (Shaywitz, 2003). With improvements in early detection, intervention may likewise be implemented earlier. At the pre-reading stage, potential indications may be detected in language skills, including difficulty with rhyming and mixing up words that sound alike. Early language impairment is strongly linked to later problems with reading development (Catts, Fey, Tomblin, & Zhang, 2002). Because dyslexia is associated with alterations in brain structure and function, MRI imaging may be a possible means by which pre-reading identification can be made, but costs and availability prohibit this option in most cases (Ozernov-Palchik & Gabb, 2016). Behavioral testing has been suggested as the most effective way to screen preschool children who may be at risk for dyslexia (Démonet et al., 2004). Based on the strong relationship found between reading readiness skills and performance on music rhythm tasks, a simple musical task such as tapping a steady beat has been suggested as a way to

evaluate and identify very young children who may be at risk for later development of reading difficulty (Kraus & Anderson, 2015). Assessment of beat-keeping ability offers unique advantages in that it can be reliably assessed at a very young age and is not constrained by language and memory ability that more traditional types of assessments might require. While published assessment batteries to identify prereaders who may be at risk for experiencing reading difficulties generally do not include tasks that assess music skill, music teachers can help with screening students by assessing the beat-keeping skills of all young children in the instructional setting. Commercial products such as Interactive Metronome have been developed and are being marketed as a remediation tool for dyslexia, but rigorous validity studies still need to be conducted.

Interventions for dyslexia generally involve supplemental practice and individual attention to improve phonological awareness skills. Enhancing students' mental representations of phonemes can improve their ability to access those phonemes as they learn to read. Research has shown that rapid and significant improvement in reading skills can result from auditory interventions, including experiences in music education (see Table 1). One of the interventions that was implemented in the past was the use of colored overlays or lenses to change the background color of printed materials. This was an attempt to enhance the visual processing of students with dyslexia. Citing a lack of scientific evidence to support the efficacy of special tinted filters, the American Academy of Pediatrics published policy statements in 2009 and 2014 announcing that special tinted filters are not endorsed and should not be recommended (American Academy of Pediatrics, 2009, 2014).

While dyslexia can be remediated, it usually persists into adulthood to some extent. Individuals with dyslexia can improve reading accuracy, but reading often remains effortful and

does not reach the level of automaticity that is achieved by normal readers (Shaywitz, 2003). This implies that working with students with dyslexia is not just a concern for elementary music teachers. Lack of automaticity in reading remains a symptom of dyslexia in successful adults. For students in secondary school or college, management of dyslexia shifts from remediation to accommodation. This would include providing additional time for reading tasks, audio supports such as recording of lectures or books, and alternative assessments such as orally administered tests, essays, or reports. Multiple-choice questions are especially difficult for students with dyslexia because of the limited availability of context clues to help in decoding words.

Music Skill Differences with Dyslexia

Because dyslexia is a reading disorder, a music teacher might assume that the most important skill area to be aware of for students with dyslexia would be their music notation reading skills. While all students vary in terms of their musical strengths and weaknesses, research studies have led to some general observations about the musical skills of students with dyslexia. These findings indicate that the most important skill area that music teachers need to be concerned with is not music notation reading skills, but rhythmic skills.

At the pre-reading stage, children ages 3 and 4 who cannot tap a steady beat have been found to perform significantly lower than those who can on assessments of pre-reading skills, including phonological processing, auditory short-term memory, and rapid naming (Carr, White-Schwoch, Tierney, Strait, & Kraus, 2014). Inability to keep a steady beat can be an early marker for preschool children who are at risk for difficulties in learning to read. At age 5, students' ability to discriminate whether two rhythm patterns were the same or different was found to be a significant predictor of their ability to associate speech sounds to letters (Ozernov-Palchik, Wolf, & Patel, 2018). At age 6, students identified as at risk for dyslexia performed significantly worse

than their lower risk peers when discriminating if two rhythms or two tempos were the same or different, and when performing rhythm patterns (Overy, 2000).

At the stage of learning to read, a linear trend has been found between pre-reading rhythm skills and longitudinal reading development; the better a student's rhythm reproduction skills at age 5, the better his or her reading performance at age 7 (Dellatolas, Watier, Normand, Lubart, Chevrie-Muller, 2009). At age 7, 8 and 9, the ability to perform rhythm patterns was found to be impaired for students who were identified as learning-disabled readers (Atterbury, 1985; Overy, 2003). For 10-year olds with dyslexia, the ability to tap accurately with a metronome predicted the students' literacy and phonology skills; students who were the most inconsistent with keeping a beat had the poorest literacy and phonological development, regardless of I.Q (Thomson & Goswami, 2008). With 8- to 11-year olds with dyslexia, rhythm reproduction ability was found to be a significant predictor of students' ability to read non-words (Flaugnacco et al., 2014). Wolff (2002) compared the rhythm performance skills of students with dyslexia with non-dyslexic peers ages 10 to 16, none of whom had received formal music instruction. Those with dyslexia were two to three times more inaccurate when tapping to a beat, had greater difficulty adjusting to a new tempo, and were significantly less accurate in tapping by rote a simple 4-beat rhythm pattern (quarter, quarter, eighth-eighth, quarter). Performance of the rhythm pattern was even worse when the students with dyslexia had to synchronize it with a metronome at their preferred tempo. When required to perform the pattern at a slightly faster tempo, their performance was described as "essentially undecipherable" (Wolff, 2002, p. 195).

Related to rhythm, musical meter is another area of difficulty for students with dyslexia. A study with 8- to 13-year olds revealed that students with dyslexia had difficulty hearing if two short rhythmic ostinatos used the same or different meters (Huss, Verney, Fosker, Mead, &

Goswami, 2011). This study found that the students' ability to discriminate meter predicted their reading and spelling ability, even after accounting for their phonological awareness ability. Flaugnacco et al. (2014) found that ability to discriminate same or different meters was a significant predictor of reading accuracy and reading speed for 8- to 11-year olds with dyslexia. Wolff's (2002) study with 10- to 16-year olds found that the students with dyslexia were less accurate than normal readers in vocally reproducing (on *pa*) repeated 3- and 4-beat metrical patterns with vocal accents on various beats.

In terms of pitch perception, some studies have shown that hearing pitch differences of a half-step or less is more difficult for children and adults with dyslexia, but with pitch differences larger than a half step, those with and without dyslexia did not differ in ability to discriminate pitch differences (Hämäläinen, Salminen, & Leppänen, 2012; Overy, 2000, 2003). Students with dyslexia may have greater difficulty detecting pitch changes within tonal patterns, but they do not differ from normal readers in ability to identify contours (Ziegler, Pech-Georgel, George, & Foxton, 2012). Students with dyslexia also do not differ from their peers in ability to perceive differences in dynamics (Hämäläinen et al., 2012).

In terms of reading music, a type of dyslexia specific to music notation, referred to as dysmusia, has been proposed based on anecdotal evidence (Gordon, 2000). However, no scientific evidence has been offered to support the existence of a type of dyslexia associated with music reading difficulty. Reading notation in the act of performing music is a complex task requiring the integration of a host of perceptual, cognitive, and motor processes. Most music educators would agree that it is a challenging skill to acquire for most students and difficulties might be experienced in any number of different areas. In a study by Benson, Lovett, and Kroeber (1997), children with and without reading impairment were taught to associate abstract

symbols to corresponding notes on a music keyboard and were then assessed on their ability to read and play, using the notation. The students with reading impairment did not differ from age-matched non-reading impaired peers or reading-level matched peers in their ability to learn to read and play these special music symbols. The researchers pointed out that music reading does not require the phonological skills of segmenting and blending that are essential to language reading. Given these findings, it seems misleading, and perhaps inappropriate, to characterize difficulty in learning to read music notation as a disability that is similar to, and comorbid with dyslexia.

Studies Using Music for Reading Intervention

Music training has been shown to lead to improvements in phonological, reading, and spelling skills for students with dyslexia (see Table 1). A pilot study by Douglas and Willatts (1994) involving a small group of 8- to 10-year olds with reading difficulties assigned students to either a supplemental classroom music instruction group or a collaborative discussion group for 6 months. The mean posttest reading score was significantly higher for the group receiving music instruction than the group participating in extra discussion. A landmark study by Overy (2003) involving students with dyslexia used music activities that focused on developing students' rhythmic skills. Overy suggested that the processing of sounds of language and music draws upon shared cognitive mechanisms, and training in the domain of music may be used as an intervention to improve cognitive processes that are also used in the domain of language.

Recent experimental studies examining the effects of music instruction on improving reading skills of all students, not just those identified with reading disability, have found similar results, affirming the potential for music education to contribute to the improvement of reading skills. Degé and Schwarzer (2011) conducted an experimental study in which 5- and 6-year olds

(pre-readers) were assigned to groups receiving either phonological training, music training, or sports training. Training took place for 10 minutes daily for 20 weeks. Both the phonological training and the music training groups, but not the sports training group, experienced significant pre- to post-test improvement in phonological awareness. Another experimental study with 8-year old normal readers examining the effects of music training on reading development found significant improvement in word reading ability after 6 months of general music lessons, but not painting lessons (Moreno et al., 2009).

Experimental studies examining the effects of music training on improving reading skills with students with dyslexia have found similar results. Thomson, Leong, and Goswami (2013) conducted an experimental study in which 9-year olds with dyslexia were assigned to either a rhythm training, phonemic training, or a control group. Training took place one-on-one for 30 minutes once a week for 6 weeks. Both the rhythm training and the phonemic training groups, but not the control group, experienced significant gains in phonological awareness. Flaugnacco et al. (2015) conducted an experimental study in which 8- to 11-year olds with dyslexia were assigned to either music training or painting training groups. Training took place for 2 hours a week for 7 months. The music training group, but not the painting training group, experienced significant improvement with reading tasks, working memory, and rhythm performance. Reading speed increased for both groups, but reading accuracy increased only in the music training group. The researchers observed that the greater improvement in rhythmic abilities, the greater the improvement in the student's phonological awareness. They suggested that music training can provide a form of remediation that is different from, though complementary to language-based remediation approaches.

How Would Music Training Improve Reading?

The relationship between rhythm and reading skills has been demonstrated in typically-developing students, not just those experiencing reading difficulty, leading researchers to believe that both skills used the same shared neural resources (Tierney & Krause, 2013b). Acquiring skill in both domains relies on consistent accurate timing processing in the auditory system. With music, the listener or the performer must focus on the precise alignment of the onset of sounds to the desired timing position. This alignment occurs within milliseconds of accuracy when synchronizing movements while performing beats or rhythms and when evaluating the accuracy of these aurally perceived sound events. Sustained attention is also required to monitor the precision between the sound and the motor response and to make ongoing adjustments as needed. Likewise, when perceiving phonemes of language such as initial consonances, the auditory system must be able to perceive and discriminate changes of sounds that occur within tens of milliseconds.

As a framework to understand why musical training may improve reading ability, Tierney and Kraus (2014) proposed the precise auditory timing hypothesis (PATH). According to PATH, the precision with which auditory timing information is registered by neurons in the subcortical auditory system helps determine the precision with which the listener can use and respond to the information. Using an analogy, Tierney and Kraus explained that blurred estimations of the timing of sounds may result if an individual's auditory system is not able to perceive the timing of sounds in a consistent and reliable manner. This imprecise timing perception would have an effect on the precision with which the listener is able to respond to sound input on higher cognitive levels, such as determining if a perceived sound falls into the /b/ or the /d/ category. Ease with, and precision in cognitively discriminating consonant categories

are essential so that a category can be associated with a specific letter when the child later begins learning to read.

Precision in perception of timing information in the auditory system is central for both phonological processing and coordinating movement to sound. When aligning movement to sounds in music, such as tapping the beat or performing a rhythmic chant, the performer has to focus on initiating the sound at the desired timing position with split-second precision. By improving accuracy of auditory–motor synchronizing with musical sounds through music training, greater precision in the perception of the timing information of sounds in general can be achieved, which would lead to improvements in processing of speech sounds. Accordingly, auditory feedback on motor timing accuracy is an important element in understanding the principal mechanism of music–reading transfer.

Discussion and Implications

Given the growing evidence that shows music training enhances basic perceptual and cognitive processes used for speech perception and later reading acquisition, researchers have advocated that music education experiences should be available to all children, and especially students with dyslexia and pre-reading students who are at risk based on poor phonological skills or family history. For example, Kraus and Chandrasekaran (2010) stated, "The beneficial effects of music training on sensory processing confer advantages beyond music processing itself. This argues for an improvement in the quality and quantity of music training in schools" (p. 604). Pointing out that dyslexia may also be characterized by failure to access phoneme representations through connectivity between brain regions, Habib et al. (2016) suggested that intervention should not focus solely on improving phonological representations, but also on improving the access to these representations by enhancing functional connections between brain

regions, which might be accomplished with music training that strengthens these connections. Crucial tracts connecting brain regions fundamental to sound perception and production have been found to be larger in volume in singers and instrumentalists compared to non-musicians (Halwani, Loui, Rüber, & Schlaug, 2011).

While music training cannot replace traditional interventions for children with dyslexia, it can enhance basic perceptual and cognitive skills used in processing sounds. Music participation provides additional opportunities to improve these skills, supplementing reading interventions and approaching learning from a different angle. Music activities can be non-literacy based, avoiding the frustration that students may experience in language learning activities. Because rhythm training has been found to improve reading skills in children with dyslexia (e.g., Habib et al., 2016), music training should focus particularly on the development of rhythm perception and performance skills, focusing on beat, meter, and rhythm more so than on pitch related skills. When performing motor movements to produce sounds for rhythm and beat, students should be encouraged to concentrate on using auditory feedback to improve the precision of timing alignment. This goal would be to use the musical sounds to sharpen general auditory timing perceptual skills that are also used in speech processing, in accordance with the Precise Auditory Timing Hypothesis proposed by Tierney and Kraus (2014). While a main goal might be the improvement of rhythmic precision, music teachers should heartily acknowledge other aspects of students' performance, such as beautiful tone or great expressivity, to help assure that students experience enjoyment and success with music making.

Though students with dyslexia have been found to have greater rhythmic accuracy when they are not required to synchronize with an external beat, it is important that they focus on improving the precision of auditory–motor connections. This might be addressed by performing

beat, rhythm, and metric structure using body movement and instruments in accurate alignment with chants and songs that they are hearing and performing. As a way to impact phonology and language development, Goswami (2011) suggested using singing activities in which students match syllable patterning to metric structure, and also playing instruments or moving in time to rhythms of music and language. Learning to tap the rhythm of songs might also be a way to practice syllable segmentation skills, which may improve spelling skills (Overy, 2003). If a music reading component is included, research has indicated that students with dyslexia should not experience greater difficulty with reading the notation than non-dyslexic peers. However, if notation uses challenging rhythms, music teachers might consider arranging the score, using simplified rhythms to help students with dyslexia achieve greater success. This might be particularly beneficial for secondary students in ensembles.

For many music educators, the primary goals for music instruction are the improvement of musical skills and the development of a greater appreciation for music. These goals remain relevant, even as music instruction can impact learning for children with dyslexia in other ways. In some school settings, students needing remedial instruction may be taken out of music class to receive extra reading support. It would seem that if educators understood the extra benefits of music education, they would be less likely to pull students from music class. The use of music as means of improving reading skills has been documented in research studies, but seems not to have been recognized in practice, at least currently.

On another level, students usually find music activities to be emotional engaging and enjoyable, while in the regular classroom on the other hand, students with dyslexia likely experience greater frustration and fear of failure than peers with typical reading skills. On an affective level, the music room can be an especially important place for learning and emotional adjustment for students with dyslexia, even providing opportunities for constructive interactions

with non-dyslexic peers in the pursuit of shared musical goals. While opportunities for learning in music are important for all students, the potential additional outcomes that arise from music learning make participation in music education especially important for students with dyslexia.

References

American Academy of Pediatrics (2009). Learning difficulties, dyslexia, and vision. *Pediatrics, 124*, 837–844. doi:10.1542/peds.2009-1445

American Academy of Pediatrics (2014). AAP publications reaffirmed or retired. *Pediatrics, 134*, e920. doi:10.1542/peds.2014-1838

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Washington, D.C.: American Psychiatric Publishing.

Atterbury, B. W. (1985). Musical differences in learning-disabled and normal-achieving readers, aged seven, eight and nine. *Psychology of Music, 13*, 114–123. doi:doi.org/10.1177/0305735685132005

Benson, N. J., Lovett, M. W., & Kroeber, C. L. (1997). Training and transfer-of-learning effects in disabled and normal readers: Evidence of specific deficits. *Journal of Experimental Child Psychology, 64*, 343–366. doi:doi.org/10.1006/jecp.1996.2342

Bhide, A., Power, A., & Goswami, U. (2013). A rhythmic musical intervention for poor readers: A comparison of efficacy with a letter-based intervention. *Mind, Brain, and Education, 7*, 113–123. doi:doi.org/10.1111/mbe.12016

Carr, K. W., White-Schwoch, T., Tierney, A. T., Strait, D. L., & Kraus, N. (2014). Beat synchronization predicts neural speech encoding and reading readiness in preschoolers. *Proceedings of the National Academy of Sciences, 111*(40), 14559–14564. doi:10.1073/pnas.1406219111

Catts, H. W., Fey, M. E., Tomblin, J. B., & Zhang, X. (2002). A longitudinal investigation of reading outcomes in children with language impairments. *Journal of Speech, Language, and Hearing Research, 45*, 1142–1157. doi:doi.org/10.1044/1092-4388(2002/093)

Degé, F., & Schwarzer, G. (2011). The effect of a music program on phonological awareness in preschoolers. *Frontiers in Psychology, 2*, article 124. doi:10.3389/fpsyg.2011.00124

Dellatolas, G., Watier, L., Le Normand, M-T., Lubart, T., & Chevrie-Muller, C. (2009). Rhythm reproduction in kindergarten, reading performance at second grade, and developmental dyslexia theories. *Archives of Clinical Neuropsychology, 24*, 555–563. doi:10.1093/arclin/acp044

Démonet, J., Taylor, M. J., & Chaix, Y. (2004). Developmental dyslexia. *The Lancet, 363*, 1451–1460. doi:doi.org/10.1016/S0140-6736(12)60198-6

Douglas, S., & Willatts, P. (1994). The relationship between musical ability and literacy skills. *Journal of Research in Reading, 17*, 99–107. doi:doi.org/10.1111/j.1467-9817.1994.tb00057.x

Flaugnacco, E., Lopez, L., Terribili, C., Montico, M., Zoia, S., & Schön, D. (2015). Music training increases phonological awareness and reading skills in developmental dyslexia: A randomized control trial. *PLoS ONE 10*(9), e0138715. doi:doi.org/10.1371/journal.pone.0138715

Flaugnacco, E., Lopez, L., Terribili, C., Zoia, S., Buda, S., Tilli, S.,…Schön, D. (2014). Rhythm perception and production predict reading abilities in developmental dyslexia. *Frontiers in Human Neuroscience, 8*, article 392. doi:10.3389/fnhum.2014.00392

François, C., Chobert, J., Besson, M., & Schön, D. (2013). Music training for the development of speech segmentation. *Cerebral Cortex, 23*, 2038–2043. doi:10.1093/cercor/bhs180

Gordon, N. (2000). Developmental dysmusia (developmental musical dyslexia). *Developmental Medicine and Child Neurology, 42*, 214–215. doi:doi.org/10.1111/j.1469-8749.2000.tb00073.x

Goswami, U. (2011). A temporal sampling framework for developmental dyslexia. *Trends in Cognitive Sciences, 15*, 1–10. doi:10.1016/j.tics.2010.10.001

Goswami, U., Power, A. J., Lallier, M., & Facoetti, A. (2014). Oscillatory "temporal sampling" and developmental dyslexia: Toward an over-arching theoretical framework. *Frontiers in Human Neuroscience, 8,* article 904. doi:10.3389/fnhum.2014.00904

Habib, M., Lardy, C., Desiles, T., Commeiras, C., Chobert, J., & Besson, M. (2016). Music and dyslexia: A new musical training method to improve reading and related disorders. *Frontiers in Psychology, 7*, article 26. doi:10.3389/fpsyg.2016.00026

Halwani, G. F., Loui, P., Rüber, T., & Schlaug, G. (2011). Effects of practice and experience on the arcuate fasciculus: comparing singers, instrumentalists, and non-musicians. *Frontiers in Psychology, 2*, article 156. doi:10.3389/fpsyg.2011.00156

Hämäläinen, J. A., Salminen H. K., & Leppänen, P. H. T. (2012). Basic auditory processing deficits in dyslexia: Review of the behavioural, event-related potential and magnetoencephalographic evidence. *Journal of Learning Disabilities,46*, 413–427. doi:10.1177/0022219411436213

Hoeft, F., Hernandez, A., McMillon, G., Taylor-Hill, H., Martindale, J. L., Meyler, A., …Gabriel, J. D. E. (2006). Neural basis of dyslexia: A comparison between dyslexic and nondyslexic children equated for reading ability. *The Journal of Neuroscience, 26*, 10700–10708. doi:10.1523/JNEUROSCI.4931-05.2006

Huss, M., Verney, J. P., Fosker, T., Mead, N., & Goswami, U. (2011). Music, rhythm, rise time perception and developmental dyslexia: Perception of musical meter predicts reading and phonology. *Cortex, 47*, 674–689. doi:10.1016/j.cortex.2010.07.010

Kraus, N., & Anderson, S. (2015). Beat-keeping ability relates to reading readiness. *The Hearing Journal, 68*(3), 54, 56. doi:10.1097/01.HJ.0000462430.33997.43

Kraus, N., & Chandrasekaran, B. (2010). Music training for the development of auditory skills. *Nature Reviews Neuroscience, 11*, 599–605. doi:10.1038/nrn2882

Moreno, S., Marques, C., Santos, A., Santos, M., Castro S. L., Besson, M. (2009). Musical training influences linguistic abilities in 8-year-old children: More evidence for brain plasticity. *Cerebral Cortex, 19*, 712–723. doi:10.1093/cercor/bhn120

Overy, K. (2000). Dyslexia, temporal processing and music: The potential of music as an early learning aid for dyslexic children. *Psychology of Music, 28*, 218–229. doi:doi.org/10.1177/0305735600282010

Overy, K. (2003). Dyslexia and music: From timing deficits to musical intervention. *Annals of the New York Academy of Sciences, 999*, 497–505. doi:10.1196/annals.1284.060

Ozernov-Palchik, O., & Gaab, N. (2016). Tackling the early identification of dyslexia with the help of neuroimaging. *Perspectives on Language and Literacy, 42*(1), 11–17.

Ozernov-Palchik, O., Wolf, M., & Patel, A. (2018). Relationships between early literacy and nonlinguistic rhythmic processes in kindergarteners. *Journal of Experimental Child Psychology, 167*, 354–368. doi:10.1016/j.jecp.2017.11.009

Pressley, M., & Allington, R. L. (2015). *Reading instruction that works* (4th ed.). New York, NY: The Guilford Press.

Ramus, F., & Ahissar, M. (2012). Developmental dyslexia: The difficulties of interpreting poor performance, and the importance of normal performance. *Cognitive Neuropsychology, 29*, 104–122. doi:10.1080/02643294.2012.677420

Raschle, N., Chang, M., & Gabb, N. (2011). Structural brain alterations associated with dyslexia predate reading onset. *NeuroImage, 57*, 742–749. doi:10.1016/j.neuroimage.2010.09.055

Schnupp, J., Nelken, I., & King, A. (2011). *Auditory neuroscience: Making sense of sound.* Cambridge, MA: The MIT Press.

Shaywitz, S. E. (2003). *Overcoming dyslexia: A new and complete science-based program for reading problems at any level.* New York, NY: Alfred A. Knopf.

Shaywitz, S. E., Shaywitz, B. A., Fletcher, J. M., & Escobar, M. D. (1990). Prevalence of reading disability in boys and girls: Results of the Connecticut Longitudinal Study. *Journal of the American Medical Association*, *264*: 998–1002. doi:10.1001/jama.1990.03450080084036

Tallal, P. (1980). Auditory temporal perception, phonics, and reading disabilities in children. *Brain and Language, 9*, 182–198. doi:doi.org/10.1016/0093-934X(80)90139-X

Tallal, P. (2004). Improving language and literacy is a matter of time. *Nature Reviews Neuroscience, 5*, 721–728. doi:10.1038/nrn1499

Tallal, P. (2012). Improving neural response to sound improve reading. *Proceedings of the National Academy of Sciences, 109*, 16406–16407. doi:10.1073/pnas.1214122109

Tierney, A., & Kraus, N. (2013a). The ability to move to a beat is linked to the consistency of neural responses to sound. *The Journal of Neuroscience, 33*, 14981–14988. doi:doi.org/10.1523/JNEUROSCI.0612-13.2013

Tierney, A., & Kraus, N. (2013b). The ability to tap to a beat relates to cognitive, linguistic, and perceptual skills. *Brain & Language, 124,* 225–231. doi:10.1016/j.bandl.2012.12.014

Tierney, A., & Kraus, N. (2014). Auditory-motor entrainment and phonological skills: Precise auditory timing hypothesis (PATH). *Frontiers in Human Neuroscience, 8,* article 949. doi: 10.3389/fnhum.2014.00949

Thomson, J. M., Leong, V., & Goswami, U. (2013). Auditory processing interventions and developmental dyslexia: A comparison of phonemic and rhythmic approaches. *Reading and Writing, 26*, 139–161. doi:10.1007/s11145-012-9359-6

Thomson, J. M., & Goswami, U. (2008). Rhythmic processing in children with developmental dyslexia: Auditory and motor rhythms link to reading a spelling. *Journal of Physiology-Paris, 102*, 120–129. doi:10.1016/j.jphysparis.2008.03.007

Torgesen, J. K. (2000). Individual differences in response to early interventions in reading: The lingering problem of treatment resisters. *Learning Disabilities Research & Practice, 15*, 55–64. doi:10.1207/SLDRP1501_6

Vellution, F. R., Fletcher, J. M., Snowling, M. J., & Scanlon, D. M. (2004). Specific reading disability (dyslexia): What have we learned in the past four decades? *Journal of Child Psychology and Psychiatry, 45*, 2–40. doi:10.1046/j.0021-9630.2003.00305.x

Wanzek, J., & Vaughn, S. (2007). Research-based implications from extensive early reading interventions. *School Psychology Review, 36,* 541–561.

Williams, V. J., Juranek, J., Cirino, P., & Fletcher, J. M. (2018). Cortical thickness and local gyrification in children with developmental dyslexia. *Cerebral Cortex, 28*, 963–973. doi:10.1093/cercor/bhx001

Wolff, P. H. (2002). Timing precision and rhythm in developmental dyslexia. *Reading and Writing: An Interdisciplinary Journal, 15*, 179–206. doi:doi.org/10.1023/A:1013880723925

Ziegler, J. C., Pech-Georgel, C., George, F., & Foxton, J. M. (2012). Global and local pitch perception in children with developmental dyslexia. *Brain & Language, 120*, 265–270. doi:doi.org/10.1016/j.bandl.2011.12.002

Table 1

Representative Experimental Studies Examining the Effects of Music Training on Language and Reading Development

Study	Participants	Effects
Bhide, Power, & Goswami (2013)	6- to 7-year olds poor readers	significant improvement in multiple reading measures after 2 months of either rhythm training or phonological training; groups did not differ
Degé & Schwarze (2011)	4- to 5-year olds pre-readers	similar significant improvement in phonological awareness with either musical or phonological training; both group improved significantly more than a sports training group
Douglas & Willatts (1994)	8- to 10-year olds reading difficulties	significant improvement in reading scores after 6 months for music instruction group but not for group participating in collaborative discussion
Flaugnacco et al. (2015)	8- to 11-year olds with dyslexia	significantly improvement in non-word reading, phonemic blending, and working memory after music training, but not painting training
François et al. (2013)	8-year olds	significant improvement in speech segmentation after music training, but not painting training
Habib et al. (2016)	7- to 12-year olds with dyslexia	significantly improvement in word reading, auditory attention, categorizing phonemes, phoneme fusion, and repeating non-words after music instruction
Overy (2003) (Study Two)	8-year olds with dyslexia	significant improvement in phonological skills, spelling, and rapid auditory processing after 15 weeks of music instruction; no control group
Thomson, Leong & Goswami (2013)	9-year olds with dyslexia	significant improvement in phonemic awareness after 6 weeks for phonemic training or rhythm training groups, but not control group; only rhythm training group improved in rise time perception

Implications Statements

- Research has found that students with dyslexia are likely to show impairment with rhythmic skills; therefore, music instruction should emphasize the development and improvement of timing skills. Music teachers might consider arranging parts with simplified rhythms for students with dyslexia.
- Research has found that inability to maintain a steady beat in pre-reading children is a strong predictor of future reading difficulties; therefore, music teachers can help identify students who are at risk for experiencing reading difficulty.
- Research has found that rhythm training can improve reading skills; therefore, students with dyslexia should be given every opportunity to participate in music activities.