Examining the Relationship between Music Skills and Reading Skills

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By

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Abstract

Word recognition in English has the flexibility to be processed at the lexical level (i.e., whole word) or at the sub-lexical level (e.g., focusing on phonological subunits). With this flexibility, recent research suggests that there are individual differences in reading style that rely more on lexical or sub-lexical processing. However, it is still under investigation as to what contributes to these individual differences or what the differences mean for overall reading procedures. The current study examined musical training as a potential correlate of individual differences in reading style. It is well documented that music, language, and reading share similar cognitive processes, and there is evidence that individuals who have musical training background have better reading outcomes. However, there are still gaps in understanding differences in how musicians process words compared to nonmusicians. In this study, measures of subskills in music and reading were collected, in addition to carrying out tasks that tap into correlates of reading style. Results suggest that while there were no differences in word identification, there was some evidence that musicians have better phonological awareness compared to nonmusicians. Furthermore, results suggest that this enhanced skill could be linked to experience with fine-grain timing required in musical training. Taken together, findings suggest that musical training may indeed be related to improved phonological awareness, but that does not necessarily translate to better word reading, per se.

Examining the Relationship between Music Skills and Reading Skills

Both music and language have many different components and uses. Musical components include notes and symbols; uses include pleasure, therapy, as well as playing or listening to music. Similarly, language has components such as letters, words, sentences and many uses, such as reading, studying, and communication. Reading begins with the knowledge and understanding of words; it begins with word recognition and the ability to apply sound and meaning to the word. Understanding of words then can contribute to the comprehension of text. Word recognition is complex, with word representations consisting of three subcomponents: phonology (sounds), orthography (visual), and semantics (meaning; Price, 1998; Perfetti & Hart, 2002). There are thought to be two different routes to identifying a word that differentially rely on phonological processing: lexical and sublexical. The lexical route is thought to access a mental lexicon of whole words, without the need to sound out words phonologically. In contrast, the sublexical route involves the activation of the pronunciation of a word (either regular words or nonwords) by using grapheme-to-phoneme conversion (Joubert et al., 2004), and activation of sub-word units (i.e., letters and phonemes).

Many outside factors can influence the reading procedures of word recognition. Research has identified musical training as one contributing factor to individual differences in reading ability (Besson et al., 2007; Bouhali, Mongelli, & Cohen, 2017; Mongelli et al., 2017). Although music and language have several differences, there are equally a number of similarities (Slevc & Okada, 2015; McMullen & Saffran, 2004). These similarities have led to the relationship between music and language to be examined, and it is well documented that musical training has a relationship with reading and phonological awareness (Patscheke, Degé, & Schwarzer, 2018; Degé & Schwarzer, 2011; Benz, Sellaro, Hommel, Colzato, 2016; Anvari et al., 2002). Although these training studies have suggested that music has a relationship to reading, there is still a gap in the literature in terms of the specific relationship between musical sub-skills and word recognition.

Individual Differences in Reading Style

Research examining individual differences in reading style is rooted in cross-linguistic differences. Studies have suggested that there are differences in reading style of word recognition (e.g., lexical vs. sublexical) across orthographies because of different design features of the writing systems: one example of this is grain size (Ziegler & Goswami, 2005). Grain size refers to the size of the phonological unit that maps onto the smallest orthographic unit in a writing system (Ziegler & Goswami, 2005). For example, Chinese has a larger grain size (i.e., a more direct symbol-to-sound representation) and is processed at the whole word level (Yum, Law, Su, Lau & Mo, 2014). Chinese, as a morphosyllabic language, is composed of characters that do not map onto smaller sound units, but usually represent a morpheme or whole word (Nelson, Liu, Fiez, & Perfetti, 2009). This whole word processing is thought to be at the lexical-level processing (Joubert et al., 2004; Kim, Taft, & Davis, 2004; Monsell, Patterson, Graham, Hughes, & Milroy, 1992).

In contrast, there are also syllabic writing systems, in which orthographic units map onto syllables, which would be considered a medium grain size. In an alphabetic writing system, like English, the orthographic units (e.g., letters) map onto phonemes (the smallest meaningful unit of sound in language), which would be considered a small grain size. Interestingly, in English a reader can learn a word as a whole or by sounding it out (Joubert et al., 2004), which has been demonstrated by the ‘reading wars’ in the American education system (Pearson, 2004). Thus, it is possible for the existence of individual differences within English readers, due to the flexibility of the different grain sizes within English. However, there is currently no widely used behavioral marker for reading style to distinguish between English readers that use one reading style vs. the other.

One measure that has been proposed to identify a more lexical-level (or holistic) way of reading is word inversion sensitivity. Inversion sensitivity has roots in the face inversion effect, positing that faces are processed holistically (Farah, Tanaka, & Drain, 1995). The face inversion effect describes that faces are processed holistically, as compared to other objects that use part-based analysis, and that face recognition is especially orientation sensitive (Farah, Tanaka, & Drain, 1995). The inversion effect has been extended to words to examine the differences in reading styles (Hirshorn et al., in prep; Carlos et al., 2019).

Indeed, word inversion sensitivity and other measures of holistic visual processing have been shown to distinguish between reading styles across writing systems, such as Chinese vs. Korean (Pae et al., 2014; 2016), Chinese-English bilinguals (Ben-Yehuda, Hirshorn, Simcox, Perfetti, & Fiez, 2018), and individual differences within English readers (Hirshorn et al., in prep; Carlos et al., 2019). In English, individuals with greater inversion sensitivity relied relatively less on sublexical phonological measures for both word recognition and passage comprehension (Hirshorn et al, in prep). This pattern is interestingly similar to Chinese-English bilingual readers, who have also shown less reliance on phonological processing for reading (Koda, 1998).

Individual Differences in Laterality of Reading and Reading Style

Connections have also been made between reading style and laterality of reading processing in the brain. For example, cross-linguistic studies have found support for differences in reading styles across writing systems in neural pathways of processing different languages (Nelson, Liu, Fiez, & Perfetti, 2009). In English, the left hemisphere, specifically the visual word form area (VWFA), is activated when reading words compared to consonant letter strings or visual controls, whereas in Chinese, the activation is more bilateral in the VWFA (Nelson, Liu, Fiez, & Perfetti, 2009). Studies using artificial orthographies have been used to study this pattern by examining the differences in laterality of the N170 (Maurer, Zevin, & McCandliss, 2008), a component in event-related potentials (ERPs), that is a marker of visual word processing (and thought to be related to neural activity in the VWFA; Alison, et al, 1994; Brem et al, 2006). Specifically, one study (Yoncheva, Blau, Maurer, & McCandliss, 2010) examined differences in laterality of the N170 when participants learned novel words either trained on whole word forms or through grapheme-to-phonemes rules. Similar to the comparison of English vs. Chinese, results suggested that there is a stronger left-lateralization for training with a focus on phonemes and a stronger right-lateralization for training with a focus on whole words (Yoncheva, Blau, Maurer, & McCandliss, 2010). Another study created two artificial orthographies to examine differences in laterality between a syllabic writing system and an alphabetic writing system. Results suggested that the artificial syllabic writing system showed a more bilateral activity compared to an alphabetic writing system (Hirshorn et al., 2016). Thus, it is not just small versus large grain size units where a difference may be seen, but differences in laterality can be seen when comparing different combinations of grain sizes (i.e., small vs. medium grain size shows a similar pattern as small vs. large). Lastly, there is evidence that reading style, defined by inversion sensitivity in English is related to VWFA laterality (Carlos, Hirshorn, Durisko, Fiez, & Coutanch, 2019), such that individuals with greater inversion sensitivity have more bilateral VWFA processing, which is also consistent with a more ‘holistic’ style of reading.

Behavioral lateralization studies have consistent results with measures of electrophysiological lateralization such that a presentation in the right visual field led to larger N170 in the left hemisphere (Dudas, Plaut, & Behrmann, 2013; 2014). The current study utilized a behavioral lateralization/visual field task to try to identify any group differences in laterality of word processing between musicians and nonmusicians.

Musical Training and Reading

An important outstanding question remains: Where do individual differences in reading style in English come from? One intriguing potential source of some individual differences in reading is exposure to musical training. It has been argued that music and language share underlying cognitive processes. Music and language are both complex processes with some seemingly analogous structural features: music encompasses pitch, melody, rhythm, and harmony whereas language encompasses phonology, semantics, syntax, morphology, and pragmatics (Besson, Chobert, & Marie, 2011). Some similar properties include: an array of different pitches and sound structures (prosodic cues); single phonemes in language and single notes in music (McMullen & Saffran, 2004). Furthermore, both music and language are hierarchical and governed by rules (Slevc & Okada, 2015). Finally, the individual units in both music (notes) and language (phonemes) can be identified even if they change in pitch, volume, tempo, or timbre, indicating a perceptual constancy (Dowling & Harwood, 1986, as cited in Anvari et al., 2002).

Perhaps not surprisingly, it is well documented that music relates positively to reading either through training programs (Degé & Schwarzer, 2011; Patscheke, Degé, & Schwarzer, 2018; Mortiz, Yampolsky, Papadelis, Thomson, & Wolf., 2013); identification of the relationships between developing reading and musical skills (Anvari, Trainor, Woodside, & Levy, 2002); or association claims (Proverbio, Manfredi, Zani, & Adorni, 2013; Benz, Sellaro, Hommel, & Colzato, 2016; Besson, Schön, Moreno, Santos, & Magne, 2007; Magne, Schön, & Besson, 2006; Gromko, 2004; Marie, Besson, Magne, 2011; Gordon, Fehd, & McCandliss, 2015; Mongelli, Dehaene, Vinckier, Peretz, Bartolomeo, & Cohen, 2017; Bouhali, Mongelli, & Cohen, 2017). For example, one study examining children (mean age of 5.9) conducted a training study in which there was a music group, phonological skills group, and a control group (Degé & Schwarzer, 2011). The music training consisted of singing, drumming, rhythm, basic notation, and intervals. The phonological skills consisted of rhyming, phoneme and syllable recognition, and introduction to words and sentences. This study examined phonological awareness scores before and after the training. Results showed that prior to phonological skills or music training, all three groups did not statistically differ from one another on phonological awareness. However, after training, both the music group and the phonological skills group scored statistically higher than the control group on phonological awareness. Importantly, the phonological skills group and music group did not statistically differ from one another post-test, suggesting that a musical training program has the same effect on phonological awareness as a phonological skills program.

Some specific aspects of music that have been examined in relation to reading are pitch and rhythm. In one study, also examining children (Anvari et al., 2002), it was illustrated that pitch and rhythm are separate entities by the age of five and were found to have different correlation patterns. The authors found that pitch correlated significantly with reading (i.e., letter identification and word reading), but not vocabulary, whereas rhythm correlated significantly with vocabulary but not reading. However, both rhythm and pitch correlated with a composite phonological measure consisting of tests at the phonemic, syllable, and rime levels. It is still unclear however, if these different musical subskills are related to different levels of phonological skills.

Other research has suggested that pitch and rhythm relate to phonological awareness specifically on the phoneme and syllable level (Besson et al., 2007; Marie et al., 2011; Magne et al., 2006; Overy, Nicolson, Fawcett, & Clarke, 2003; Moritz et al, 2013). One study examining kindergartners (Moritz et al., 2013) found that a group that received daily music training showed better phonological awareness than the group who received training once a week. Specifically, rhythm pattern copying was significantly correlated with syllable segmentation and marginally significantly correlated with initial phoneme isolation and syllable deletion. It was suggested that because both rhythm and language involve specific timing between notes and words or syllables, rhythm training can strengthen abilities such as better syllable recognition and segmentation, deletion and segmentation of phonemes, rhyming, and blending (Mortiz et al., 2013).

A recent study, examining children ages four to six, suggested that rhythm could enhance rhyming and segmentation and pitch could enhance phonological awareness by promoting auditory discrimination (Patscheke, Degé, & Schwarzer, 2018). This study examined how pitch and rhythm as separate training programs would affect phonological awareness. This training program was for 16 weeks and resulted in the pitch training group significantly increasing between pre- and post-test in phonological awareness at the word level, but not at the phoneme level. A possible explanation for why there was no increase at the phoneme level was that 16 weeks of musical training was not a long enough period of time to fully train the auditory awareness at this level. Since this was a treatment design, causality of musical training (specifically pitch) on greater phonological awareness, is possible (Patscheke, Degé, & Schwarzer, 2018). Thus, previous research suggests musical skills (specifically pitch and rhythm) positively influence phonological awareness at different levels of grain size. However, how this increased phonological awareness relates to ultimate reading outcomes (style or proficiency) is less studied.

Although there is a relationship between music and reading, most of these studies have been done on children. Recently, a study examined the associations between reading and musical training in adults (Swaminathan, Schellenberg, & Venkatesan, 2018). They found no correlations between music skills and reading skills in adult English readers but rather their results suggested that musical training and reading differences could be related to individual differences in general cognition. It was further suggested by Swaminathan, Schellenberg, & Venkatesan (2018) that individuals with higher general cognition are more likely to participate in musical training and that musical training then continues to strengthen general cognitive skills. Therefore, the current research will address the link between specific musical and readings subskills in adults, along with how they relate to word recognition style, controlling for general cognition.

Laterality of Reading in Musicians

There has also been evidence of a link between musical training and the neural underpinning of reading (Bouhali, Mongelli, & Cohen, 2017; Mongelli, et al., 2017; Proverbio et al., 2013). In one study examining the differences of professional musicians (mean age of 31.7, SD = 12) and nonmusicians (mean age of 26, SD = 9), the N170 was recorded during tasks of note selection and letter selection (Proverbio et al., 2013). The results suggested that musicians had bilateral activation during both tasks, whereas nonmusicians had left lateralized activity for the letter selection task. In two other studies, examining the differences in musicians and nonmusicians, fMRI was used during a picture repetition task (faces, houses, music, and words). The results of these studies showed that musicians had more left hemispheric activations when looking at words, compared to houses or tools, than the nonmusicians (Mongelli et al., 2017; Bouhali, Mongelli, & Cohen, 2017). The conflicting reports of laterality seen in musicians compared to nonmusicians opens up further questions of how music experience relates to reading styles in English readers.

Current Study

The current study focuses on two cognitive processes involved in music that are also relevant for reading: pitch and rhythm. There were two potential hypotheses for the current study regarding the relationship between musical and reading skills. Hypothesis 1 is that compared to nonmusicians, musicians would: (a) have greater pitch awareness compared to nonmusicians and thus greater phoneme awareness compared to nonmusicians; (b) have relatively greater accuracy and faster reaction times (RTs) for words presented in the right visual field (RVF) compared to the left visual field (LVF); (c) be less likely to be inversion sensitive (i.e., greater use of sublexical/analytic style of reading than lexical/holistic style of reading); and (d) more likely have word recognition and reading comprehension that is correlated with their phonological sub-skills.

Since greater rhythm awareness has been associated with greater phonological awareness, including syllable awareness (Anvari et al., 2002; Marie, Magne, & Besson, 2011; Mortiz et al., 2013), and larger phonological grain size has been associated with more bilateral reading-related activation (Carlos et al., 2019), there is a second alternative hypothesis to explain conflicting research among musicians and the hemispheric activation during word recognition. Hypothesis 2 is that compared to nonmusicians, musicians would (a) have greater rhythm awareness compared to nonmusicians and thus greater syllable awareness compared to nonmusicians; (b) be more likely to have similar accuracy and RTs for words presented in the LVF and RVF; (c) more likely be inversion sensitive (i.e., greater use lexical/holistic style of reading than sublexical/analytic style of reading); and (d) less likely to have word recognition and reading comprehension that is correlated with their phonological sub-skills.

Regardless of potential group differences between musicians and nonmusicians, the current study aims to start to tease apart what specific aspects of musical expertise are correlated with different components of reading processes, and how that might relate to word recognition style.

Method

Participants

Thirty-two students (7 Male, 23 Female, 2 Other/No Response; Mean Age: 21) were recruited from SUNY New Paltz via flyers, SONA system, emails, and in class announcements. There were 16 musicians and 16 nonmusicians. Inclusion criteria for musicians was determined through length of musical training and hours practiced. Musicians have had musical training for at least 9 years starting prior to age 10 and have continuously studied music, on the same instrument(s), up until the current time. The musical training had been either through lessons or practice at least 3 hours a week (George & Coch, 2011). Table 1 lists the types of instruments and how many participants played each instrument. Several participants played more than one type of instrument. Musicians were first recruited through the Music Department, and then through the general student population via a campus wide email, using an eight-question survey regarding musical training to make this determination (Appendix A).

Inclusion criteria for nonmusicians was less than one year of music training in childhood outside of the school curricula (Featherstone, Morrison, Waterman, & MacGregor, 2014). Exclusion criteria for all participants was any reading, speech, language, or hearing problems. Inclusion criteria for all participants included being right-handed and monolingual English speakers. Short-term memory measures were collected in order to be able to control for general cognition in later analyses. Musicians and nonmusicians were determined to have different baseline skill level (see Table 4 and Discussion). Participants were incentivized with either SONA credit for psychology majors or a $20 gift card, through grant funding from the Student Association.

Table 1

Participant	Instrument Type										
	Cello	Clarinet	Drums	Flute	French Horn	Guitar	Piano	Saxophone	Trumpet	Ukulele	Voice	Violin
1			X									
2	X							X		X		
3	X											
4							X			X		
5	X											X
6						X	X					X
7		X					X				X	
8						X	X			X		X
9			X				X					
10							X					X
11							X					
12							X				X	
13						X						X
14				X		X	X			X	X	
15					X		X		X			
16	X					X						

Materials and Procedure

Testing was conducted through one session for all participants, in which testing time was approximately two hours. Participants were instructed that they were allowed to take breaks during the testing period. Task order was randomized to prevent confounds such as one task influencing another task. For all pre-recorded listening tasks participants wore headphones.

Standardized Reading Measures

Behavioral tasks included standard word reading ability and comprehension (Woodcock Reading Mastery Test (WRMT; Woodcock, 1998): Word ID, Word Attack, Passage Comprehension, and Vocabulary (Antonyms); phonological awareness (Comprehensive Test of Phonological Processing (CTOPP; Wagner, Torgesen, Rashotte, & Pearson, 2013): Blending Words, Phoneme Isolation, and Elision; and syllable awareness: the Tractenberg Syllable Segmentation Task (Tractenberg, 2001).

Word ID involves seeing a word and being able to pronounce it and Word Attack is nonword recognition. Passage Comprehension involves reading a short segment with a blank space and completing the segment with an appropriate word. Vocabulary knowledge was tested with the Antonym subtest, in which participants were given a word and had to say an antonym of the given word. Blending Words includes hearing the individual phonemes of a word (e.g. C-A-T) and then pronouncing that word as a whole (e.g. cat), Elision involves saying a word without a single phoneme (e.g. saying BLANK without the "L" would be "BANK"), and Phoneme Isolation involves pronouncing certain phonemes of a given word (e.g. what is the third sound in music = /z/). Syllable Segmentation requires dividing up a given word into its syllables and identifying how many syllables are in that word. For these tasks, words and passages, would start out simpler and become more complex.

Pitch Perception

The Pitch Perception task included 22 musical clips (~two measures/one full phrase each; Appendix B), half of which were familiar melodies (e.g. *Happy Birthday*; Johnson et al., 2011) and the other half of which were from the classical repertoire (Besson & Faïta, 1995). All songs were recorded using only the treble clef. The final note of the short melodic clip was either congruous (correct) or using the computer program, Logic Pro X with Melodyne, the final note was digitally manipulated so that it was incongruous (1/4 tone (25 cents) higher (sharp) or lower (flat); Magne, Schön, & Besson, 2006).

Participants were instructed to listen to short melodies (through E-Prime software) and determine if the last note of the song was correct or incorrect, by pressing one of two buttons on a response box, using their right-hand index and middle fingers. The button presses were counterbalanced. The short songs were randomized between familiar melodies and classical music. Reaction time and accuracy were recorded.

Rhythm Discrimination

There were two tasks used to assess rhythm perception: Rhythm Discrimination and Tempo Copying. The Rhythm Discrimination task consisted of 14 pairs of rhythm patterns (one measure each), half were the same and half were different. Through E-Prime software, participants were instructed to listen to one measure of a rhythmic pattern, followed by one measure of resting (silence), and then another measure of a rhythmic pattern. Participants were asked to determine if both measures were the same or different by pressing one of two buttons on a response box, using their right-hand index and middle fingers. The button presses were counterbalanced. Reaction times and accuracy were recorded.

The Tempo Copying task consisted of ten different tempos (60, 80, 100, 120, 140, 160, 180, 200, 220, and 240 bpm; Bhide, Power, Goswami, 2013). Participants were instructed to begin tapping along with the metronome after hearing 3 taps and continue tapping at the same tempo for an additional 10 beats, even after the metronome had stopped. The participants tapped on a Chronos response box (with millisecond accuracy; Psychology Software Tools, 2019), which collected every individual tap through E-Prime Software. From each response or tap, Tempo Error for each button press was calculated by subtracting the absolute value of each tap reaction time from the previous tap (lower scores indicating greater precision). An average absolute Tempo Error was computed from the button presses.

General Cognition

General cognition was measured by a Digit Span task (CTOPP; Wagner, Torgesen, Rashotte, & Pearson, 2013) to measure short-term memory (STM), and a Backward Digit Span task to measure working memory (WM; Conway et al., 2005). During the Digit Span task, participants were instructed to listen to a series of numbers and repeat them back in the same order in which they were heard. During the Backward Digit Span task, participants were instructed to listen to a series of numbers and repeat them back in the reverse order in which they were heard. Both of the general cognition tasks were measured for accuracy.

Word Inversion Task

Word inversion sensitivity was assessed using a lexical decision task (LDT) in which the stimuli was presented in an upright or inverted (rotated 180 degree) orientation. There were 40 words and 40 nonwords (Appendix C), with half of each presented in each orientation. Words in the upright and inverted conditions were controlled for frequency, length, orthographic neighbors (how many words differ by one letter), and bigram frequency by position (frequency of any two letters following each other in a particular position in a word). The nonwords in the upright and inverted conditions are controlled for length, orthographic neighbors, and bigram frequency by position.

Participants completed the word inversion task on the computer through E-Prime software. The font used was Helvetica with a size of 28. They were asked to determine if the word (upright or inverted) on the screen was word or not a word by pressing the A or L key on the keyboard (keyboard presses were counterbalanced). Reaction time and accuracy were recorded.

Behavioral Lateralization Task

Behavioral lateralization was assessed using a one-back task where participants had to indicate when a word was repeated. There were 192 study words and 192 test words (Appendix D). The test words differed by one letter from their study word counterpart by either the second or third letter (similar to Dundas, Plaut, & Behrmann, 2013).

Participants completed the Behavioral Lateralization task on the computer through E-Prime software. They were presented with a fixation cross in the center of the screen, a study word would then appear in the center for 750 ms, then another fixation cross would appear and while keeping their eyes on the fixation cross a second test word appeared on the screen, for 150 ms in either their right visual field (RVF) or left visual field (LVF). The participants would then press a button to indicate whether the second word was the same or different than the first (button presses were counterbalanced). Reaction time and accuracy were recorded.

Results

Independent-samples *t*-tests

Reading Skills

Table 2 shows differences between musicians and nonmusicians on reading subtests. Musicians were better on measures of phonological awareness: CTOPP, Word Attack, and Syllable Segmentation. Musicians were also better on general reading (Passage Comprehension) and on Vocabulary. There were no differences on Word ID, which enabled us to examine the differences in *how* groups are decoding words, controlling for overall word identification skill.

Table 2.

Task		Group	Mean	SD	*t* (30)	Cohen's d	*p* (two-tailed)	p < .05 marked by *
Standardized Reading Measures	CTOPP Composite Score	Musicians	M = 105.3	SD = 10.34	2.9	1.06	.007	*
		Nonmusicians	M = 95	SD = 9.64				
	WRMT Word ID	Musicians	M = 542.38	SD = 17.29	.427	.16	.672	
		Nonmusicians	M = 540.44	SD = 5.45				
	WRMT Vocabulary	Musicians	M = 23.88	SD = 2.42	3.17	1.16	.003	*
		Nonmusicians	M = 21.44	SD = 1.90				
	WRMT Word Attack	Musicians	M = 519.81	SD = 8.27	2.07	.76	.047	*
		Nonmusicians	M = 514.13	SD = 7.23				
	WRMT Passage Comprehension	Musicians	M = 530.75	SD = 7.31	2.15	.79	.040	*
		Nonmusicians	M = 524.56	SD = 8.90				
Syllable Segmentation	Correct Digit	Musicians	M = 15.17	SD = 3.61	2.70	.99	.011	*
		Nonmusicians	M = 10.69	SD = 5.55				
	Correct Division	Musicians	M = 10.25	SD = 4.31	2.41	.88	.022	*
		Nonmusicians	M = 6.66	SD = 4.13				

Music Skills

Table 3 shows the differences between musicians and nonmusicians on the music measures. For the rhythm tasks, there was only statistically significant differences between groups on Rhythm Discrimination, $p = .012$, such that musicians had higher accuracy scores compared to nonmusicians. There was no statistical significance between groups on Tempo Average Error or Pitch Detection tasks.

Table 3.

Task		Group	Mean	SD	*t* (30)	Cohen's d	*p* (two-tailed)	p < .05 marked by *
Pitch Detection	1/4 down Accuracy	Musicians	M = .64	SD = .15	.468	.17	.643	
		Nonmusicians	M = .62	SD = .13				
	1/4 down RT	Musicians	M = 7140.1	SD = 423.24	1.31	.48	.20	
		Nonmusicians	M = 6823	SD = 871.63				
	1/4 up Accuracy	Musicians	M = .47	SD = .20	-.485	.18	.631	
		Nonmusicians	M = .50	SD = .12				
	1/4 up RT	Musicians	M = 7443.6	SD = 689.02	0.223	.08	.83	
		Nonmusicians	M = 7364.5	SD = 1237.1				
	Average Out of Tune Accuracy	Musicians	M = .56	SD = .15	-.068	.02	.946	
		Nonmusicians	M = .56	SD = .08				
	Average Out of Tune RT	Musicians	M = 7308.3	SD = 489.27	.938	.34	.356	
		Nonmusicians	M = 7051.3	SD = 980.58				
	In Tune Accuracy	Musicians	M = .84	SD = .21	1.32	.48	.197	
		Nonmusicians	M = .74	SD = .21				
	In Tune RT	Musicians	M = 6498.3	SD = 415.12	-.13	.05	.898	
		Nonmusicians	M = 6538.1	SD = 1156.18				
Rhythm	Rhythm Accuracy	Musicians	M = .92	SD = .07	2.68	.98	.012	*
		Nonmusicians	M = .80	SD = .15				
	Rhythm RT	Musicians	M = 7163.9	SD = 519.00	1.64	.6	.112	
		Nonmusicians	M = 6621.4	SD = 1220.22				
	Tempo Average Error	Musicians	M = 89.41	SD = 133.38	-.878	.32	.387	
		Nonmusicians	M = 154.64	SD = 265.56				

General Cognition

An independent-samples *t*-test was also conducted for general cognition (Table 4) in which musicians outperformed nonmusicians on the Digit Span task: musicians were able to recall longer lengths of numbers than nonmusicians. There was no statistically significant difference between musicians and nonmusicians on the Backward Digit Span task.

Table 4.

Task		Group	Mean	SD	*t* (30)	Cohen's d	*p* (two-tailed)	p < .05 marked by *
General Cognition	CTOPP Digit Span	Musicians	M = 11.56	SD = 1.79	2.68	.98	.012	*
		Nonmusicians	M = 9.69	SD = 2.15				
	Backward Digit Span	Musicians	M = 11.44	SD = 3.39	1.46	.53	.156	
		Nonmusicians	M = 9.94	SD = 2.35				

Word Inversion Sensitivity

A 2 x 2 analysis of variance (group x word orientation) was conducted to examine the differences between word inversion sensitivity among musicians and nonmusicians (Appendix F). There was a main effect of word orientation, Wilks' Lambda = .41, $F(1, 30) = 43.80$, $\eta^2 = .59$, $p < .001$, with both groups showing faster reaction times for upright words than inverted words. The main effect of group was not statistically significant, $F(1, 30) = 2.34$, $\eta^2 = .072$, $p = .134$. There was a marginally statistically significant interaction between group and word orientation, Wilks' Lambda = .902, $F(1, 30) = 3.26$, $\eta^2 = .098$, $p = .081$. In an exploratory manner, follow-up *t*-tests were conducted and there was a marginally statistically significant difference in Inverted RT, in which case musicians (M = 1272.12, SD = 345.69) were faster than nonmusicians (M = 1638.96, SD = 776.84; $t(30) = -1.73$, $d = .63$, $p = .095$). There was no difference between groups for Upright RT.

Behavioral Lateralization Score

A 2 x 2 analysis of variance (group x visual field) was conducted to examine differences in behavioral lateralization between musicians and nonmusicians on RTs (Appendix F). There was no significant main effect for visual field, Wilks' Lambda = .93, $F(1, 30) = 2.39$, $\eta^2 = .074$, $p = .13$. The main effect comparing the two groups was marginally statistically significant, $F(1, 30) = 3.26$, $\eta^2 = .098$, $p = .081$, such that nonmusicians had slightly faster RTs than musicians. There was no significant interaction between group and visual field, Wilks' Lambda = .97, $F(1, 30) = .970$, $\eta^2 = .031$, $p = .33$.

Musician Bivariate Correlations

Bivariate correlations were conducted by group to further examine relationships between music and reading subskills and identify group differences and correlational patterns. To decrease the likelihood of making a Type I Error, a Bonferroni Adjustment was conducted and only results that were less than .007 were considered statistically significant. Due to the exploratory nature of this research, there was also an adjustment conducted for marginal results: results less than .014 could be considered marginally statistically significant. In musicians (Table 5), there was a statistically significant correlation between Tempo Copying and Word ID ($p < .001$). There were also marginally statistically significant (corrected) correlations between Tempo Copying and Word Attack ($p = .012$). The marginal relationship between Tempo Copying and Word Attack supports Hypothesis 1, which musicians are relying more heavily on smaller phonological units during word decoding.

Table 5. Musicians

			Music Measures			Reading Measures			
			Average Out of Tune Accuracy	Rhythm Discrimination	Tempo Copying	CTOPP Composite	Word ID	Word Attack	Syllable Segmentation
Music Measures	Average Out of Tune	*r*	1	.078	-.060	.275	.132	.000	.208
		p		.775	.825	.303	.625	.999	.440
	Rhythm Discrimination	*r*		1	-.227	.110	.201	.201	-.099
		p			.398	.685	.456	.456	.716
	Tempo Copying	*r*			1	-.558	-.823*	-.611	-.156
		p				.025	.000	.012	.565
Reading Measures	CTOPP Composite	*r*				1	.543	.220	.412
		p					.030	.414	.113
	Word ID	*r*					1	.572	.217
		p						.021	.421
	Word Attack	*r*						1	.452
		p							.079
	Syllable Segmentation	*r*							1
		p							

p < .007 indicated by *

Nonmusician Bivariate Correlations

In nonmusicians (Table 6), there was a statistically significant correlation between CTOPP and Syllable Segmentation (*p* = .005). The lack of correlations between music and reading subskills, compared to musicians, may indicate that nonmusicians do not rely as heavily on rhythmic skills during word recognition. Furthermore, the correlation between CTOPP and Syllable Segmentation may indicate that nonmusicians are relying on larger phonological units compared to musicians.

Table 6. Nonmusicians

			Music Measures			Reading Measures			
			Average Out of Tune Accuracy	Rhythm Discrimination	Tempo Copying	CTOPP Composite	Word ID	Word Attack	Syllable Segmentation
Music Measures	Average Out of Tune	*r*	1	.015	.177	.054	-.085	.023	.142
		p		.955	.513	.842	.754	.933	.599
	Rhythm Discrimination	*r*		1	-.165	.196	.030	.142	-.237
		p			.543	.466	.911	.600	.376
	Tempo Copying	*r*			1	-.007	-.518	-.061	-.077
		p				.981	.040	.821	.776
Reading Measures	CTOPP Composite	*r*				1	.365	.344	.661*
		p					.164	.191	.005
	Word ID	*r*					1	.227	.384
		p						.398	.142
	Word Attack	*r*						1	.269
		p							.313
	Syllable Segmentation	*r*							1
		p							

$p < .007$ indicated by *

Group Differences in Reading Style

Multiple regression analyses with group x subskill interactions were conducted to assess potential significant differences in reading style (i.e., reliance on subskills) between groups. These were limited to examining relationships between tasks that showed marked differences in bivariate correlations in the two groups.

First, a multiple regression was run with Group and Word Attack on Word ID (Model 1) and additionally a Group x Word Attack interaction on Word ID (Model 2; see Table). Results suggest that Model 1 was statistically significant, $F(2, 29) = 3.91$, $p = .031$, with an R-squared of .21 (21% of the variance in Word ID scores was accounted for by our predictor variables). Word Attack was a significant predictor of Word ID scores, $\beta = .75$, $t(29) = 2.76$, $p = .010$, controlling for group. Controlling for group, with each unit increase in Word Attack scores, Word ID scores increase .75 points across groups, 1 SD higher scores on Word Attack corresponded to almost ½ SD higher levels of Word ID, standardized beta weight = .49, a medium effect size. Group was not an effective predictor of Word ID scores, $\beta = -2.34$, $t(29) = -.53$, $p = .60$, controlling for Word Attack scores.

When the interaction term was added (Group x Word Attack) in Model 2, the model became even more statistically significant, $F(3, 28) = 4.12$, $p = .015$ with an R-squared of .31 (31% of the variance in Word ID scores was accounted for by our predictor variables). Group x Word Attack interaction was a marginally significant predictor of Word ID scores, $\beta = 1.02$, $t(29) = 1.95$, $p = .062$. As Word Attack scores increase, there is an increase in Word ID scores moderated by group: Word Attack was a greater predictor of Word ID in musicians than nonmusicians.

A multiple regression was also conducted with Group and Syllable Segmentation on CTOPP (Model 1) and Group x Syllable Segmentation interaction on CTOPP (Model 2). Results suggest that Model 1 was statistically significant, $F(2, 29) = 11.29$, $p < .001$ with an R-squared of .44 (44% of the variance in CTOPP scores were accounted for by the predictor variables). Syllable segmentation was a statistically significant predictor of CTOPP scores, $\beta = 1.25$, $t(29) = 3.36$, $p = .002$, controlling for group. Controlling for group, with each unit increase in Syllable Segmentation scores, CTOPP scores increase 1.25 points across groups, 1 SD higher scores on Syllable Segmentation corresponded to almost ½ SD higher levels of CTOPP, standardized beta weight =

.51, a medium effect size. When the interaction term was added (Group x Syllable Segmentation) in Model 2, the model becomes slightly less statistically significant.

Group Differences in Music Skills Predicting Reading Skills

First, a multiple regression was run with Group, Tempo Copying, and Backward Digit Span on CTOPP (Model 1) and a Group x Tempo Copying interaction on CTOPP (Model 2), while controlling for general cognition. Results suggests that Model 1 was statistically significant, $F(3, 28) = 3.06$, $p = .045$ with an R-squared of .25 (25% of the variance in CTOPP scores was accounted for by the predictor variables). Tempo Copying and Backward Digit Span were not significant predictors of CTOPP scores, controlling for group.

When the interaction term was added (Group x Tempo Copying) in Model 2, the model becomes even more statistically significant, $F(4, 27) = 3.65$, $p = .017$ with an R-squared of .35 (35% of the variance in CTOPP Composite scores was accounted for by the predictor variables). Group x Tempo Copying interaction was a statistically significant predictor of CTOPP Composite scores, $\beta = -.044$, $t(27) = -2.08$, $p = .047$, controlling for general cognition. As Tempo Copying scores decrease (i.e., accuracy increases), there was an increase in CTOPP Composite scores, moderated by group: tempo was a greater predictor of CTOPP scores in musicians, controlling for general cognition.

A multiple regression was conducted with Group, Tempo Copying, and Backward Digit Span on Word Attack (Model 1) and a Group x Tempo Copying interaction (Model 2) on Word Attack, controlling for general cognition. Results suggest that Model 1 was marginally statistically significant, $F(3, 28) = 2.71$, $p = .064$, with an R-squared of .23 (23% of the variance in Word Attack scores were accounted for by the predictor variables). Tempo Copying and Backward Digit Span scores were not statistically significant predictors of Word Attack scores.

When the interaction term was added (Group x Tempo Copying) in Model 2, the model becomes more statistically significant, $F(4, 27) = 3.39$, $p = .023$, with an R-squared of .33 (33% of the variance in Word Attack scores were accounted for by the predictor variables). Group x Tempo Copying was a statistically significant predictor of Word Attack scores, $\beta = -.033$, $t(27) = -2.12$, $p = .045$, controlling for group. As Tempo Copying scores decrease, there was an increase in Word Attack scores, moderated by group: Tempo Copying (Accuracy) was a greater predictor of Word Attack scores in musicians, controlling for general cognition.

An additional multiple regression was conducted with Group, Tempo Copying, and Backward Digit Span on Word ID (Model 1) and Group x Tempo Copying interaction on Word ID (Model 2), controlling for general cognition. Results suggest that Model 1 was statistically significant, $F(3, 28) = 4.29$, $p = .013$ with an R-squared of .32 (32% of the variance in Word ID scores was accounted for by the predictor variables). Tempo Copying was a statistically significant predictor of Word ID scores, $\beta = -.026$, $t(28) = -2.67$, $p = .012$, controlling for group and general cognition. Controlling for group and general cognition, with each unit decrease in Tempo Copying, Word ID scores increase by .026 point across groups, 1 SD lower scores on Tempo Copying corresponded to almost ½ SD higher levels of Word ID, standardized beta weight = -.44, a medium effect size.

When the interaction term was added (Group x Tempo Copying), in Model 2, the model becomes even more statistically significant, $F(4, 27) = 13.20$, $p < .001$ with an R-squared of .66 (66% of the variance in Word ID scores was accounted for by the predictor variables). Group by Tempo Copying was a statistically significant predictor of Word ID scores, $\beta = -.092$, $t(27) = -5.26$, $p < .001$, controlling for general cognition. As Tempo Copying scores decrease (become more accurate), there was an increase in Word ID scores, moderated by group: tempo was a greater predictor of Word ID scores in musicians, controlling for general cognition.

Factor Analyses

To assess the relationship between reading subskills, an exploratory factor analysis using Varimax Rotation with a Kaiser normalization was employed (de Winter, Dodou, & Wieringa, 2009) including CTOPP, Word ID, Word Attack, and Syllable Segmentation. For both musicians and nonmusicians, the factor analyses showed a single component, accounting for 55% and 54% of the variance respectively (Table 7).

Table 7. Factor Loading for Reading Subksill

Musicians	**Components**	**Nonmusicians**	**Components**
	1		1
CTOPP	.727	CTOPP	.848
Word ID	.805	Word ID	.653
Word Attack	.762	Word Attack	.571
Syllable Segmentation	.674	Syllable Segmentation	.831

Finally, because there were group differences on Vocabulary and Passage Comprehension, additional factor analyses were conducted using CTOPP, Word ID, Word Attack, Vocabulary, and Passage Comprehension. For musicians, the factor analysis showed two components that accounted for 73% of the variance (50% for the first and 23% for the second; Table 8). The first component had high factor loading for Vocabulary and Passage Comprehension (.887, and .796), medium factor loading for CTOPP (.618) and low factor loading for Word ID and Word Attack (.074 and .156). The second component had high factor loading for Word ID and Word Attack (.958 and .730), medium factor loading for CTOPP (.507) and low factor loading for Vocabulary and Passage Comprehension (-.068 and .302). In nonmusicians the factor analysis also showed two components accounting for 71% of the variance (50% for the first and 21% for the second). The first component had high factor loading for CTOPP, Vocabulary, and Passage Comprehension (.748, .813, and

.829), medium factor loading for Word ID (.683), and low factor loading for Word Attack (.152). The second component had high factor loading for Word Attack (.932) and low factor loading for CTOPP, Word ID, Vocabulary, and Passage Comprehension (.298, .217, -.341, and .201).

Table 8. Factor Loading for Reading Subksill

Musicians	**Components**		**Nonmusicians**	**Components**	
	1	2		1	2
CTOPP	.618	.507	CTOPP	.748	.298
Word ID	.074	.958	Word ID	.683	.217
Word Attack	.156	.730	Word Attack	.152	.938
Vocabulary	.887	-.068	Vocabulary	.813	-.341
Passage Comprehension	.796	.302	Passage Comprehension	.829	.201

Discussion

This current study examined the relationship between music skills and reading skill, comparing musicians to nonmusicians. Results suggest that, overall, musicians had greater reading abilities compared to nonmusicians. However, there were no differences between groups on Word ID, which allowed for examining *how* words are decoded while controlling for overall word recognition skill. Results suggest that musicians might be engaging smaller phonological units when identifying words than nonmusicians. These results support Hypothesis 1, parts (c) and (d), suggesting that musical training does have a relationship to reading style. Specifically, current findings suggest that tempo may be related to the increased phonological awareness seen in musicians, which is supported by extensive previous literature that musicians have greater phonological awareness than nonmusicians (Degé & Schwarzer, 2011; Moritz et al., 2013; Anvari et al., 2002; Patscheke, Degé, & Schwarzer, 2018). In addition, musicians showed moderately less inversion sensitivity compared to nonmusicians, indicating they may be utilizing a more analytic approach to word identification (Hirshorn et al, in prep). Hypothesis 2 was not supported by these findings.

Reading skills

There were no group differences in Word ID, which suggests that both groups have similar word identification skills. Since both groups had similar word identification skills, the way in which musicians and nonmusicians identify/process words could be examined. Performance in a nonword decoding task (Word Attack), which relies on phonological processing, was different between groups: musicians scored statistically significantly higher than nonmusicians. To examine how word identification is different between groups, an exploratory multiple regression analysis was conducted with Group x Word Attack on Word ID, and there was a marginally statistically significant interaction on Word ID, suggesting that musicians rely relatively more on phonological decoding than nonmusicians in the service of word identification. These findings are consistent with previous research on the subject (Anvari et al., 2002; Moritz, et al., 2013; Patscheke, Degé, & Schwarzer, 2018).

Behavioral Lateralization

Previous research (Dundas, Plaut, & Behrmann, 2014; 2015) has examined behavioral lateralization or visual field studies to identify hemispheric dominance for word identification. However, the current study did not find statistically significant differences between groups. This may be due to possible inconsistency with the participants: some participants moved more than others, even though they were instructed to sit straight and upright. This study did not utilize eye-tracking during this study in which case some participants may not have been staring at the fixation cross during the tasks, despite being instructed to do so. Furthermore, there was no head-rest, in which case some participants may have moved their heads more than was instructed during the task. Finally, this task, although allowed breaks, did not require that participants take a mandated break, which could have led to cognitive fatigue or eye-strain.

Word Inversion Sensitivity

There was a marginally statistically significant interaction between group and word orientation, with the follow-up *t*-test also confirming that musicians had marginally statistically significantly faster RTs for inverted words compared to nonmusicians. Although these results were in the a priori predicted directions, since these results were only approaching significant, more research would need to be conducted in order to determine the extent of this relationship. However, if further supported, this pattern of results could indicate that musicians may be relying more on analytic word processing skills than nonmusicians for word identification (Hirshorn et al, in prep).

Musical Skills

Previous research has suggested that musical training relates to increased phonological awareness (Ozernov-Palchik, Wolf, & Patel, 2018; Patscheke, Degé, & Schwarzer, 2018; Moritz et al., 2013), which this current study supported. To understand these differences in word processing/identification, we examined how musical subskills, specifically tempo, related to these group differences in word processing.

Rhythm Discrimination

To examine the rhythm subskill of musical training, two rhythm tasks were designed to examine differences between groups on rhythmic awareness (Rhythm Discrimination and Tempo Copying). Not surprisingly, musicians had greater accuracy than nonmusicians on the Rhythm Discrimination task, suggesting that musicians have greater rhythmic abilities.

Although there were no group differences in Tempo Copying, there were different correlational patterns in the two groups in terms of how it related to reading measures. To examine these patterns, a Group x Tempo Copying on CTOPP, Group x Tempo Copying on Word Attack, and Group x Tempo Copying on Word ID multiple regressions were conducted, and resulted in statistically significant interactions moderated by group, in which Tempo Copying predicted Word Attack and Word ID scores better in musicians than nonmusicians, controlling for general cognition. This suggests the specific timing in the tapping task was possibly employing similar processes used in phonological awareness in musicians. This precise timing between phonemes and precise timing in the tapping task, which is necessary for both music and language (Tierney & Kraus, 2014), suggests that musicians are engaging in fine-grain temporal processing which is engaging fine-grain phonemic processing when decoding words, whereas nonmusicians do not necessarily access this process.

One previous study proposes a transfer of rhythm to reading (Tierney & Kraus, 2014), using PATH which is: Precise Auditory Timing Hypothesis. The main tenet of PATH is the ability to entrain, similar to the tapping task in the current study, which can be described as the ability to coordinate the motor (tapping) skills with the auditory skills. It is possible that this current study supports PATH with the statistically significant interactions of Group x Tempo Copying on CTOPP and Word Attack.

Pitch Perception

Previous research (Patscheke et al., 2018) on music and reading skills has found that pitch relates to better phonological awareness in musicians. Why was this not found in the current study? The pitch task designed for this study may have been too difficult. The pitch detection task utilized either a correct (or in-tune) final note or an incorrect (or out-of-tune) final note, which was not an actual musical note. The manipulation of the final note to ensure that it was out-of-tune was only 25 cents or a ¼ sharp (up) or a ¼ flat (down). Future research could utilize a similar design but by using an actual musical note, such as a ½ step sharp or flat.

Another reason why the pitch detection task found no statistically significant differences between groups could be because the population used was adults. Previous research typically examines children, however one recent study examined adults (Swaminathan, Schellenberg, & Venkatesan, 2018), and found that, in adults, melody perception was not related with reading abilities.

Reading Factor Analysis

Results of the exploratory factor analyses on reading subskills indicate that musicians and nonmusicians differ in how they may use the individual subskills. Specifically, in musicians the factor loading of both Word ID and Word Attack together may indicate that musicians are relying more on phonology during word recognition. In contrast, in nonmusicians, the factor loading of Vocabulary, Word ID, and Passage Comprehension together, speculating, may indicate that nonmusicians are relying more on semantics.

Overall Group Differences

Since there were no group differences on Word ID scores between musicians and nonmusicians, *how* words are being recognized could be examined. All of the converging evidence from these different measures suggests that musicians rely more on phonological awareness than nonmusicians for word recognition. Specifically, results suggest that musicians are engaging a fine-grain temporal processing which in turn is engaging their fine-grain phonological awareness. The multiple regression models indicate that Tempo Copying (fine-grain temporal processing) predicts CTOPP and Word Attack scores (fine-grain phonological awareness) better in musicians. In addition, the multiple regression also indicates that Tempo Copying predicts Word ID scores better in musicians, which suggests that fine-grain temporal processing is related to word identification in musicians. Those results along the marginally statistically significant interaction for Word

Inversion Sensitivity further supports the idea that that musicians are identifying words more analytically (musicians had faster RTs than nonmusicians for inverted words).

Implications in Dyslexia Research

Why is this important? One reason to better understand how music subskills and reading subskills are related could lead to using music as a strategy to help struggling readers, specifically dyslexia, as previous research has suggested (Habib et al., 2016; Flaugnacco et al., 2015; Overy et al., 2003). Since developmental dyslexia is primarily an impairment in phonological awareness (Snowling, 1987, as cited in Overy et al., 2003), and music is suggested to increase phonological awareness (Habib et al., 2016; Flaugnacco et al., 2015; Overy et al., 2003), musical interventions seem to be appropriate for improving reading skills in dyslexia. One study (Flaugnacco et al., 2015) conducted a music or painting intervention on children with dyslexia and found that after the intervention those in the music group showed significant improvement in phonological awareness compared to the painting group. Furthermore, they found that as rhythmic awareness increased, phonological awareness increased (Flaugnacco et al., 2015). The rhythm task, although not identical to the Tempo Copying task in this current study, was similar, which suggests that this tapping task could be used as part of a music intervention for developmental dyslexia.

It has also been suggested that one specific impairment in dyslexia of phonological awareness is the temporal processing (Flaugnacco et al., 2015; Bishop-Liebler, Welch, Huss, Thompson, & Goswami, 2014), again suggesting that rhythmic training through music could improve phonological awareness in developmental dyslexia. This current study supports the idea that fine-grain temporal processing may be involved in the fine-grain phonemic processing seen in musicians.

Future Research

Another area that could show the relationship between musical training and reading styles could be examining both the visual aspects of musical reading and the auditory aspect. This current study examined the auditory aspect of music only, but taken together with the visual aspect, perhaps differences in reading style may be more fully examined. In continuing to identify the specific relationship between music and reading, a music note reading task may be designed to identify how the visual aspect of music (rather than auditory as in the current study) may relate to reading skills. One reason this may further our understanding of music and reading skills is because both music and reading (in English) are done from left to right. However, one difference with music (compared to English word reading) is there is also vertical reading as well (such as Chinese). Recent research in this domain examined music reading and how it relates to lateralization in groups of musicians and nonmusicians (Tze Kwan Li & Hui-wen Hsiao, 2018). This study's results found that musical training, specifically the visual component seems to encourage faster RH processing in musician English readers. However, Tze Kwan Li and Hui-wen Hsiao (2018) only had musicians that played piano, which may be one reason why there are differences between musicians and the lateralization of reading in the literature.

With those findings in mind, one contributor to differences in reading styles could be the specific instrument that musicians have experienced during their training. The current study found that rhythm seems to be related to fine-grain phonologic awareness, however, this study did not compare differences based on specific instrument experience. To hypothesize, percussionists might rely more heavily on rhythmic abilities whereas cellist or violinists (or other stringed instruments) may rely more heavily on pitch abilities. If these differences related to the neural organization of reading, it may explain why we did not observe any lateralization differences in a group of musicians with heterogeneous instrumental background. However, this would need further research to fully understand how different instrumental training plays a role in reading ability and individual differences in reading style.

Finally, another research question to be examined in the future would be: do individuals who partake in musical training have greater phonological awareness to begin with? One article (Schellenberg, 2015), suggests that children who engage in musical lessons to begin with have differences from those who do not engage in music lessons. Some differences include, genetic predispositions (i.e., IQ) and environmental factors (i.e., SES). Therefore, greater phonological awareness could be one factor that would encourage an individual to engage in music lessons. In addition, having greater phonological awareness could also factor into the method into how musical training is obtained: playing by ear (Suzuki method) vs. reading music. However, future research would need to be conducted in this domain to fully understand how preexisting variables relate to musical training and phonological awareness skills.

Limitations

This study had some limitations, the first of which was that this was correlational research. Since the nature of this study was exploratory and correlational, causation cannot be made from the results. In addition, this study did not incorporate SES into the participant background, which as stated in the future directions, could be one area contributing to who engages in musical training in the first place. Future research may want to incorporate SES into the demographics to see if this does indeed relate to musical training. Another variable that could be examined in the future would be gender. This could also be a contributing factor to group differences in reading style as well. Finally, the sample size (N=32) was small, future research could utilize a similar study with a large sample size.

Conclusion

As discussed, music and reading have long been examined in relationship to one another, with these current results suggesting that musicians rely more heavily on fine-grain phonological awareness and are more analytic when identifying words. The specific musical subskill identified in relationship with phonological awareness is tempo. Although this study identifies tempo as a musical rhythmic subskill, perhaps tempo is more related to fine-grain temporal processing skills than general rhythm skills, per se. Overall, these findings suggest that musical training seems to be related to improved phonological awareness, but not necessarily better word reading.

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Appendix A

Musical Training:

1. What type of musical instrument(s) do you play? ___________________________

2. When did you start each instrument? _________________________

3. For how many years have you played a musical instrument as an amateur (including voice)? _________

4. For how many years have you received formal instruction (e.g. private lessons/training, school courses), in a musical instrument (including voice)? _________

5. For how many years/semesters have you taken a music theory class? (Do not include ensembles, such as orchestra, band, or choir). _________

6. How many hours per week do you spend playing or practicing your instrument? (if you play more than one, include the sum amount of time spent playing all of them). ___________________

7. Would you consider yourself a musician?
    a. Yes – a professional
    b. Yes – an amateur
    c. It's more of a hobby
    d. I like music, but wouldn't call myself a musician
    e. I am not musical at all

Appendix B

Pitch Perception Task Melodies:

Familiar Melodies

1. Oh, My Darling Clementine
2. For He's a Jolly Good Fellow
3. Happy Birthday
4. I've Been Working on the Railroad
5. She'll Be Coming 'Round the Mountain
6. My Country Tis of Thee
7. Amazing Grace
8. Let Me Call You Sweetheart
9. Oh, Susanna
10. Oh, When the Saints Go Marching In
11. You are my Sunshine

Classical Repertoire

1. Fur Elise, Beethoven
2. Ode to Joy, Beethoven
3. Nocturne in E Flat, Chopin
4. The Little Negro, Debussy
5. New World Symphony, Dvorak
6. Morning, Grieg
7. Eine Kleine Nachtmusik, Mozart
8. Piano Sonata, Mozart
9. Le Tamourin, Rameau
10. Swan Lake, Tchaikovsky
11. Spring, Vivaldi

Appendix C

Word Inversion Task

Words:	bear	Nonwords:	wuff
did	comb	ret	gode
pour	huge	wosh	tave
tank	surf	hoil	dite
great	slam	mune	hode
hoist	pose	pard	carm
shade	mice	lond	nust
stood	weak	pold	coom
swarm	curb	heam	rell
dodge	fold	tord	sust
trunk	dock	hean	sweal
pitch	place	cobe	prock
pledge	notch	deave	prass
height	phase	preet	brate
roof	steak	prape	prang
crop	tempt	droif	reash
cape	tease	dease	trosk
coal	shirt	brobe	corch
rust	shark	grool	streal
damp	trough	corth	tranch
bump		treath	

Appendix D

Behavioral Lateralization Task

Study Words	send	ramp	seed	nest
cord	hail	cane	dank	folk
band	dark	sole	dime	club
fume	dire	dork	slop	cave
rile	slip	song	grub	core
stop	grab	dare	hard	pony
romp	hand	more	tire	site
cone	time	code	form	inch
mile	foam	land	chop	bird
sing	chip	bade	like	camp
mare	lime	runt	some	knit
cede	sore	bane	lode	week
lend	done	free	bank	wife
bode	bark	dine	seat	mail
rant	sent	made	best	rate
bone	beat	pale	swim	echo
flee	card	bind	will	nail
mode	bond	sale	pair	drug
pare	fame	carp	quit	weed
same	rule	lard	game	urge
ship	tame	shop	harm	miss

heat	want	whip	Test Words	seed
peak	sick	easy	card	dank
read	fire	keep	bond	dime
clay	lack	silk	fame	slop
stun	tree	take	rule	grub
beer	back	rise	tame	bane
path	pole	bake	ramp	hard
navy	tent	acid	cane	tire
self	crop	plug	sole	form
boat	lazy	leaf	dork	chop
park	fool	pest	song	like
lung	fair	lily	dare	some
hide	copy	bulb	more	lode
lick	roar	twin	code	bank
snow	feel	rock	runt	seat
film	half	bald	free	best
dull	dish	help	dine	cord
bolt	swop	tidy	made	band
date	lock	bite	pale	fume
solo	meat	show	bind	rile
mole	care	dead	carp	stop
hall	love	hear	lard	romp
slow	cash		shop	cone

mile	time	bird	park	fool
sale	foam	camp	lung	fair
sing	chip	knit	hide	opy
mare	lime	week	lick	roar
cede	sore	wife	snow	feel
lend	done	mail	film	half
bode	bark	rate	dull	dish
rant	sent	echo	bolt	swop
bone	beat	hail	date	lock
flee	swim	drug	solo	meat
mode	will	weed	mole	dome
pare	pair	urge	hall	care
same	quit	miss	slow	love
land	game	heat	want	cash
ship	harm	peak	sick	whip
send	nest	read	fire	easy
hail	folk	clay	lack	keep
dark	club	stun	tree	silk
dire	cave	beer	back	take
slip	core	path	pole	rise
grab	pony	navy	tent	bake
bade	site	self	crop	acid
hand	inch	boat	lazy	plug

leaf	bulb	bald	bite	hear
pest	twin	help	show	
lily	rock	tidy	dead	

Appendix E

Tractenberg Syllable Segmentation Task

List 1

1. OWL
2. CELERY
3. HANGER
4. FLUTE
5. HELICOPTER
6. LOBSTER
7. GOAT
8. KITE
9. BUTTERFLY
10. CANNON
11. RULER
12. EAGLE
13. SCISSORS
14. ANCHOR
15. MUSCHROOM
16. GIRAFFE
17. LIGHTBULB
18. PEACOCK
19. PAINTBRUSH
20. CARROT

List 2

1. FOOTBALL
2. CHICKEN
3. MOUNTAIN
4. BREAD
5. TABLE
6. FINGER
7. WINDOW
8. CIGARETTE
9. WAGON
10. PENCIL
11. BOTTLE
12. ORANGE
13. FLOWER
14. BARREL
15. ENVELOPE
16. IRON
17. SCREW
18. BARN
19. DESK
20. PITCHER

Appendix F

Word Inversion ANOVA

Word Inversion Sensitivity 2 x 2 ANOVA (group x word orientation)

Effect	*df*	*F*	partial eta squared	*p*
Orientation	1, 30	43.80*	.593	< .001
Group	1, 30	2.34	.072	.137
Orientation x Group	1, 30	3.26	.098	.081

* p < .01

Behavioral Lateralization ANOVA

Behavioral Lateralization Score 2 x 2 ANOVA (group x visual field)

Effect	*df*	*F*	partial eta squared	*p*
Visual field	1, 30	2.39	.074	.132
Group	1, 30	3.26	.098	.081
Visual field x Group	1, 30	.970	.031	.332