SEVERAL STUDIES HAVE REPORTED THAT MUSICAL APTITUDE (untrained music ability) is positively associated with reading development (e.g., Anvari, Trainor, Woodside, & Levy, 2002; Atterbury, 1983, 1985; Barwick, Valentine, West, & Wilding, 1989; Douglas & Willatts, 1994; Forgear, Schlaug, Norton, Rosam, Ingeng, & Winner, 2008; Lamb & Gregory, 1993; Peynircioglu, Durgunoglu, & Oney-Kusufoglu, 2002). These studies found that intrinsic, untrained music abilities, such as those measured by tests of pitch discrimination and rhythm discrimination, are correlated with reading skills such as phonological awareness and word recognition. Children who perform higher on tests of pitch discrimination and rhythm discrimination also perform higher on measures of phonological awareness, reading, and writing (Anvari et al., 2002; Atterbury, 1983, 1985; Barwick et al., 1989).

Although relatively few studies have examined the association between music and reading, all of them noted that basic auditory processing skills are related to abilities in both music and reading. A meta-analysis of correlational studies comparing reading performance of students with and without music training showed that those with music training scored significantly higher on standardized tests of reading and verbal ability, although causality could not be established because of the correlational designs (Butzlaff, 2000). It is not surprising that an association exists between musical aptitude and reading ability. Phonological processing skills such as segmentation and blending are the best predictors of reading success (Wagner & Torgesen, 1987) and call upon on the same basic auditory processing skills as those used in discriminating harmonies and rhythms and other music perception tasks. Barwick and colleagues (1989) noted that children with reading difficulties often exhibit difficulty on music tasks. Indeed, children and adults with phonological deficits demonstrate rhythmic and tempo deficits (Jones, Lucker, Zalewski, Brewer, & Drayna, 2009; Overy, 2003). Moreover, children participating in a music program that targets listening skills required for both music and phonological skills perform better on tests of phonological awareness compared to children in a standard music program (Bolduc, 2009). Together, this body of research supports the hypothesis that the same set of basic auditory processing skills underlies the documented association between music and reading.

There is little agreement about the specific elements of music perception that correlate with reading development. Although various studies indicate that an association exists between various musical aptitude and reading skills, few studies have provided conclusive evidence as to the full extent of this association. Most studies demonstrate a positive association between pitch discrimination and phonological processing skills in children (Anvari et al., 2002; Barwick et al., 1989; Douglas &
associations between music discrimination tests and reading abilities among children with music training compared to untrained children, which suggests that music training influences the development of reading and language skills. The authors also noted that improvement on the reading test “near significantly” (p. 386) predicted rhythm discrimination but not melodic discrimination, especially among children with music training. These results are inconclusive, however, because of the small sample size of the no-music group (only four children) and the fact that the baseline assessments of the musically trained children occurred 20 to 35 weeks after music training had begun. The findings reported by Chan et al. (1998), Ho et al. (2003), and Forgeard et al. (2008) are also limited by their correlational designs, which preclude inferences of causation from music training to reading. Nevertheless, these results suggest that the established association between musical aptitude and reading skills may depend on whether children have formal music training.

The purpose of the present investigation was to extend our understanding of the association between formal music training and reading abilities. We examined whether music processing skills differentially predict reading performance for children with and without formal music training. Unpacking this association may provide a key to understanding the mechanisms by which music training may facilitate reading skill.

Method

Participants

Seventy children between the ages of 5 years and 9 years (mean age = 7.2 years) participated. Forty-three had no formal music lessons. One child who was receiving lessons was eliminated from the data analyses because he was unable to complete any of the music or reading tasks. Of the remaining 26 children who were receiving lessons, 21 were being instructed in piano, 2 in violin, 2 in voice, and 1 child was receiving instruction in both voice and cello. On average, the musically trained children had 2 years of music lessons (SD = 1.27; range: .5 to 5 years). Socioeconomic status was estimated by mother’s level of education, which had the following distribution: 2.9% had some high school, 13.0% completed high school, 24.6% completed a college degree, 7.2% had some university education, 33.3% completed a university undergraduate degree, and 18.8% completed a postgraduate degree. There was a significant difference between socioeconomic status as estimated by mother’s education between children with music
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lessons (median education level “university undergraduate degree”) and those without (median education level “completed some university”), Mann-Whitney U = 324, p < .01. The majority of children (88.4%) came from monolingual English homes. Children were recruited through local branches of the Canadian Conservatory of Music and through a developmental database maintained by the Department of Psychology at the University of Western Ontario.

**Reading and Cognitive Skills Measures**

The Peabody Picture Vocabulary Test—4th Edition (PPVT; Dunn & Dunn, 2006) was administered as an estimate of verbal intelligence. Although not used in the analyses, the measure was used to ensure that our groups were matched on verbal IQ. This test is a commercially available standardized test of vocabulary in which children are asked to identify various objects presented through pictures (e.g., canoe, funnel). Testing is discontinued after eight errors in a block of 12 trials.

Reading was assessed using the Word Identification subtest of the Woodcock Reading Mastery Test—Revised (NU; Woodcock, 1998). This is a commercially available standardized test in which children read individual words that become progressively more difficult (e.g., go, see, which, investigate). Testing is discontinued after six consecutive errors.

Phonological skill was assessed using the Test of Auditory Analysis Skills (Rosner, 1979). This test is a commercially available standardized phoneme deletion task that requires children to repeat a word spoken by the experimenter after deleting a particular phoneme (e.g., say “stale” without saying the /t/). Children completed all 13 trials and proportion correct was recorded.

**Tests of Musical Ability**

Three measures of music perception were created for this study. Each task was a same-different comparison task, based on items used by Bentley (1966) and Gordon’s (1986) Primary Measures of Music Audiation. Variations of the tasks devised by Bentley (1966) and Gordon (1986) have been used in previous studies (e.g., Atterbury, 1983; 1985; Anvari et al., 2002). In each task, children listened to two short pieces of music and indicated whether they were the same or different. Each task consisted of three practice trials and 10 test trials. Half of the test trials were same trials and half were different trials.

All music stimuli were created using Finale 2007 software and converted into digital sound files. Stimuli were presented with a CD player at a consistent volume for all participants. Children indicated to the experimenter whether the two pieces of music were the “same” or “different”.

**Melody discrimination.** All melodies were five notes in length and the pitch range was restricted to an octave between A4 (440 Hz) and A5 (880 Hz), which is within the range of normal singing for children (Bentley, 1966). All melodies were presented in piano timbre. The differences in the melodies for the different trials ranged from highly salient (e.g., three-note reversal, semitone out-of-key change) to very subtle (e.g., semitone in-key change, tone in-key change).

**Rhythm discrimination.** Rhythmic patterns ranged in length from 3 to 10 note patterns, in either triple or duple time. Patterns presented were either three or four beat patterns with duple or triple subdivisions. All rhythmic patterns were presented in piano timbre and on the pitch of A4. On different trials, the change ranged from highly salient (e.g., a quarter-note duration was replaced with four 16th-note durations) to less salient (e.g., a triplet was replaced with two 8th notes). Changes were restricted to a single beat of the pattern.

**Timbre discrimination.** Timbre trials consisted of two notes of equal pitch (A4) and duration (500 ms). The timbres included very commonly heard timbres (e.g., piano, violin, piccolo) as well as more uncommon timbres (e.g., harp, oboe).

**Procedure**

All children were tested individually in one session lasting approximately 40 min. The PPVT was always administered first because this test provides an easy means of establishing a rapport between the child and the experimenter. The music tasks were administered together, but the order in which they were administered was counterbalanced across participants. The order of the two reading tests (Woodcock and Rosner TAAT) was also counterbalanced across participants, as was presentation order of the music tasks and the reading tasks. While the child was being tested, a parent completed a short background questionnaire that asked about the extent of the parents’ and their child’s music lessons and experiences as well as other pertinent demographic information.

**Results**

**Group Comparisons**

Table 1 illustrates children’s performance on reading and music tasks separately for musically trained and
untrained children. Although standard scores are presented for ease of interpretation, raw scores were used in subsequent correlational analyses. Trained children outperformed untrained children on the measures of pitch discrimination, $t(67) = 3.34, p = .001$, rhythm discrimination, $t(67) = 2.61, p = .01$, and phonological skills, $t(67) = 2.95, p < .01$. The two groups performed similarly on tests of word identification, timbre discrimination, and receptive vocabulary, $ps > .30$.

**Partial Correlations and Regressions**

As illustrated in Table 2, a series of partial correlations controlling for the age of participants was performed separately for children with and without music lessons. As expected, the three music tasks were significantly intercorrelated for both groups. The sole exception involved the timbre task, which was not correlated with the other music tasks among the trained children. As expected, phonological skill was significantly correlated with word identification for children with and without formal training. The pattern of partial correlations between music and reading skills differed depending on whether or not children had formal music lessons. Although pitch discrimination was significantly correlated with both word identification and phonological skill for children without music lessons, for children with lessons, none of the music tasks was associated with either word identification or phonological skill.

The differential nature of these associations was explored further in separate regression analyses for both outcome measures (word identification and phonological skill). The initial main effects models included age, SES, the music variables (pitch, rhythm, and timbre discrimination), and music training (dummy coded). Tests of interactions between the music variables and music training were conducted subsequently by adding each interaction term separately to the model one at a time.

**TABLE 1. Means and Standard Deviations on All Measures for Children With and Without Formal Music Training.**

<table>
<thead>
<tr>
<th></th>
<th>Formal music training ($n = 26$)</th>
<th>No formal music training ($n = 43$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vocabulary</td>
<td>114.6 (9.8)</td>
<td>113.5 (13.6)</td>
</tr>
<tr>
<td>Word identification</td>
<td>113.7 (16.2)</td>
<td>109.3 (21.8)</td>
</tr>
<tr>
<td>Phonological skill</td>
<td>.82 (.19)</td>
<td>.64 (.27)</td>
</tr>
<tr>
<td>Pitch discrimination</td>
<td>.79 (.17)</td>
<td>.61 (.24)</td>
</tr>
<tr>
<td>Rhythm discrimination</td>
<td>.85 (.13)</td>
<td>.70 (.27)</td>
</tr>
<tr>
<td>Timbre discrimination</td>
<td>.92 (.11)</td>
<td>.83 (.27)</td>
</tr>
</tbody>
</table>

a = standard score with mean = 100; SD=15; b = proportion correct

**TABLE 2. Partial Correlations Controlling for Age for Children With (Below Diagonal) and Without (Above Diagonal) Formal Music Training.**

<table>
<thead>
<tr>
<th>Measures</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1) Word identification</td>
<td>.63***</td>
<td>.54***</td>
<td>.22</td>
<td>.13</td>
<td></td>
</tr>
<tr>
<td>(2) Phonological skill</td>
<td>.54**</td>
<td>.39**</td>
<td>.24</td>
<td>.24</td>
<td></td>
</tr>
<tr>
<td>(3) Pitch discrimination</td>
<td>.18</td>
<td>.26</td>
<td>.72***</td>
<td>.54***</td>
<td></td>
</tr>
<tr>
<td>(4) Rhythm discrimination</td>
<td>.30</td>
<td>.31</td>
<td>.48*</td>
<td>.55***</td>
<td></td>
</tr>
<tr>
<td>(5) Timbre discrimination</td>
<td>-.08</td>
<td>-.08</td>
<td>.24</td>
<td>.31</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05; **p < .01; ***p < .001

For word identification, the main effects model was significant, $R^2 = .70, p < .001$. Age, SES, and pitch made significant unique contributions to the model, $p < .001$. Improvements in word identification were accompanied by increases in age with SES and the music variables held constant, by increases in SES with age and the music variables held constant, and by increases in pitch discrimination abilities with age, SES, and the other music variables held constant. The main effect of pitch was qualified by a significant interaction between pitch and music training, $p < .05$. Other two-way interactions between music training and the music variables were not significant. Separate regressions for the musically trained and untrained children indicated that for untrained children, pitch perception was a significant predictor of word identification even when age, SES, and the other music variables were held constant, $pr = .58, p < .001$. The same partial association was not significant for children with formal music training, $p > .40$.

For phonological skill, the main effects model was again significant, $R^2 = .55, p < .001$. Age and pitch made significant unique contributions to the model, $p < .05$. Phonological skill improved with increases in age when SES and the music variables were held constant, and with increases in pitch discrimination ability when age, SES, and the other music variables were held constant. Because there were no two-way interactions between the music variables and music training, evidence that formal music training moderated the association between phonological skill and pitch discrimination ability (or other music abilities) was not as strong as it was for word identification.

**Discussion**

The present study examined whether the association between music perception tasks and reading skill differed depending on whether or not children have formal music training. Results indicated that while pitch perception was associated with phonological skills and word identification for children without formal music training, this was not the case for children with formal music training. More specifically, the association...
between pitch perception and word identification was significant for untrained but not for trained children, and the magnitude of the association differed significantly between groups. For phonological skill, the results were not as clear. Although the association between pitch perception and phonological skill was significant only for the untrained children, the magnitude of the association did not vary significantly between groups.

Our findings are generally in agreement with previous studies that examined the association between reading and music development. An association between pitch processing and phonological awareness has been found in several studies (Anvari et al., 2002; Barwick et al., 1989; Lamb & Gregory, 1993). The results of the present study also suggest, however, that music training may moderate the pattern of associations between music skills and reading, because the association with word identification was significant only for children without formal music training. This differential pattern of results based on music training suggests that children with and without music training should not be treated as a single group, as is often the case in many correlational studies examining the association between music and non-musical abilities that do not test for interactions with training. Formal music training may be an important moderator in associations between various music perception skills and reading skills.

The association between pitch perception and phonological skill in the present study bolsters the notion put forward by many researchers that basic auditory processing skills are strongly correlated with basic reading skills (Anvari et al., 2002; Gromko, 2005; Peynircioglu et al., 2002). However, the lack of associations between music perception and word reading or phonological skills in children with music training conflicts with this idea. Music training improves music perception skills (e.g., Corrigall & Trainor, 2009; Morrongiello, 1992) and music perception skills are often related to reading (Anvari et al., 2002; Barwick et al., 1989). Thus, one might expect to see a stronger association between pitch discrimination and reading in trained than in untrained children. However, it is possible that while the basic auditory processing skills required for pitch discrimination predict phonological skills for all children, other, as yet unidentified processes that contribute to pitch perception are more distally related to reading skill for trained than untrained children. For example, Corrigall and Trainor (2011) found that duration of training was associated with reading comprehension but not with word identification for 6- to 9-year-olds taking music lessons. In the present study, the untrained children showed greater variance in both word identification and pitch discrimination, thus enabling pitch discrimination to become a significant predictor of word identification for this group.

It should also be noted that there were no significant associations between rhythm discrimination and reading skill in our data. Although Douglas and Willatts (1994) found a significant association between rhythm perception and phonological awareness, Atterbury (1983) found that 7- to 8-year-old poor readers had lower performance on rhythm production tasks but not on rhythm discrimination tasks compared to children identified as normal readers. Our study included only a rhythm discrimination task, and the lack of rhythm production measures makes it impossible to compare our results directly to Atterbury (1983). Furthermore, the children in this study (7.2 years) were younger than those tested by both Douglas and Willatts (1994) and Atterbury (1983; 8.0 years and 7.5 years, respectively), precluding direct comparisons. Thus, the association between rhythm sensitivity and reading acquisition remains unclear.

Although we did not find any association between rhythm discrimination and reading ability, temporal processing is an important component of word identification (Breznitz, 2006). In proficient readers, word identification is an automatic process that allows for increased cognitive resources to be devoted to comprehension. Automaticity is inherently related to processing speed, and thus temporal processing factors (Perfetti & Hogaboam, 1975; Torgeson, 1986; see Hudson, Lane, & Pullen, 2005 for a review). Only a small number of studies have examined directly the role of temporal factors such as rhythm during reading development, yet these studies indicate that temporal sensitivity may be a precursor to reading. Tests of auditory-visual rhythmic pattern matching predict reading ability in 8- to 9-year-olds (Rudnik, Sterritt, & Flax, 1967; Sterritt & Rudnik, 1967). Holliman, Wood, and Sheehy (2008) found that children’s sensitivity to lexical stress patterns in isolated words predicted reading attainment in 5- and 6-year-olds, even after controlling for phonological awareness. There are also a growing number of experimental studies using music interventions to remediate some of the behavioral correlates of developmental dyslexia (e.g., Forgeard et al., 2008; Overy, 2003), but the results of these studies are mixed, indicating that more research is required to determine the specific links between temporal processes, pitch processes, and reading ability. Although the results of the present study do not clearly support an association between rhythm perception and reading development, more research on this question is warranted.

There are limitations to the conclusions of the present study. Due to the small sample size and resulting power issues, the results should be considered preliminary and interpreted with caution. The study included a broad age range of children, and although age was taken into account in the analyses, it should also be noted that all of
the skills we tested undergo significant maturation-based changes during this period. Thus, it is possible that the patterns of correlations may change depending on the specific age tested. Future research should examine narrower age ranges and explicitly compare the patterns of associations between musical skills and reading skills, and how these associations interact with music training across different ages.

Lastly, while we have demonstrated that the patterns of associations between music skills and reading skills differ depending on whether or not children have formal music training, our study is a correlational one, and no causal conclusions can be drawn. It is possible that the two groups of children differed systemically in others ways that were not examined here, such as number and/or type of extracurricular activities other than music, which may have also contributed to differences between the two groups. Although there are a few published quasi-experiments examining the effect of music intervention on children’s reading (e.g., Douglas & Willatts, 1994; Forgeard et al., 2008; Overy, 2003), the majority of studies that examine the causal association between music training and reading performance compare children taking music lessons to children not taking lessons of any kind. Thus, it becomes difficult to determine whether the non-musical benefits are due to improved music skills or to structured extracurricular activities in general. Future research should try to examine the causal nature of the association between music training and reading more explicitly, focusing specifically on both pitch and rhythmic processing skills as they pertain to reading outcomes.

It is clear from the present study that children with formal music training show different patterns of associations between music skills and reading skills than do children with no formal music training. The results are broadly consistent with previous studies examining music and reading, and support the notion that music and phonological processing share similar auditory mechanisms. Furthermore, these findings help to clarify the separate roles of pitch and rhythm processing as they relate to reading development. Our results highlight the importance of considering music training when examining relations between music perception and other cognitive domains.

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