ACADEMIC PRESS

J. Experimental Child Psychology 83 (2002) 111–130

Journal of Experimental Child Psychology

www.academicpress.com

Relations among musical skills, phonological processing, and early reading ability in preschool children

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Received 6 August 2001; revised 17 August 2002

Abstract

We examined the relations among phonological awareness, music perception skills, and early reading skills in a population of 100 4- and 5-year-old children. Music skills were found to correlate significantly with both phonological awareness and reading development. Regression analyses indicated that music perception skills contributed unique variance in predicting reading ability, even when variance due to phonological awareness and other cognitive abilities (math, digit span, and vocabulary) had been accounted for. Thus, music perception appears to tap auditory mechanisms related to reading that only partially overlap with those related to phonological awareness, suggesting that both linguistic and nonlinguistic general auditory mechanisms are involved in reading.

Keywords: Music; Reading; Auditory processes; Development

Although learning to read involves the visual processing of written language, the ease of reading acquisition is related to the development of phonological awareness. Those children who develop the ability to hear the

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PII: S0022-0965(02)00124-8

individual sound categories within a word are able to associate these phonemes with their written letter representations (Bradley & Bryant, 1983; Goswami, 1990; Stanovich, 1986). Because English uses an alphabetic orthography that maps the written code onto its phonemic equivalent (for the regular part of English), a child who shows auditory sensitivity to the spoken phonemic units has an advantage in learning the orthographic to phonological mapping system (Goswami, 1990; Stanovich, 1986). A large body of research has demonstrated that phonemic awareness correlates strongly with reading acquisition (Bruck & Treiman, 1990; Stahl & Murray, 1994). Children who are poor readers typically are strikingly insensitive to rhyme and alliteration (Bradley & Bryant, 1978, 1983). These findings indicate a close link between reading and auditory analysis skills.

Recent research has proposed that some auditory analysis skills used in the processing of language, such as blending and segmenting sounds, are similar to the skills necessary for music perception, such as rhythmic, melodic, and harmonic discrimination (Lamb & Gregory, 1993). If early reading skill is closely linked to skill in processing the auditory components of speech, it is reasonable to hypothesize that the auditory analysis skills necessary for music perception may also be associated with reading development (Atterbury, 1985; Barwick, Valentine, West, & Wilding, 1989; Douglas & Willats, 1994; Lamb & Gregory, 1993). The purpose of this study was to examine the relation between music perception and early reading development in 4- and 5-year-old children.

Music, like language, is based in the auditory modality and the primary mode of music production, singing, uses the same vocal apparatus as speech. Both speech and music involve combining small numbers of elements (phonemes, notes) according to rules (referred to as grammars in music theory) that allow the generation of unlimited numbers of phrases or utterances that are meaningful (e.g., Lerdahl & Jackendoff, 1983). Furthermore, there is recent evidence that speech and music share some cortical areas and mechanisms (Patel & Peretz, 1997; Patel, Peretz, Tramo, & Labrecque, 1998). This commonality suggests that music and speech might be closely related in early development. Speech directed to young infants is often referred to as musical speech (Fernald, 1989) because it contains musical characteristics, such as abundant repetition, high pitch, slow tempo, and large slow pitch contours (up/down patterns). Interestingly, musical speech is used similarly across languages and cultures (Ferguson, 1964; Fernald, 1991; Fernald et al., 1989; Papousek, 1992; Werker, Pegg, & McLeod, 1994), and caregivers, non-parents, and even siblings intuitively use it with infants (Dunn & Kendrick, 1982).

Learning a language requires learning the basic building blocks of words, syllables, and phonemes. The elements of music are different from those of language, but the basic learning processes may be similar (Saffran, Johnson, Aslin, & Newport, 1999). Western music has three basic structural aspects: rhythm, melodic (sequential) pitch, and harmonic (simultaneous) pitch.

Rhythmic structure consists of the actual sequences of durations of the notes in a musical composition as well as the underlying hierarchical beat (perceived pulse) structure, and young infants are sensitive to rhythm (Baruch & Drake, 1997; Demany, McKensie, & Vurpillot, 1977; Thorpe & Trehub, 1989). Notes with particular pitches and durations are concatenated according to rules to form melodies and harmonies. These rules are specific to a musical system, such as Western tonal structure. Although infants are sensitive to some universal aspects of melodic pitch structure (Schellenberg & Trainor, 1996; Schellenberg & Trehub, 1996; Trainor, 1997; Trainor & Heinmiller, 1998; Trainor & Trehub, 1993), implicit knowledge of system-specific scales and harmonic structure is not complete until at least 7 years of age (Costo-Gioma, 1994; Trainor & Trehub, 1992, 1994). Thus, as with speech perception, infants show early sensitivity to some musical features, whereas other features are musical-system-specific and thus need to be learned. It should also be noted that, as with language, acquisition of musical structure occurs without formal musical training, simply through everyday experience with music.

There is another parallel between linguistic and musical information. In both domains, a normalization process must be in operation in order to achieve perceptual constancy. A phoneme in speech is recognizable despite changes in duration, loudness, timbre, and pitch across speakers and linguistic contexts. Similarly, a melody retains its identity across changes in tempo, loudness, timbre, and pitch level, as long as the intervals between successive pitches remain correct (Dowling & Harwood, 1986).

What all of this suggests is that music and speech may depend on many of the same basic auditory processes, and hence, early skill with music might enhance reading acquisition to the extent that reading depends on the same basic auditory analysis skills. Musical training may enhance other linguistic skills as well. Melodic and rhythmic grouping of digits helps children as young as 4 years to remember random digits and multiplication tables (Clausson & Thaut, 1997). Chan, Ho, and Cheung (1998) have demonstrated that musical training in childhood may confer long-term benefits in verbal memory. Adults with musical training were significantly (on average 16%) better in recalling verbally presented words than non-musically trained adults.

A separate body of research demonstrates that dyslexics have specific deficits in basic perceptual processing. While there are reports of impaired frequency discrimination (Talcott et al., 1999) and excessive backward masking (Wright et al., 1997) in dyslexia, the most prevalent finding concerns difficulty in the temporal processing demands needed for perceiving rapid sequences (Kujala et al., 2000; Nagarajan et al., 1999; Tallal, Sainburg, & Jernigan, 1991; Tallal & Piercy, 1973). Tallal et al. (1991) argue that dyslexics have deficits in responding to rapidly presented stimuli across modalities (e.g., visual processing, motor sequencing, and auditory sequencing). It is thus reasonable to suggest that this processing deficit might be present in both speech and music perception. This may account for the finding that dyslexics perform more poorly overall than normal readers in music perception tasks (Atterbury, 1985; Miles & Miles, 1990), as such a deficit would be expected to interfere both with the segmentation of speech into phonemic units and the segmentation of music into notes and phrases.

There are few studies to date that have directly compared music and reading development, and there is little agreement on the particular elements of music perception that correlate with reading difficulty in school-aged children. Atterbury (1985) compared the musical abilities of 7- to 9-year-old reading-disabled and age-matched controls, using the Bentley Test of Musical Ability (1966). She found that the poor readers were significantly impaired in tonal discrimination and rhythm production, but not on rhythm perception. Barwick et al. (1989) used a simplified version of the Bentley Test of Musical Ability (1966) and compared musical ability to reading age in children 7–10 years of age. They found that tonal memory and chord analysis abilities correlated with reading age. However, Douglas and Willats (1994) concluded that only rhythm discrimination correlated with reading ability in 7- and 8-year-old children. Neither of the latter two studies administered production tasks, making it impossible to compare them directly with Atterbury (1985).

Only one published study to date has compared reading readiness and musical ability in pre-readers. Lamb and Gregory (1993) presented 16 4- and 5-year-old children with pitch and timbre discrimination tasks, phonemic awareness, and a simple reading test. As expected, phonemic awareness correlated with simple reading ability. They also reported that pitch discrimination was significantly correlated with phonemic awareness. This study is suggestive of a link between music and early reading skill in preschool children. However, it is limited in that there were only 16 children in the sample and a limited number of musical skills were tested.

The study reported here provides a more extensive analysis of the relation between developing reading and musical skills. One hundred 4- and 5-year-old children were administered a set of music tasks that focused rhythm, melody, and chord processing, a set of phonemic awareness tasks known to predict reading success, and a standardized measure of early reading development (WRAT 3). Four- and 5-year-olds were studied because musical skills and early reading skills are both developing at a fast pace during this time. As well, children of this age particularly enjoy participating in musical activities. The aim of the study was to examine the relation between musical processing and phonemic awareness in a large sample of young children, as well as to examine how these factors are related to reading development. Using ordered regression analyses, we planned to examine whether musical variables predicted reading success, even when the contribution from phonemic awareness had been taken into account. Finally, in a first attempt to study some of the more general cognitive variables through which music might influence reading development, we also tested digit span, vocabulary, and mathematical skills. By performing separate analyses in which one of digit span, vocabulary, and mathematical skill was removed in the initial step of a hierarchical regression, and examining whether music and/or phonemic awareness continued to predict reading, we could begin to explore the potential roles of auditory memory, vocabulary, and mathematical skill, respectively, in the links between music and reading.

Method

Participants

Fifty 4-year-old (29 female; 21 male) and 50 5-year-old (30 female; 20 male) children were recruited from schools and daycare centers in the Hamilton-Wentworth region of Canada. Permission was received from the principal of the school, the daycare director, the teachers, and the child's parent or guardian before any child participated in the study. Participants ranged in age from 4 years 0 months to 4 years 11 months, for 4-year-olds (mean age: 4 years 7 months) and 5 years 0 months to 5 years 11 months of age (mean age: 5 years 5 months) for 5-year-olds.

Materials and design

The children were given a battery of tests over the course of five sessions, each lasting approximately 20–30 min. In all tasks, three practice trials were given with feedback to make sure that the child understood the procedure. Some tasks were standardized tests while others were developed by the authors after extensive pilot testing. The tests were presented to each child individually in a quiet room. Many of the tests involved interaction with a dog puppet. With the exception of the rhythm production task, all the musical stimuli were created with Midilab and were presented on audio tape using a stereo cassette player at a comfortable volume. The timbre selected for the musical tasks was that of a piano, because this instrument is probably most familiar to children. Each child received a sticker book at the beginning of testing and was allowed to select a sticker to put in his or her sticker book after completing each task. The tasks were administered in a standard order, alternating music and language tasks, but the number of tasks completed each session varied, depending on the attention span of the child. The common order was Rhyme Generation, Rhythm Production, Blending, Same/Different Rhythm Discrimination, Oddity, Same/Different Chord Discrimination, Rosner, Chord Analysis, Wide Range Achievement Test-3 (WRAT) Reading Subtest, Same/Different Melody Discrimination, Digit Span, Mathematics, and Peabody Picture Vocabulary Test (PPVT). A description of each task follows.

Phonemic awareness

(i) *Rhyme Generation*. Twelve target words (cat, ball, car, not, bed, cake, will, hold, tent, boat, kind, and train) were presented one at a time and the child was asked to generate as many words as possible that rhymed with the target word, with no time limit.

(ii) *Oddity*. Each of 18 trials consisted of four words. One of the four words either began with a different sound (can-cat-car-sun), ended with a different sound (huff-cup-muff-puff), or differed in the middle sound (thank-sank-walk-bank). The child indicated which word sounded different at the specified position.

(iii) *Blending*. Because a large majority of pre-readers are unable to blend individual phonemes as in "c-a-t" makes "cat" (Adams, 1990) we used the easier task of blending onsets and rimes as in "c-at" makes "cat" (Adams, 1990; Goswami, 1990). Thus, in each of the 10 trials each child was asked to blend the onset and rime to form a word (c-at, d-og, p-en, sh-ell, d-ig, c-ook, str-eet, f-udge, st-ep, pl-ant). The task was presented to the child by asking him or her to decode the disjointed speech of the dog puppet.

(iv) *The Rosner Test of Auditory Analytic Skills (Standardized)*. The 13 items in this test measure skill in identifying, segmenting, deleting, and recombining the component syllables and sounds of a word. For example, the child is asked to say "cowboy" without the "boy", or to say "coat" without the "c" sound.

Reading

The reading subtest of the standardized Wide Range Achievement Test-3 (WRAT-3) was used. This test begins with letter identification and progresses to reading a graded series of words, beginning with very easy words.

Vocabulary

Receptive vocabulary was measured using the Peabody Picture Vocabulary Test—Revised (Dunn & Dunn, 1981), in which the child is required to point to the one of four pictures that best represents the word read out loud by the experimenter.

Music

We presented both sequential (rhythm and melody) and simultaneous (chord) music tasks to parallel the above segmentation and blending tasks with speech sounds. All musical stimuli were comprised of piano tones.

All of the same/different tasks closely parallel the oddity task for phonemic awareness. Whether the stimulus was sequential (melody and rhythm) or simultaneous (chords), the child was required to determine whether two presentations were identical or different in one element. In each task, half of the trials were identical and half were different.

(i) *Same/Different Rhythm Discrimination*. The child was required to determine whether two computer generated rhythmic patterns were the same or different. The difficulty of the discrimination increased across 10 trials. Trials ranged from rhythms containing 3 isochronous beats to rhythms of 4 beats including duple and triple subdivisions. Changes were restricted to one beat of the pattern.

(ii) *Same/Different Melody Discrimination*. On each of 8 trials the child was required to determine whether two computer generated melodies were the same or different. Melodies ranged from 3 to 11 notes in length and the differences ranged from subtle (one note changed by 1/12th of an octave) to quite salient (pitch contour (up/down) reversals).

(iii) *Same/Different Chord Discrimination*. On each of 10 trials the child was asked to determine whether a pair of chords were the same or different. The chords varied in consonance and dissonance, and contained either two or three notes. Changes were made in either one or two of the notes.

(iv) *Rhythm Production*. On each of 8 trials the child listened to a vocally produced rhythm and was asked to reproduce it (e.g., la-lala-la). The stimuli ranged in length from 3 to 10 beats. This task was used because many children of this age may not have the motor dexterity to clap or tap a complex rhythm.

(v) *Chord Analysis*. On each of 12 trials the child had to determine whether the musical sound consisted of a single note or two notes played simultaneously (a chord). The chords varied in consonance or dissonance.

Digit Span

Because many of the reading and music discrimination tasks rely on auditory memory, the digit span subtest of the WISC-R was used to assess auditory memory span.

Mathematics

To obtain a general measure of cognitive ability we administered four mathematics problems in the form of a story about the travels of a dog puppet and the objects he collects, as originally devised by Sophian and Vong (1995). The set consisted of two addition and two subtraction problems. In one of each the child was required to calculate the final unknown quantity and in the other the child was required to calculate an initial unknown quantity. For example, one story involved a bear who had five apples. A friend gives him one more and the child is asked how many apples the bear now has.

Results

We first explore the relations among the music variables and the relations among the phonological variables using factor analysis, to define the underlying factors. We then use hierarchical regression analyses to test whether musical ability explains variance in reading skills over and above that explained by phonemic awareness. Finally, we explore separately whether auditory memory, vocabulary, and mathematical ability might be involved in the relation between music and reading.

Factor analyses

Musical tasks

Table 1 contains the mean scores with standard deviations for each of the 13 tasks used in the study for 4- and 5-year-olds separately. A principal component factor analysis on the 4-year-olds' normalized scores for the music tasks (same/different melody, same/different chord, chord analysis, same/different rhythm, and rhythm production) revealed a single factor that accounted for 48.2% of the variance (see Table 2 for weights). Thus a single music macro-variable consisting of the factor-weighted average of the five normalized music variables was constructed for use in regression analyses. The same factor analysis on the 5-year-olds' data revealed two factors, corresponding to pitch perception (same/different melody, same/different chord, and chord analysis) and rhythm perception (same/different rhythm, rhythm production), which together accounted for 65.2% of the variance (see Table 2 for weights). Thus, by 5 years of age, separate pitch and rhythmic abilities can be measured. Two music macro-variables, consisting of the factor-weighted averages of the normalized pitch and the normalized rhythm variables were created for use in regression analyses.

Table 1
Mean performance and standard deviations for the 13 tasks for 4- and 5-year-old children

Task	Four-year-olds		Five-year-olds	
	Mean	*SD*	Mean	*SD*
Rhyme	6.36	8.25	8.68	8.22
Oddity	.32	.20	.39	.20
Blending	.31	.25	.47	.30
Rosner	.28	.25	.42	.25
WRAT	9.96	5.76	12.86	5.58
Rhythm production	.53	.25	.66	.22
Rhythm same/different	.66	.19	.77	.18
Chord analysis	.63	.23	.62	.19
Chord same/different	.54	.21	.61	.18
Melody same/different	.57	.19	.65	.15
Math	.47	.30	.58	.26
Digit Span	9.4	3.26	10.52	3.40
Peabody	98.86	27.53	97.38	17.27

Table 2
Principal component analysis of the music variables for 4- and 5-year-old children

	Factor 1	
Four-year-olds		
Same/different melody	.76	
Same/different chord	.81	
Chord analysis	.83	
Same/different rhythm	.33	
Rhythm reproduction	.61	
Percentage of variance	48.3%	
	Factor 1	Factor II
Five-year-olds		
Same/different melody	.81	.17
Same/different chord	.80	.32
Chord analysis	.64	−.14
Same/different rhythm	.14	.80
Rhythm reproduction	.02	.87
Percentage of variance	41.3%	23.9%

It has been argued that pitch and rhythm represent two distinct dimensions of music perception that are processed separately and in parallel (Carroll-Phelan & Hampson, 1996; Peretz & Kolinsky, 1993). Much of the evidence for this comes from dissociations between pitch and rhythm processing abilities in brain injured patients (Springer & Deutsch, 1989). Our data suggest that by age 5 clearly separable pitch and rhythmic abilities have emerged.

Phonemic awareness tasks

Table 1 shows the mean performance with standard deviations for these tasks for both age groups. Factor analyses on normalized scores from the phonological awareness tasks (rhyme generation, oddity, blending, and Rosner) revealed only one factor for 4-year-olds, which accounted for 50% of the variance and only one factor for 5-year-olds, which accounted for 53% of the variance (see Table 3 for weights). Therefore, single phonemic awareness macro-variables were created for each age group consisting of the factor-weighted average of the phonemic awareness variables (rhyme generation, oddity, blending, and Rosner) for use in regression analysis.

Correlation analyses: Simple relations between phonological awareness, music, and reading

Because a single factor accounted for 4-year-olds' musical performance whereas separate pitch and rhythm factors were needed to account for 5-year-olds' performance, it was necessary to perform separate correlational

Table 3
Principal component analysis of the phonemic awareness variables for 4- and 5-year-old children

	Factor 1
Four-year-olds	
Rhyme generation	.73
Oddity	.83
Blending	.49
Rosner	.72
Percentage of variance	50.0%
Five-year-olds	
Rhyme generation	.76
Oddity	.76
Blending	.71
Rosner	.65
Percentage of variance	52.8%

and regression analyses for the two age groups. Simple correlations are shown in Table 4 for 4- and 5-year-olds. As expected, in both age groups, phonological awareness correlated significantly with reading. This supports the vast literature outlining the strong relationship between phonological awareness and reading skill (e.g., Bradley & Bryant, 1983).

It can also be seen in Table 4 that in both age groups phonemic awareness was correlated with musical ability, as predicted. In the 4-year-olds, musical ability was correlated with reading, and in the 5-year-olds, pitch processing, although not rhythmic processing, was correlated with reading. Thus, the auditory processing necessary for music perception appears to be related to the auditory processing necessary for phonological awareness and, ultimately, reading.

Regression analyses I: Do music and phonemic awareness uniquely predict reading?

The next question of interest was whether the power of music to predict reading is a result of shared variance between musical skills and phonological awareness, or whether music predicts reading after the variance due to phonological awareness has been removed. A hierarchical regression was conducted with reading scores as the dependant variable. Phonological awareness was entered on the first step. For 4-year-olds, the music macro-variable was entered on the second step. For 5-year-olds, the pitch macro-variable was entered on the second step. (Rhythm was not entered as the simple correlation between rhythm and reading was not significant.) For the 4-year-olds, music accounted for significant variance after phonemic awareness had been entered (Table 5). For the 5-year-olds, pitch accounted

Table 4
Simple correlations between macro-variables, reading, digit span, and vocabulary

	Music	Reading	Digit Span (WISC-R)	Vocabulary (PPVT-R)	Math	
Four-year-olds						
Phonemic awareness	.59**	.54**	.52**	.57**	.53**	
Music		.57**	.68**	.73**	.35*	
Reading (WRAT)			.57**	.53**	.38*	
Digit Span (WISC-R)				.64**	.43**	
Vocabulary (PPVT-R)					.48**	
	Pitch	Rhythm	Reading (WISC-R)	Digit Span (PPVT-R)	Vocabulary	Math
Five-year-olds						
Phonemic awareness	.36**	.33*	.47**	.61**	.45**	.22
Pitch		.27	.45**	.46**	.15	.23
Rhythm			−.09	.54**	.30*	.16
Reading (WRAT)				.19	.24	.17
Digit Span (WISC-R)					.37**	.22
Vocabulary (PPVT-R)						.08

Note. $N = 50$ at each age.
* $p < .05$.
** $p < .01$.

Table 5
Hierarchical regression predicting reading scores for 4- and 5-year-old children

	R^2	β	R^2 change	F	p
Four-year-olds					
Step 1					
Phonemic awareness	.30	.54	.30	20.05	<.0001
Step 2					
Phonemic awareness		.32			
Music	.39	.39	.09	7.49	<.009
Five-year-olds					
Step 1					
Phonemic awareness	.22	.47	.22	13.59	<.001
Step 2					
Phonemic awareness		.35			
Pitch	.31	.32	.09	6.08	<.017

for significant variance after phonemic awareness had been entered (Table 5). Thus, music ability adds to the prediction of reading skill, once phonological awareness has been accounted for in both age groups.

The above findings provide evidence for a relation between music perception and reading skill in 4- and 5-year-old children. Music perception is significantly correlated with both reading skill and phonological awareness, but is also predictive of reading in its own right. Therefore, music perception appears to be tapping auditory mechanisms related to reading skill that only partially overlap with those related to phonological awareness.

In the remaining regression analyses, we explore various cognitive variables that might be involved in the relation between music and reading.

Regression analyses II: Is auditory memory involved in the relation between music and reading?

One possibility is that music ability is associated with good auditory memory. Adults who had musical training in childhood show better verbal memory than those without musical training (Chan et al., 1998). Table 1 shows the means and standard deviations for the digit span task (from the WISC-R). Digit Span was significantly correlated with music in 4-year-olds and pitch in 5-year-olds, as expected (Table 4). Interestingly, as can also be seen in Table 4, digit span was significantly correlated with reading in the younger, but not in the older, age group. Perhaps as children become more proficient at phonemic awareness, auditory memory becomes

Table 6
Hierarchical regression predicting reading scores from digit span, phonemic awareness, and music (pitch for 5-year-olds) for 4- and 5-year-old children

	R^2	β	R^2 change	F	p
Four-year-olds					
Step 1					
Digit Span	.33	.57	.33	23.63	<.0001
Step 2					
Digit Span		.40			
Phonemic awareness	.41	.33	.08	6.48	<.01
Step 3					
Digit Span		.29			
Phonemic awareness		.26			
Music	.43	.22	.02	1.87	.18
Five-year-olds					
Step 1					
Digit Span	.04	.19	.04	1.88	.18
Step 2					
Digit Span		−.15			
Phonemic awareness	.23	.56	.19	12.07	<.001
Step 3					
Digit Span		−.30			
Phonemic awareness		.51			
Pitch	.36	.40	.13	9.07	<.004

a less important factor. When hierarchical regressions were conducted with digit span entered on step 1, phonemic awareness on step 2, and the musical skill variable (music for 4-year-olds, pitch for 5-year-olds) on step 3, only for the 5-year-olds did pitch explain additional variance in reading scores (Table 6). These results are consistent with musical skill being associated with enhanced auditory memory, but that only in the younger children can this association explain the relation between music and reading. In the 5-year-olds, music continues to explain variance in reading after variance due to auditory memory and phonemic awareness has been factored out.

Regression analyses III: Is vocabulary size involved in the relation between music and reading?

Another possibility is that musical skill predicts reading because both abilities are correlated with general vocabulary. Table 1 contains the mean standardized Peabody scores with the standard deviations for both age groups. In the 4-year-olds, vocabulary scores were correlated with phonemic awareness, reading, and musical ability (Table 4). In the 5-year-olds, vocabulary was correlated with phonemic awareness, but not with reading or pitch (Table 4), although there was a trend ($p < .09$) for a correlation between reading and vocabulary. This suggests that vocabulary cannot explain the relation between music and reading ability. Regression analyses were conducted with vocabulary entered in step 1, phonemic awareness in step 2, and either music (for the 4-year-olds) or pitch (for the 5-year-olds) in step 3. The addition of phonemic awareness in step 2 significantly explained additional variance in both age groups (Table 7). The variance explained was significantly increased by the addition of pitch in step 3 in the 5-year-olds, and the increase in the variance explained approached significance by the addition of the music variable in the 4-year-olds. Again, this suggests

Table 7
Hierarchical regression predicting reading scores from vocabulary, phonemic awareness, and music (pitch for 5-year-olds) for 4- and 5-year-old children

	R^2	β	R^2 change	F	p
Four-year-olds					
Step 1					
Vocabulary	.28	.53	.28	18.88	<.0001
Step 2					
Vocabulary		.33			
Phonemic awareness	.37	.36	.09	6.45	<.02
Step 3					
Vocabulary		.17			
Phonemic awareness		.28			
Music	.40	.29	.03	2.69	.11
Five-year-olds					
Step 1					
Vocabulary	.06	.24	.06	3.00	.09
Step 2					
Vocabulary		.04			
Phonemic awareness	.22	.45	.16	9.85	<.003
Step 3					
Vocabulary		.05			
Phonemic awareness		.32			
Pitch	.32	.33	.10	6.41	<.02

that vocabulary cannot explain all of the relation between music and reading.

Regression analyses IV: Is mathematical ability involved in the relation between music and reading?

Consistent with the trend for reduced correlations between cognitive variables and reading in the 5-year-olds compared to the 4-year-olds described in the last two sections, mathematical ability was correlated with phonemic awareness, music, and reading in the 4-year-olds, but none of these relations were significant in the 5-year-olds (Table 4). Again, this suggests that mathematical ability is not involved in the relation between music and reading. Regression analyses with mathematical ability entered in step 1, phonemic awareness in step 2, and either music (for the 4-year-olds) or pitch (for the 5-year-olds) in step 3 revealed that both the addition of phonemic awareness

Table 8
Hierarchical regression predicting reading scores from math, phonemic awareness, and music (pitch for 5-year-olds) for 4- and 5-year-old children

	R^2	β	R^2 change	F	p
Four-year-olds					
Step 1					
Math	.14	.38	.14	7.96	<.007
Step 2					
Math		.13			
Phonemic awareness	.31	.48	.17	11.08	<.002
Step 3					
Math		.10			
Phonemic awareness		.26			
Music	.40	.38	.09	7.14	<.01
Five-year-olds					
Step 1					
Math	.03	.17	.03	1.41	.24
Step 2					
Math		.07			
Phonemic awareness	.23	.45	.20	11.92	<.001
Step 3					
Math		.02			
Phonemic awareness		.35			
Pitch	.31	.32	.08	5.66	<.02

and music resulted in a significant increase in the variance explained (Table 8). This strongly suggests that mathematical ability is not involved in the relation between music and reading.

Discussion

The results of this study indicate that music perception skill is reliably related to phonological awareness and early reading development. Furthermore, music perception is predictive of reading skill even when the variance shared with phonological awareness is removed, suggesting that skill in music perception is related to auditory or cognitive mechanisms beyond those tapped by phonological awareness. It is important to note that the tasks used in this study measure beginning music and reading skills; these children are in the early stages of letter identification or at most read a few words. Thus the relation being discussed is between early reading and early music development.

These results are broadly in agreement with previous studies that have examined the relation between music and reading. Atterbury (1985) found that 7- to 9-year-old poor readers were impaired in tonal discrimination. Barwick et al. (1989) found that tonal memory and chord analysis abilities were related to reading abilities in 7- to 10-year-olds. Lamb and Gregory (1993) found that pitch discrimination was related to phonemic awareness in 4- and 5-year-old children. Interestingly, the relation between musical rhythm and reading is less clear. Atterbury (1985) found that poor readers were impaired on rhythm production tasks, but not on rhythm discrimination, whereas Douglas and Willats (1994) found that only rhythm discrimination correlated with reading ability. Both of these studies had small samples. However, we also found inconsistent results for rhythmic tasks even with our sample of 100 4- and 5-year-olds. Specifically, in 4-year-olds both the rhythm production and rhythm discrimination tasks correlated with the musical pitch tasks and with reading. In contrast, for the 5-year-olds, the rhythm tasks did not correlate with either the musical pitch tasks or with reading. At this point it remains unclear as to why musical pitch (melody and harmony) appears to relate more consistently to phonemic awareness and reading. However, at least with Western music, rhythmic skill may develop earlier than musical-system-specific melodic and harmonic knowledge, and pitch perception skills might therefore reflect to a greater extent the ability to internalize important sound structures in the environment in 4-and 5-year-old children.

The relation between phonological awareness and music perception suggests that they may share some of the same auditory mechanisms. Phonological awareness requires the listener to be able to segment speech into its component sounds, and to recognize those sound categories across variations in the pitch, tempo, speaker, and context. The perception of music also requires the listener to be able to segment the stream of tones into relevant units, and to be able to recognize compositions across variations in pitch (key), tempo, performer, and context.

Much recent research has in fact indicated that basic auditory processing problems underlie many instances of reading problems. Poor frequency resolution (Talcott et al., 1999), excessive backward masking (Wright et al., 1997), poor temporal resolution, and poor temporal sequencing abilities (e.g., Farmer & Klein, 1995; Kujala et al., 2000; Nagarajan et al., 1999; Tallal et al., 1991; Tallal & Piercy, 1973) have all been found to distinguish good from poor readers. It is likely that some of these basic auditory skills are also used for the perception of music. For example, distinguishing melodies or rhythms must require temporal sequencing abilities, and the ability to discriminate two chords or two melodies will likely be worse if frequency or temporal resolution is poor.

Perhaps the most interesting result of the present study is that music perception skill predicts reading even after the variance shared with phonemic awareness is removed. This suggests that phonemic awareness and music perception ability tap some of the same basic auditory and/or cognitive skills needed for reading, but that they each also tap unique processing skills. At this point, we can only speculate as to which underlying skills are associated with each of phonemic awareness and music perception. Our results do suggest that none of auditory memory, vocabulary, and mathematical ability can fully explain the relation between music, phonological awareness, and reading. However, a more precise determination of these relationships remains an important question for future research.

Acknowledgments

This research was supported by operating grants to Drs. Trainor and Levy, and a postgraduate scholarship to S. Anvari, from the Natural Sciences and Engineering Research Council of Canada. We thank the daycares and schools that participated in our study, as well as the children and their parents for their support of this work. We also thank Samantha Minnett and Sandra Martin-Chang for help in testing the children.

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