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Task-Dependent Mechanisms in the Perception of Music and Speech: Domain-Specific Transfer Effects of Elementary School Music Education

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Abstract

Previous studies have demonstrated that active engagement in musical activities benefits auditory and cognitive processing. However, it is still unclear whether musical experience improves domain-general mechanisms reflected in superior functioning in language or the enhancement is selective and limited to musical abilities. In the present study, we evaluated the transfer effect of general elementary school music education on the development of linguistic abilities. The relationship between specific musical auditory skills, phonological awareness, and reading was investigated in 30 second-grade children who attended either a class with an intensive music curriculum or a class with a regular curriculum. Results indicated no significant differences between the music and the regular class, suggesting that 1 year of Kodály-based classroom music education is not enough to yield relevant improvement in musical and linguistic abilities. Although there was no considerable relationship between reading and musical abilities, phoneme deletion accuracy was specifically associated with tonal memory. These findings suggest that similar cognitive mechanisms may be required to process melodic and phonological sequences. Therefore, we assume that task-dependent mechanisms may exist in melody and speech perception, which might account for the presence of inconsistent findings in the music transfer literature.

Keywords

music education, music perception, phonological awareness, reading, task-dependent processing

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Although several studies have investigated the associations between music and language in children, the characteristic of this relationship is still debated. As both domains are closely related to the auditory modality, it is assumed that language and music share common auditory-processing mechanisms (McMullen & Saffran, 2004; Peretz & Coltheart, 2003). However, domain-specific mechanisms may also exist to process acoustic differences specific to music or speech (Asaridou & McQueen, 2013). This raises the question whether training of musical auditory skills benefits speech perception as well, indicating a domain-general improvement in auditory perception or musical activities leads to fine-grained perceptual abilities and enhanced processing only in the music domain.

Diverse music training methods have been used to estimate the effects of music experience on enhancing children's auditory perception. There is evidence that regular musical activities lead to improved auditory encoding and particularly to enhanced sensitivity to acoustic features of speech sounds (Kraus & Chandrasekaran, 2010). However, it is argued how experience in music transfers to the language domain. In the expanded "OPERA" (overlap–precision–emotion–repetition–attention) hypothesis, Patel (2014) emphasized that taking music lessons per se may not result in improved speech perception and language processing, but enhancement occurs when particular conditions are met. According to this model, music training could drive functional plasticity in speech processing through the *overlap* in subcortical and cortical brain networks underlying sensory processing that represent acoustic information involved in both music and language, through *precision* that music places higher demands on these shared networks than speech processing, through positive *emotions* elicited by musical activities, and through regular *repetition* and focused *attention*.

In another neurocognitive model, Moreno and Bidelman (2014) proposed that, besides the length and intensity of music training, transfer to the language domain might depend on the degree to which the training affects cognitive abilities in and out of the music domain, from domain-specific, low-level auditory mechanisms to higher-order, domain-general cognitive processes. Thus, music transfer outcomes are affected by the parameters of the applied training programs as well as by participants' individual differences regarding their cognitive capacity.

Background

Motivated by the evidence showing that there may be a link between music experience and enhanced encoding of speech, the relationship between phonological awareness and musical ability is in the focus of research interest. *Phonological awareness* refers to the explicit knowledge of building blocks in speech and to the ability to manipulate speech sounds (Ramus & Szenkovits, 2008). Speech segmentation requires rapid auditory judgments and precise temporal processing of speech sounds. Moreover, phoneme categorization and discrimination necessitates the accurate detection of spectral changes (Tierney & Kraus, 2013). The characteristics of phonological processing raise the question whether the overall music module or either spectral or temporal features specifically substantiate the transfer of music audition to phonological abilities (Peretz & Coltheart, 2003).

Music-induced improvement in the encoding of speech has been shown through better phonemic categorization and phonological-lexical processing (Besson, Chobert, & Marie, 2011). However, the majority of studies measuring auditory skills in preschool- and school-age children revealed that improved phonological skills were associated not with music audition but with either the perception of rhythm and meter (e.g., David, Wade-Woolley, Kirby, & Smithrim, 2007; Holliman, Wood, & Sheehy, 2010; Moritz, Yampolsky, Papadelis, Thomson, & Wolf, 2013) or pitch processing (e.g., Anvari, Trainor, Woodside, & Levy, 2002; Bolduc & Montésinos-Gelet, 2005; Loui, Kroog, Zuk, Winner, & Schlaug, 2011).

It has been shown that phonological awareness is an essential precursor of later reading ability (Pratt & Brady, 1988); thus, research has been expanded to discover the potential relationship not just between musical hearing and phonological awareness but also between musical hearing and reading acquisition. Correlational studies have demonstrated positive associations between phonological skills, reading, and musical abilities specifically related to either rhythm and meter or pitch perception in children. Douglas and Willats (1994) demonstrated in a study with 8-year-olds that reading and spelling ability were correlated with rhythmic processing. By contrast, tonal memory and chord analysis were associated with reading ability in a sample of 7- to 11-year-old typically developing children and children with poor reading skills (Barwick, Valentine, West, & Wilding, 1989). Similarly, Lamb and Gregory (1993) found that reading skills were related to pitch processing in 4- and 5-year-old kindergarteners. Further, Forgeard et al. (2008) revealed in 6- to 7-year-old children that musical discrimination ability predicted phonological and reading skills, and moreover, normal-reading children who received music instruction outperformed control and dyslexic children in melody discrimination.

The association between classroom music education and language-related abilities in children has been investigated in a few research studies. Moritz et al. (2013) explored whether daily music training leads to more improved phonological skills in kindergarteners than less intensive training. At the beginning of kindergarten, rhythmic skills were specifically related to phonological segmentation, and those children who participated in the intensive music training showed improvement in phonological skills at the end of kindergarten. Moreover, a strong relationship was revealed between kindergartners' rhythmic abilities and their later phonological awareness and basic word identification skills in second grade. In another study with 4- to 5-year-old children, Register (2001) examined the effects of a music curriculum focusing primarily on prereading and writing skills. Both the experimental and control groups received 30-min music lessons twice a week for a school year, but the focus of the lessons differed in the classes. Results indicated that prewriting skills were enhanced in both groups at the end of the school year, but children in the experimental group, with music lessons specifically designed to teach prereading and writing concepts, scored significantly higher on word recognition and logo identification tasks than children in the control group, with no emphasis on teaching prereading and writing skills. Results from these studies indicate that both the intensity of music instruction and the focus of the music curriculum can affect the development of phonological and reading ability in preexisting groups.

Conducting research on the transfer effect of classroom music education has been especially relevant in Hungary, where music instruction is generally available in elementary schools. The philosophy of music instruction is based on the principles of the Hungarian composer, educator, and ethnomusicologist Zoltán Kodály (1882–1967). As Kodály emphasized the importance of constant, sequential practice from an early age, the general school curriculum in Hungary embodies music education from the first elementary school year. Although the concept of music education and basic teaching methods are identical in all Hungarian schools, classes may differ in the intensity of musical activities provided; special music classes exist in which the curriculum involves considerably more music lessons compared to regular classes with no specialized curriculum.

The long-term transfer effects of Hungarian music education have been examined previously by Klára Kokas (1969) and later by Zoltán Laczó (1985, 1987). These studies focused on the potential influence of music instruction on intelligence and, in a longitudinal study by Barkóczi and Pléh (1977), on the development of creativity, comparing children who attended a class with either an intensive music or a regular curriculum. Although a few studies have been conducted on the development of music perception and its relationship with basic learning skills and academic achievement (Gévayné Janurik, 2010), no studies have investigated the impacts of music education on language-related abilities in Hungary. Therefore, we aimed to explore the association between musical and linguistic abilities in a school context measuring intact classes of second-grade students. This research design provided a unique opportunity to investigate the effectiveness of a curriculum-based music education program using the Kodály concept in children who were at an early stage of reading attainment.

Aims of the Present Study

Research literature concerning music transfer effects clearly shows that results obtained by music training programs and correlational studies are inconsistent. These discrepancies could be explained, on the one hand, by fundamental differences in the focus, the length, and other relevant parameters of the applied music training and, on the other hand, by the diverse methods used to assess music aptitude and language-related abilities in children between the ages of 4 and 10.

The purpose of the present study was twofold. The first was to investigate the association between specific musical auditory skills, phonological awareness, and reading ability in 7- to 8-year-old students. The second purpose of the study was to explore whether second-grade children who receive more intensive Kodály-based music instruction demonstrate better musical, phonological, and reading skills than children who receive less music instruction.

Method

Participants

Two groups with different school curricula were recruited from the same public elementary school in Szigethalom, Hungary. Thirty second-grade children participated in the study: 14 students (10 girls, four boys) were in the intensive music class, and 16 students (six girls, 10 boys) were in the class with the regular curriculum. Our sample ranged between 7 and 8 years. Children in the music class were in the age range of 7 years 5 months to 8 years 11 months, and children in the regular class were between 7 years 4 months and 8 years 10 months. All children were monolingual native speakers of Hungarian and had no known hearing or neurological deficits, attentional deficit disorders, or reading or learning disabilities.

Parents of children provided informed consent for the administration of tests, and children gave an oral agreement before beginning each testing session. The study was approved by the Research Ethics Committee of Eötvös Loránd University Faculty of Education and Psychology, Budapest, Hungary.

Curriculum Description

The general music curriculum in Hungary is based on the educational principles of Zoltán Kodály. According to his approach, music instruction aims to provide musical experiences through vocal and rhythmic games using folk songs of the native culture to improve musical hearing of melody, rhythm, harmony, and timbre and also to develop the skills of singing, listening, improvisation, music literacy (reading and writing notation), and music comprehension (Dobszay, 1972; Hanson, 2001). The Kodály-based education program approaches the teaching of music tonality and syntax through the use of solfège and hand signs. The method incorporates the "moveable-*do*" *sol-fa*, assigning a syllable to each note (e.g., *do-re-mi-fa-sol-la-ti* where the tonic is *do* and the dominant is *sol*), and each syllable can be combined with a particular hand sign representing a particular pitch. Additionally, rhythmic syllables are used to represent rhythmic patterns with different durations (Göktürk Cary, 2012).

In line with our purposes, a music and a regular class participated in the present study. Students in the music class were provided music lessons four times a week (4 × 45 min), which included the instruction of playing the flute as well as two extra choir lessons weekly (2 × 45 min) also in the school environment. In the class with the regular curriculum, students had only one music lesson a week (1 × 45 min) and did not engage in any other musical activity outside of school. The program was implemented for a period of 37 weeks in the 1st year and for an additional 7 weeks in the 2nd year until assessments were carried out in October. None of the participants had received formal music lessons or had played any musical instrument before school instruction; children started participating in the music program at the beginning of the first school year. Qualified music educators taught students in both classes, in groups of 20 to 25 in the school environment.

Measurements

Cognitive abilities. General intellectual abilities were evaluated through three subtests from the Hungarian standardized version of the Wechsler Intelligence Scale for Children, Fourth Edition (WISC-IV; Nagyné Réz, Lányiné Engelmayer, Kuncz, Mészáros, & Mlinkó, 2008; Wechsler, 2003). We administered Block Design to measure nonverbal reasoning and visual-spatial skills. In this subtest, children had to arrange and match red and white square blocks to colored designs. Scores were given for accurately designed items within the time limit. We examined verbal reasoning and concept formation by applying the subtest of Similarities. Trials required the child to describe how two presented words (e.g., *milk* and *water*) were alike, and scores reflected the degree to which the response described the primary, general property of both items. We recorded the Digit Span task to test verbal working memory. Children were asked to repeat sequences of digits in forward (three to nine digits) and backward (two to nine digits) order. Accuracy scores were calculated from the longest correctly repeated forward and backward sequence.

Reading and phonological awareness. The Hungarian version of Dyslexia Differential Diagnosis Maastricht (3DM-H; Blomert & Vaessen, 2009; Tóth, Csépe, Vaessen, & Blomert, 2014) was used to measure linguistic abilities. The standardized test battery consisted of 11 computer-based subtests measuring a wide range of cognitive mechanisms substantial to language-related abilities. Two subtests were administered from the battery. The Reading subtest presented participants several blocks of words that varied in type (high frequent, low frequent, pseudoword) and length (number of syllables). Instructions were presented on the screen and heard via headphones simultaneously. Seventy-five items belonged to each word type, and five practice words were followed by blocks of 15 words. Children were asked to read aloud as many words in 30 s as possible. Based on the number of correct words read in a second (items per second), a reading fluency score was calculated for each word type.

The Phoneme Deletion subtest measured phonological awareness by asking participants to delete specified speech sounds from the beginning, end, or middle of one-syllable pseudowords and to pronounce the resulting words. The complexity of test words increased across the trials, from simple consonant-vowel-consonant words (e.g., *cák* without *k* [= *cá*]) to more compound pseudowords (e.g., *dénz* without *z* [= *dén*]). During the testing, 27 pseudowords were presented. Participants were not allowed to see the words on the screen; they heard the instructions and the test items via the headphones. The number of correct items defined the accuracy scale (percentage of correct answers) as an indicator of phonological awareness.

Musical abilities. Arnold Bentley's Measures of Musical Abilities (MMA; Bentley, 1966, cited in Young, 1973) was developed to evaluate children's musical abilities "that are basic and essential to progress in active music-making as vocalist and instrumentalist—i.e., to the performance of music" (Bentley, 1966, p. 20; cited in Young, 1973, p. 74). We created the Hungarian version of the test based on the German version's manual (Bentley, 1973). The instructions were recorded in Hungarian using the Praat program (Version 4.5; Boersma & Weenink, 2007), and the auditory stimuli were developed by means of sound editor software (Finale 2012 Version 2012.r1; MakeMusic Inc., 2012; Wavepad Sound Editor Version 5.32; NCH Software, 2012; Tone Generator Version 3.07; NCH Software, 2013). Sounds were generated by an oscillator for the Pitch Discrimination test, and in the other three subtests, musical stimuli were played on piano timbre.

The test battery consisted of four subtests to measure fundamental music perceptual abilities in children. In the Pitch Discrimination subtest, each trial presented participants pairs of tones, and children were asked to decide after each pair whether the tones were identical or the second pitch was higher or lower compared to the first. The fundamental frequency of the first tone was fixed at 440 Hz across all trials, and the frequency of the second tone ranged from 414 Hz to 466 Hz. The difficulty of discrimination increased across the 20 trials as frequency intervals decreased from a whole tone to 3/26 of a tone. In the Tonal Memory subtest, short melodies were presented in pairs, and children were asked to tell at which tone position the sequence was altered. All melodies consisted of five notes, and changes occurred at each tone position twice. The subtest comprised 10 trials, of which five trials included a whole-tone shift and five trials included a semitone shift. In the Chord Analysis subtest, two to four tones were played simultaneously, and participants were asked to decide how many sounds they could hear at the same time. In 10 trials, chords of two tones were presented. Chords of three tones were played in eight trials, and chords of four tones occurred in two trials. In the Rhythm Memory subtest, two rhythmic patterns in 4/4 meter were presented one after another. Each structure consisted of four beats with various rhythmic configurations, and participants were asked to report whether the second rhythmic sequence was identical to the first one or, in case of difference, at which beat position the rhythmic pattern was altered. The rhythmic pattern was changed in eight trials, and alterations occurred at each beat twice. There were two trials in which no alteration occurred.

In each of the music tests, participants received instructions and musical auditory stimuli via headphones. Children heard each stimulus once during the testing period and were not allowed to return to the previous items. Answers were given orally and were recorded by the administrator in writing. There was no time limit for the individual trials, but items followed each other in a certain time interval. Children received 1 point for each correct answer; therefore they obtained a score out of 20 in Pitch Discrimination and Chord Analysis and a score out of 10 in Tonal Memory and Rhythm Memory. Accuracy scores were calculated for each subtest based on the percentage of correct answers.

Procedure

Tests were administered once in the fall term of the school year, in October. Children completed the tasks in a quiet room in their school, under the direction of the test administrator. Each participant was assessed individually in two sessions, each lasting approximately 30 min. The order of sessions was counterbalanced across children: WISC-IV and 3DM-H were recorded in one session, and the musical ability test was conducted separately. Subtests within the test batteries were run in fixed order.

Data Analysis

Data were analyzed with IBM SPSS Statistics Version 22.0 (IBM Corp., 2013). 3DM-H and MMA scores were not standardized values; therefore reading fluency, phoneme deletion accuracy, and musical accuracy scores were transformed into comparable Z scores. WISC-IV standardized scores were based on Hungarian norms. Mean scores were calculated for each test. Normal distribution for each variable in each class was tested by Sapiro-Wilk tests.

Two-tailed independent-samples t tests and Mann-Whitney U tests were performed to compare the performance of the classes. Gender differences were also tested using the same procedure. To obtain a standardized indicator of the effect size, r was calculated as $Z/\sqrt{N}$ for each subtest. An effect size of 0.1 was considered small, 0.3 was considered medium, and 0.5 was considered large (Field, 2009).

As multiple comparisons were conducted, we corrected significance levels according to the method described by Benjamini and Hochberg (1995). The Benjamini-Hochberg method controls the false discovery rate, the expected proportion of incorrectly rejected null hypotheses (i.e., type I error) using sequential Bonferroni-type corrections. In this process, adjusted p values are computed using a desired significance level and the initial p values calculated by multiple tests.

Additionally, Bayesian independent-samples t tests were performed, and Bayes factors (BFs) were calculated to evaluate whether the collected data favor the null hypothesis (H_0) or the alternative hypothesis (H_1). In the case of comparing the performance of the music class and the regular class, H_0 states that there is no difference between the two groups in performance, and H_1 reflects that mean scores are different in the classes. The calculated BFs indicate the strength of evidence provided by the observed data. For H_0, if BF values are between 1 and 3, they indicate anecdotal evidence; if they are between 3 and 10, they indicate substantial evidence; values above 10, 30, and 100 indicate strong, very strong, and extreme evidence, respectively. For H_1, respective values are 1/3 to 1, 1/10 to 1/3, 1/10, 1/30, and 1/100. If BF_{01} is around 1, it does not support either H_0 or H_1 (Wagenmakers, 2007). We report BF_{01} values that were calculated using JASP (Version 0.8.1.2; JASP Team, 2017).

Finally, Spearman correlation coefficients were calculated to evaluate potential associations between the variables. A coefficient value of 0.1 reflects a small, 0.3 a medium, and 0.5 a large effect (Field, 2009). We corrected significance levels for multiple comparisons according to the Benjamini-Hochberg formula (Benjamini & Hochberg, 1995).

Results

Differences Between the Music Class and the Regular Class

Descriptive statistics for IQ, language-related, and music-related measurements are presented by group in Table 1. First, two-tailed independent-samples *t* tests and, in case of violating the assumption of normality, Mann-Whitney *U* tests were conducted to explore differences between the classes. According to the mean scores, children in the music class scored higher on the subtests of MMA, especially in Pitch Discrimination and in Rhythm Memory, and performed better on Phoneme Deletion, as compared to students in the regular class. On the other hand, children in the regular class outperformed the music class in reading and also in Block Design and Similarities. At the same time, the differences were not large enough to approach significance in any subtests; that is, the music class and the regular class did not differ significantly in intellectual or linguistic abilities or in music perception. Accordingly, effect sizes represent relatively low effects.

Further independent-samples *t* tests and Mann-Whitney *U* tests were run to compare performance in each test using gender as a grouping variable. The analysis yielded only one significant difference, in the case of Chord Analysis ($Z = -2.60$, $p = .009$, $r = -.47$), but this result did not remain significant applying the Benjamini-Hochberg-adjusted *p* value ($p < .001$).

We reanalyzed data from a Bayesian perspective to estimate to what extent the observed data provide evidence in favor of the null hypothesis. The estimated Bayes factors were all between the range of 0 to 3 ($0.95 \leq BF_{01} \leq 2.89$ for group comparison; see also Table 1; $0.11 \leq BF_{01} \leq 2.89$ for gender differences), indicating anecdotal evidence in favor of the null hypothesis. It confirms results obtained by *t* tests, that is, the overall absence of group and gender differences in all measured abilities.

Correlation Analyses: Relations Between Music, Phonological Awareness, and Reading

A correlation matrix was created using scores from 3DM-H and MMA subtests to explore associations between linguistic and musical abilities. We report only those results in detail that remained significant after the Benjamini-Hochberg correction was conducted (adjusted $p = .006$).

The most significant positive associations were identified within 3DM-H: Reading subtests were highly correlated with each other ($r_s = .86$, $p < .001$, for high-frequent and low-frequent word reading; $r_s = .83$, $p < .001$, for low-frequent and pseudoword reading; $r_s = .70$, $p < .001$, for high-frequent and pseudoword reading). Phoneme Deletion showed no significant association with any of the reading tasks after the significance level was corrected (for all reading tests: $r_s \leq .43$, $p \geq .019$). In the case of Bentley's MMA, we found only one relevant correlation within the test, between Tonal Memory and Pitch Discrimination ($r_s = .49$, $p = .006$; for all other musical subtests: $r_s \leq .37$, $p \geq .042$).

Table 1. Means, Standard Deviations, and Basic Between-Group Differences in the Measurements of IQ, Reading, Phonological Awareness, and Musical Abilities.

	Music Class		Regular Class					
Variable	*M*	*SD*	*M*	*SD*	*t*/*Z* (28)	*p*	*r*	BF_{01}
WISC-IV[a]								
Block Design[b]	9.07	3.47	9.50	2.71	−0.69	.489	−.13	2.74
Similarities[b]	8.93	2.65	9.19	3.33	−0.78	.437	−.14	2.84
Digit Span[b]	10.86	1.46	10.50	1.46	−0.87	.386	−.16	2.45
3DM-H[c]								
Reading								
High-frequent words	0.75	0.20	0.88	0.27	2.22	.148	.27	1.27
Low-frequent words	0.63	0.18	0.73	0.18	2.36	.136	.28	1.21
Pseudowords	0.56	0.15	0.66	0.15	3.00	.093	.31	0.95
Phoneme Deletion	68.25	24.90	59.95	26.65	0.88	.388	.16	2.17
MMA[d]								
Pitch Discrimination[b]	50.00	23.37	39.69	19.02	−0.94	.345	−.17	1.49
Tonal Memory	37.86	24.86	38.75	20.94	−0.11	.916	.02	2.89
Chord Analysis	34.29	11.58	33.13	14.48	0.24	.812	.05	2.84
Rhythm Memory[b]	30.71	20.93	22.50	8.56	−1.08	.279	−.20	1.34

Note. BF = Bayes factor (intensity of evidence that the data provide for the null hypothesis versus the alternative hypothesis); WISC-IV = Wechsler Intelligence Scale for Children, Fourth Edition; 3DM-H = Hungarian version of Dyslexia Differential Diagnosis Maastricht; MMA = Measures of Musical Abilities.
a. Shows standardized scores based on Hungarian norms.
b. Mann-Whitney *U* tests were conducted in case of violating the assumption of normality.
c. Reading fluency and phoneme deletion accuracy are *Z* scores.
d. Accuracy scores are shown in percentages.

Pairwise correlations revealed a significant association between Phoneme Deletion and Tonal Memory ($r_s = .53$, $p = .003$; see Figure 1). The amount of shared variance in ranks regarding Tonal Memory and Phoneme Deletion was greater in the music class compared to the regular class (36.24% vs. 25.20%). However, we found no significant difference between the groups in the strength of correlation ($Z = 0.35$, $p = .362$), indicating that the association between melody perception and phonological awareness was similarly robust in the groups, regardless of the intensity of music instruction.

Discussion

In the present study, we explored connections between several specific musical auditory abilities (i.e., pitch, melody, chord, and rhythm perception), phonological awareness, and reading skills in a school context measuring intact classes of second-grade students. We also investigated whether musical and linguistic abilities were different in two groups of children, one class with an intensive music curriculum and another class with a regular school curriculum.

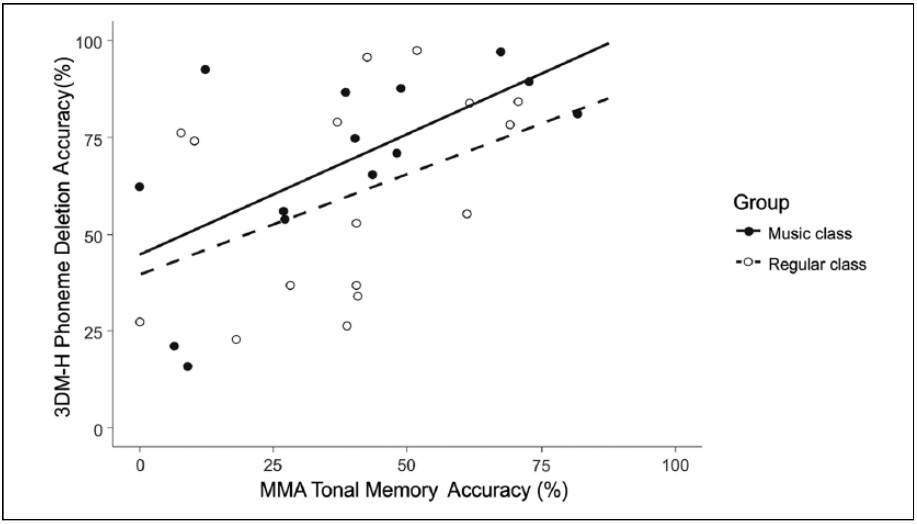

Figure 1. Scatterplot of the relationship between Tonal Memory and Phoneme Deletion split by groups. The solid line represents the regression line for the data in the music class; the dashed line represents the regression line in the regular class.

We found no differences between the music class and the regular class in reading accuracy or phonological awareness; moreover, the classes did not differ in performance on any musical subtests. Our results contradict some previous findings suggesting that more intensive classroom music education may contribute to having more-improved language-related abilities (Forgeard et al., 2008; Moritz et al., 2013; Register, 2001). The lack of difference between the classes in auditory and cognitive processing might indicate that 1 year of intensive classroom music education is not enough to enhance musical and linguistic abilities. It is also conceivable that the impact of music instruction was obscured due to music instruction received by both groups, as the school curriculum differed only in the intensity, not in the presence, of music lessons. In a Hungarian study concerning the development of musical abilities, Asztalos and Csapó (2017) found a significant difference in musical auditory skills between music classes and regular classes comparing second graders, but this difference between the groups was not present among first- and third-grade students. These results suggest that in the first 3 years of elementary school education, music lessons cannot advance musical abilities considerably; therefore, domain-general transfer effects of music lessons may not appear in students, either.

However, our findings are in contrast to previous studies revealing long-term positive effects of school-based music training programs related to musical abilities (Ilari, Keller, Damasio, & Habibi, 2016), literacy-related language skills (for a review, see Gordon, Fehd, & McCandliss, 2015), or memory functions (Roden, Grube, Bongard, & Kreutz, 2014; Roden, Kreutz, & Bongard, 2012) in elementary school children. It is important to point out that many longitudinal studies demonstrated positive effects on developing language and cognitive skills, mainly in kindergarten children, and found that music training might not lead to overall improvements but enhance certain aspects of cognitive functioning. As different aspects of music, language, and cognitive development seem to follow different time courses, it is feasible that the presence of transfer effect might depend on the individual's development trajectory (White, Hutka, Williams, & Moreno, 2013). Therefore, music training may lead to quantitatively and qualitatively different cognitive changes in different age groups. To the more nuanced understanding of the effects of music training in childhood, the transfer effects at different points in development and the role of sensitive periods require further investigation.

Our findings indicate that 1 year of classroom education might not be comparable to private music lessons or intensive training programs, which provide different conditions for music learning. We might speculate that the size of the class, the educational approach, the employment of musical instruments, the focus of musical activities, and individual differences in motivation may determine musical and transfer outcomes and may provide a possible explanation for the contradictory results found in the present investigation. Future research should take into consideration to what extent the conditions in elementary school music education and the characteristics of music curricula could support the appearance of domain-specific and domain-general transfer effects.

Correlational analyses revealed no overall association between performance on musical measurements and language-related tests. Further, reading accuracy did not correlate with music perception. These findings are in contrast to previous studies in which reading showed significant correlations with particular components of musical audition (e.g., Anvari et al., 2002; David et al., 2007). Interestingly, we found a significant relationship between Phoneme Deletion and Tonal Memory. This suggests that phonological awareness is specifically related to melody discrimination, confirming the line of research showing links between phonological awareness and pitch processing, rather than temporal processing, in children (e.g., Anvari et al., 2002; Forgeard et al., 2008; Lamb & Gregory, 1993; Loui et al., 2011).

Previous studies usually explained this relation in terms of the sensitivity to frequency changes, indicating that pitch perception might play a role in superior performance on melody tasks and phonological awareness tests. However, melody perception demands not only the comparison of pitch values but the detection of pitch pattern changes in the musical sequence. Accordingly, the structural complexity of melodies might affect the processing of pitch sequences at the cognitive level (Patel, 2003). Similarly to music, speech also comprises complex pitch pattern changes that promote segmentation and stress location in spoken language (Jusczyk, 1999; Morton & Jassem, 1965). It has been suggested that pitch pattern processing in speech might be related to a mechanism that is responsible for the processing of the structure in the sequence (Ziegler, Pech-Georgel, George, & Foxton, 2012). For this reason, we hypothesize that in the Phoneme Deletion and Tonal Memory tasks, analogous, higher-order cognitive processes are required to elaborate the structure of the given melody and the given pseudoword, and subsequently, lower-level perceptual

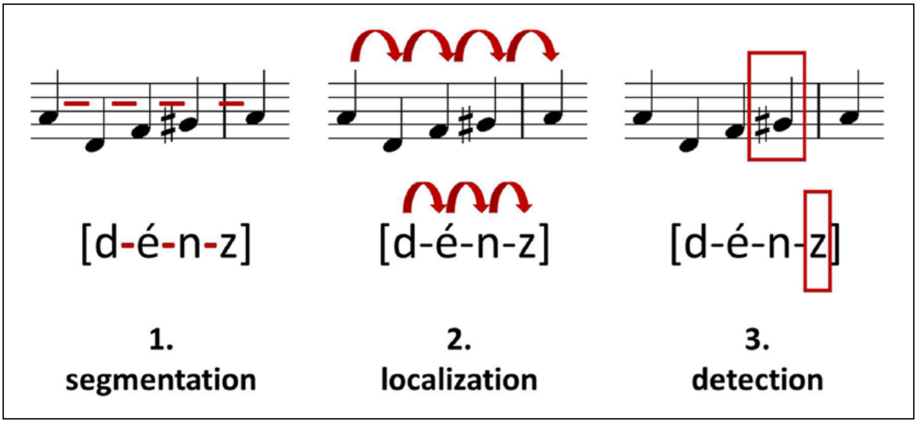

Figure 2. Illustration of the hypothesized processing steps involved in the Tonal Memory and Phoneme Deletion subtests.

processes (e.g., pitch perception) are needed to accomplish tone-by-tone comparisons to find a specified sound in the sequence.

In our interpretation, the relationship between Tonal Memory and Phoneme Deletion might originate from the similar cognitive processes underlying the tasks. The hypothetical mechanism, which processes musical and phoneme sequences, may be completed in three steps (see also Figure 2): (1) *segmentation* of the sequence, (2) *localization* of the tone position where the alteration occurred/from where the sound must be deleted, and (3) *detection* of the specified sound. Through these steps, the access to the sound-level units is developed, and sound-by-sound pitch interval comparisons are needed to discriminate between successive phonemes and musical tones. We propose that these local pitch-processing mechanisms enable the systematic processing of pitch values and pitch intervals in music and speech perception. The reason why we did not find any associations with reading accuracy might be that reading is related to a more holistic, global pitch pattern–processing mode. Because reading ability was not connected to melody perception or to phonological awareness, we assume that specific, task-dependent mechanisms may exist underlying pitch sensitivity.

Summary and Conclusion

Further longitudinal research is required to clarify whether the lack of difference in abilities between the class with musical curriculum and the regular class and the relationship found between Tonal Memory and Phoneme Deletion show reliable effects or are due to the unusual classroom design and small sample size. We propose that the inconsistent results in the existing literature concerning the music–language association might be attributed to the various test methods used in the studies. In recent meta-analyses (Jaschke, Eggermont, Honing, & Scherder, 2013; Sala & Gobet, 2017), it has been suggested that music training does not reliably enhance children's and young adolescents' cognitive or academic skills. We propose that a battery of tests providing various measurements to investigate musical and language-related abilities on multiple levels might resolve discrepancies in the literature, thereby contributing to the understanding the nature of the transfer effects of music education.

This still-contradictory picture concerning the association between music education and the development of linguistic abilities might also draw our attention to the need for reconsidering the quality and quantity of general music instruction in elementary schools. We assume that classroom music lessons in schools could provide all children an enjoyable opportunity to achieve long-term enhancements in auditory skills. Thus, improving the content of the music curricula and developing new methods for music education would be crucial in elementary schools. In an ongoing longitudinal study, a movement-based music education program is being employed among Hungarian elementary school students to explore the short- and long-term effects of classroom music instruction on a wide range of cognitive abilities.

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