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Music and cognitive development during the early primary school years: Exploring associations and learning outcomes

Theses of the doctoral dissertation

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LIST OF PUBLICATIONS RELATED TO THE DISSERTATION

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Lukács B. (2021). Az aktív zenetanulási módszerek kognitív és szocio-emocionális hatásainak vizsgálata. In Honbolygó F., Lukács B. (Eds), *Az aktív zenetanulás két modelljének pszichológiai és idegtudományi hatásvizsgálata* (pp. 47−65). Támogatott Kutatócsoportok Irodája.
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Lukács, B., Asztalos, K., Honbolygó, F. (2021). Longitudinal associations between melodic auditory-visual integration and reading precursor skills in beginning readers. *Cognitive Development, 60,* 101095. https://doi.org/10.1016/j.cogdev.2021.101095

Lukács, B., Honbolygó, F. (2019). Task-dependent mechanisms in the perception of music and speech: Domain-specific transfer effects of elementary school music education. *Journal of Research in Music Education, 67*, 2, 153−170. https://doi.org/10.1177/0022429419836422

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1. BACKGROUND

There is a fundamental demand for general school education to provide children with knowledge and experience that can be applied beyond the immediate learning context. There have been thus constant efforts to design classroom curricula for children in the early primary school years that foster the acquisition of academic skills as well as general competencies like problem-solving, critical, analytical, and creative thinking, cooperation, communication, and social interaction. However, a crucial issue in education and psychology has been the extent to which skills or knowledge acquired in one domain can be applied in domains independent of the original learning environment. Transfer, or the broad impact of learning, can be observed in the generalisation of experience, which can facilitate the application of acquired knowledge to new situations (Bransford, Brown, & Cocking, 2000). The question is, under what conditions can learning be transferred?

Over the last few decades, art education has been considered a possible means of facilitating children's general skill development. Sustained engagement with music is a specific learning situation that requires intensive learning in various skill areas, including different aspects of perception, motor skills, and cognition (Miendlarzewska & Trost, 2014), which are also essential for other non-musical cognitive tasks occurring in everyday life. This raises the question of whether music learning can effectively support the development of these non-musical cognitive functions in addition to musical abilities, especially in children who are highly receptive to experiences. Although artistic programs aim to improve art-specific skills, art educators often detect enhancements for non-artistic skills in children participating in the arts. Based on these observations, the transfer effects of music have been a subject of sustained and intense interest for many decades.

Current research shows that music learning in childhood has beneficial effects not only on perceptual, motor, and sensorimotor abilities related to music (e.g., Bolduc & Lefebvre, 2012; Ilari et al., 2016; Maróti et al., 2019) but also on specific domains such as language, including reading and its cognitive precursors (e.g., Degé & Schwarzer, 2011; Moreno et al., 2009; Rautenberg, 2015; Slater et al., 2014). Furthermore, research has demonstrated that music education can enhance general cognitive abilities, including executive functions (e.g., Bugos & DeMarie, 2017; Jaschke et al., 2018; Roden et al., 2012; Roden, Grube, et al., 2014) and, in some cases, intelligence (e.g., Schellenberg, 2004). It is important to note that much of the empirical evidence regarding music training has been obtained through various intensive programs with different age groups. Typically, children show significant improvements in

specific aspects of a given skill (Cooper, 2019). Additionally, most educational programs incorporate different forms of movement in musical activities. However, the study of the effects of movement is still relatively unexplored. Although attempts have been made for years to explore the impact of music education in natural settings (see Tervaniemi et al., 2018, for a review), the effectiveness of comprehensive music education programs and the role of movement in these methods remains unclear.

A key area of research into the effects of music learning is the interrelationship between music and language. This line of research originates from the shared acoustic characteristics and complex structural organization of both music and language (Jentschke, 2018). The dominant theories (e.g., common acoustic processes hypothesis, Besson et al., 2011; top-down control hypothesis, Moreno & Bidelman, 2014; OPERA hypothesis, Patel, 2011, 2014) explaining the relationship assume that there are overlapping perceptual and cognitive mechanisms. This notion has inspired the study of the relations of music to phonological processing and reading. Although this area of research is now decades old, the nature of the relationship in childhood is still unclear. Some evidence suggests a general relationship between various musical and reading-related abilities (e.g., Degé et al., 2015; Steinbrink et al., 2019), while others suggest a specific relationship with either rhythmic (e.g., Douglas & Willats, 1994; Moritz et al., 2013) or tonal music processing (e.g., Forgeard et al., 2008; Loui et al., 2011). It is important to emphasize, however, that these studies typically do not take into account that both musical abilities (Gooding & Standley, 2011; Trainor & Corrigall, 2010) and reading-related abilities (Ziegler & Goswami, 2005) undergo significant normative development during childhood, the course of which may be modified by formal learning. It is therefore conceivable that the nature of the music-reading relationship may change from the beginning of reading and music learning. This raises the question of whether parallels can be identified in the development of music and reading.

My doctoral research aimed to conduct a longitudinal investigation on the association between music and cognitive development in an ecologically valid setting during the early years of primary school. As part of this, a comprehensive evaluation was conducted to assess the impact of classroom music education programs on the development of schoolchildren from the beginning of school until the end of the second year. The studies incorporated body movement into the school music curricula, and it was of particular interest whether the different application of movement could promote distinct improvements in both musical and non-musical abilities. Additionally, the research involved a longitudinal investigation of the relationship between

music and reading-related cognitive abilities, exploring whether the relationship between these domains changes with increasing experience in reading and music instruction.

2. RESEARCH OBJECTIVES AND QUESTIONS

The dissertation had two main objectives: 1) to uncover how various classroom music learning programs, with or without body movement, contribute to children's music-related and non-musical cognitive development, and 2) to longitudinally investigate the nature of relations of music-related abilities to non-musical cognitive functions over the first years of school. The following research questions were addressed through five empirical studies:

1) Does the amount of classroom music education experience play a role in cognitive development? Is greater classroom music experience associated with better musical, reading-related, and general cognitive abilities in second graders?
2) Does the incorporation of body movement into classroom music education programs have additional impacts on children's cognitive development in the first two years of school?
3) Do various movement-based music programs employing body movement differently have distinct effects on children's cognitive development in the first two years of school?
4) Do music-related abilities have stable patterns of relations to phonological processing and word reading over the first two years of schooling? Does the ability to integrate musical auditory and visual information correlate with reading-related abilities in the early years of formal reading and music instruction?
5) Do the developmental trajectories of musical and reading-related abilities show similarities? Do the patterns of association between the improvements in musical and reading-related abilities remain consistent across the first and the second years of schooling?

3. RESULTS

3.1. STUDY 1: The relation of music to reading-related and general cognitive competencies in second-grade children

Study 1 aimed to investigate whether the advantages of comprehensive classroom music instruction could be observed in any functions after one year of formal music instruction. Building on the positive outcomes of previous longitudinal research (e.g., Degé & Schwarzer, 2011; Ilari et al., 2016; Jaschke et al., 2018; Rautenberg, 2015; Roden et al., 2012), which investigated the impact of music education on school-aged children, a comprehensive study of children's cognitive performance in relation to school music instruction was conducted. The study compared two classes of 7−8-year-old children who received classroom music lessons according to either the regular or intensive Kodály music curricula. The aim was to investigate whether greater classroom music experience is associated with higher general cognitive, reading-related, and musical abilities at the beginning of second grade. In addition, I examined the nature of the relationship between the subcomponents of musical auditory abilities and reading-related cognitive abilities in second-grade children. Given the contradictory research findings (e.g., Degé et al., 2015; Douglas & Willats, 1994; Forgeard et al., 2008; Loui et al., 2011; Moritz et al., 2013; Steinbrink et al., 2019), I sought to answer the question of whether only specific music and reading-related abilities are associated, or whether the music-reading relationship is global at this early stage of formal reading and music instruction.

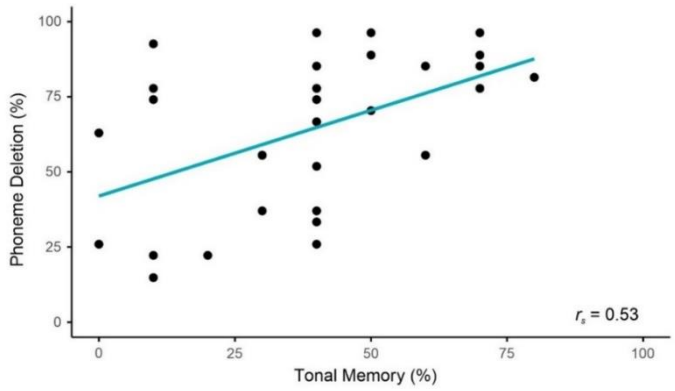
Thirty children (M_{age} = 8 years, SD = 0.5) from two second-grade school classes with approximately one year of experience in Kodály-based classroom music lessons with varying intensity were studied. The *Intensive class* (n = 14) participated in four music lessons per week, while the *Regular class* (n = 16) participated in one weekly music lesson. At the beginning of the second school year, participants' general intelligence, phoneme awareness (PA), word reading ability, and musical auditory abilities were assessed.

The results of the between-group comparisons did not reveal any significant differences in any measures between children who participated in intensive classroom music instruction and those who participated in less intensive music instruction during the first school year. The lack of group differences was supported by the analysis of data using Bayesian methods. Participating in classroom music lessons for one year, with varying intensity, does not appear to be associated with differences in music perception, phoneme awareness, reading fluency, or general intelligence in second graders.

The results of the correlation analysis indicated a specific association between performance on Tonal Memory and Phoneme Deletion tasks (Figure 3.1.1). No additional associations with reading or its cognitive precursors were observed. This close relationship between melody perception and phoneme awareness implies that pitch pattern processing may play an important role in the processing of melodic and speech sound sequences.

Figure 3.1.1

Scatterplot showing the association between Tonal Memory and Phoneme Deletion



Thesis 1. *Participation in classroom music education with varying intensity for one year is associated with similar levels of musical, reading-related, and general cognitive abilities in second-grade children.*

3.2. STUDY 2: The effects of classroom music education with or without body movement on children's cognitive development

Study 2 examined whether incorporating body movement in classroom music learning enhances cognitive development in the early primary school years. Previous research (Lewis, 1988; Maróti et al., 2019; Rohwer, 1998; Yazejian & Peisner-Feinberg, 2009) has shown that movement-based music instruction has limited cognitive benefits in children. However, it is difficult to determine the extent to which movement-based school music learning can influence the development of various cognitive capabilities as most studies have focused on specific and distinct cognitive areas. Additionally, previous movement-based music learning programs have shown the potential to considerably improve music-related abilities within a few months.

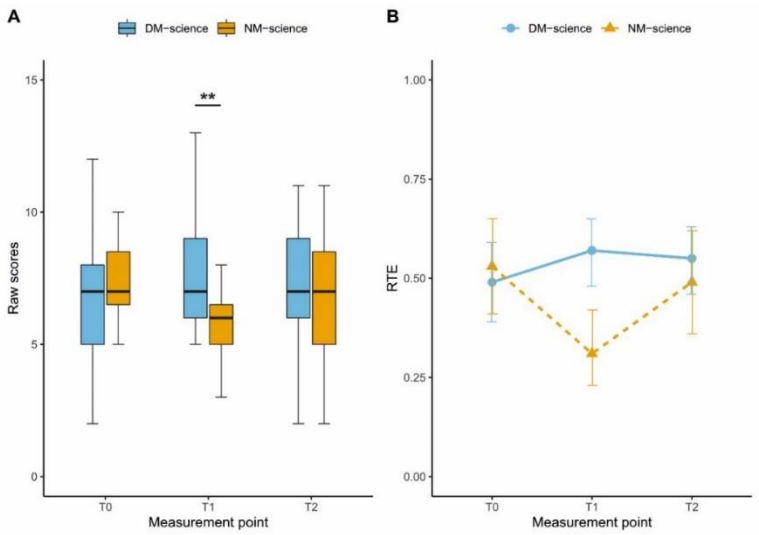
However, improvements in non-musical cognitive functions may not be observed even after several months of music instruction. Therefore, it is possible that the non-musical benefits of movement-based music education programs may only become apparent after longer periods of learning.

Thus, Study 2 conducted comprehensive longitudinal research to investigate the effects of school music education programs, with or without body movement, on the development of musical discrimination, auditory-visual connection ability, synchronized and continuation tapping, phoneme awareness, rapid automatized naming (RAN), reading fluency, executive functions, and general intelligence three times (T0 = beginning of schooling, T1 = end of the first year, T2 = end of the second year) during the first two years of primary school. Two classes of children (M_{age} = 6.95 years, *SD* = 0.31 at baseline) were followed from the beginning of schooling until the end of second grade. The *Directed Movement science (DM-science) class* (*n* = 25) received a movement-based music curriculum, while children in the *No-Movement science (NM-science) class* (*n* = 15) received the traditional Kodály music curriculum without body movement incorporated into music lessons.

In most of the examined areas, children in the NM-science class showed similar improvements to those in the DM-science class. Concerning Melody Discrimination (Figure 3.2.1), the performance of children in the DM-science class remained relatively stagnant over the 18-month investigation period, while the performance of children in the NM-science class significantly declined during the first year and then stagnated during the second school year. Furthermore, the classes exhibited varying rates of development in Verbal IQ (Figure 3.2.2). The DM-science class exhibited more significant enhancements during the first school year, whereas the NM-science class showed more pronounced improvements during the second school year. However, these developmental patterns do not imply that either music program is better suited to support the development of the classes. The overall benefits of the music programs were comparable. The results of Study 2 suggest that the 18-month music instruction, which included movement, did not lead to improved development in either music-related or non-musical domains.

Figure 3.2.1

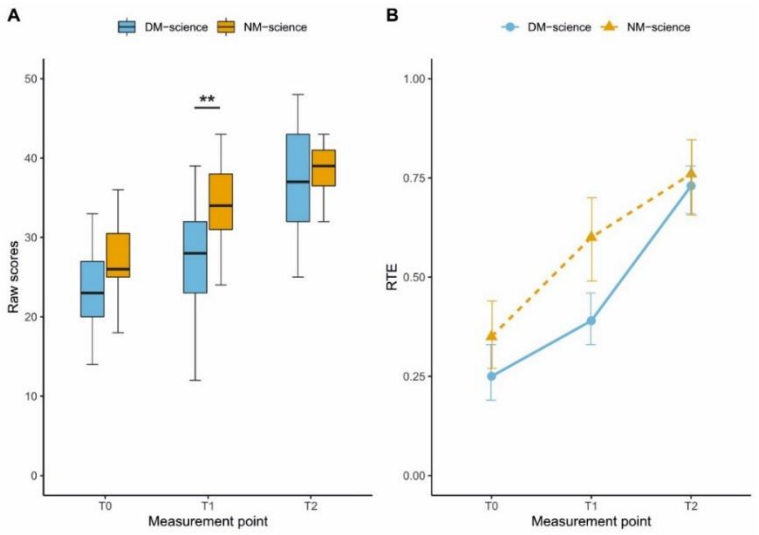
Performance on the Melody Discrimination task for all time points in the science classes



Note. (A) Boxplots showing the changes in performance on the Melody Discrimination test from T0 to T2. Asterisks indicate significant differences between the groups. ***p* < .01. (B) Relative treatment effects (RTEs) for each measurement point by groups. Error bars show the 95% confidence intervals for RTEs.

Figure 3.2.2

Performance on the measure of Verbal IQ for all time points in the science classes



Note. (A) Boxplots showing the changes in performance on the WISC-IV Vocabulary subtest test from T0 to T2. Asterisks indicate significant differences between the groups. ***p* < .01. (B) Relative treatment effects (RTEs) for each measurement point by groups. Error bars show the 95% confidence intervals for RTEs.

Thesis 2. *Classroom music education programs, regardless of the inclusion of movement, lead to similar improvements in both music-related and non-musical cognitive abilities during the first two years of primary school.*

3.3. STUDY 3: The impacts of classroom music education combined with directed or improvised body movement on children's cognitive development

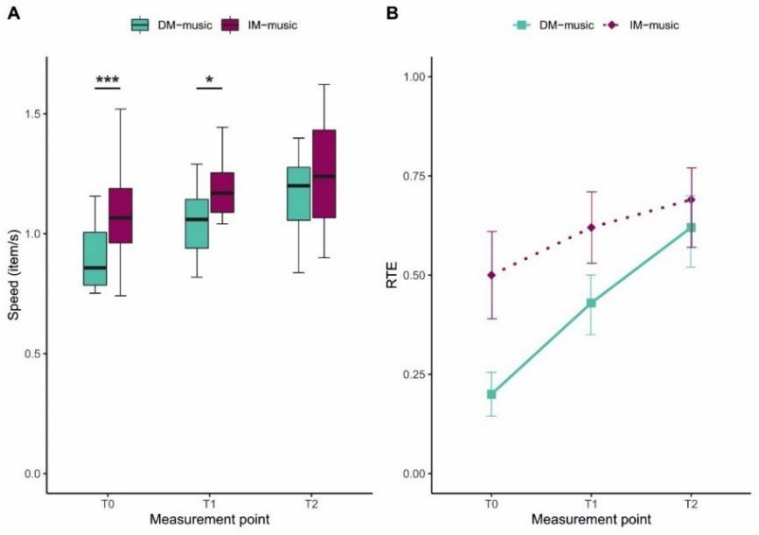
Study 3 aimed to investigate whether different implementations of movement in classroom music education led to specific improvements during the first years of primary school. Current research on the contribution of diverse movement-based music education programs to music-related and non-musical cognitive development in the early school years is limited. In the pilot study conducted by Maróti et al. (2019), it was found that the application of different movements during music lessons did not have a differential impact on children's development over an 8-month period in their first year of school. Thus, in the present study, the focus was on whether the different use of movement impacted schoolchildren's cognitive development over an extended 18-month learning period. The study followed the development of participants' musical abilities, rhythmic synchronization, phoneme awareness, rapid naming, reading, executive functions, and general intelligence during the first two years of primary school.

Two classes of children (M_{age} = 7.02 years, *SD* = 0.34 at baseline) were investigated from the beginning of schooling until the end of second grade. The *Directed Movement music (DM-music) class* (*n* = 22) received a movement-based music curriculum that combined Kodály music lessons with teacher-directed movements, while the *Improvised Movement music (IM-music) class* (*n* = 18) received Kodály music lessons combined with improvisational body movements. The measures and procedures employed in the current study were identical to those used in Study 2.

Over the 18-month period, the DM-music class and the IM-music class showed comparable improvement in most measured skills. However, there were differences in the developmental courses for RAN pictures and Verbal IQ. Children in the DM-music class showed greater improvement in rapid naming of pictures compared to their peers in the IM-music class (Figure 3.3.1). As there was a significant difference between the classes at baseline, classroom music instruction could have a larger impact on the development of rapid naming in the class with more room for growth. The distinct developmental patterns in Verbal IQ (Figure 3.3.2) could be similarly explained. Overall, these developmental patterns do not indicate that the diverse incorporation of body movement into intense classroom music instruction can have distinct effects on any music-related or non-musical functions during the first two years of school.

Figure 3.3.1

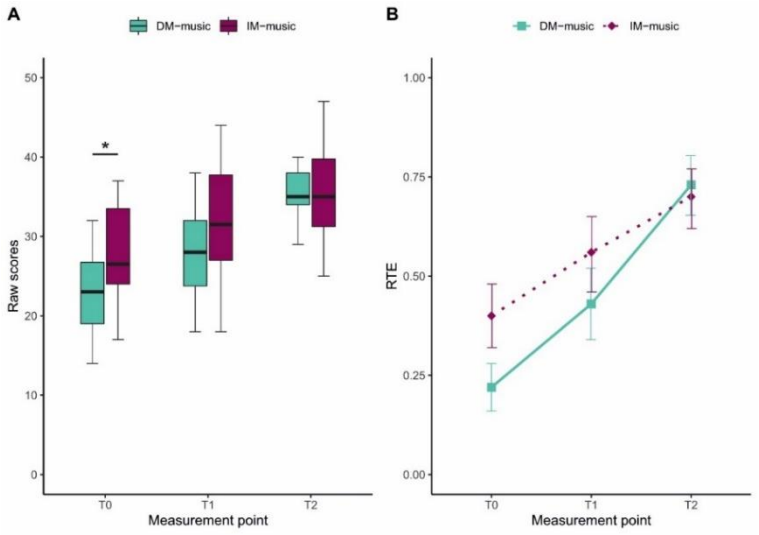
Performance on the RAN Pictures task at each measurement point in the music classes



Note. (A) Boxplots showing the changes in performance on the RAN Pictures test from T0 to T2. Asterisks indicate significant differences between the groups. *p < .05. ***p < .001 (B) Relative treatment effects (RTEs) for each measurement point by groups. Error bars show the 95% confidence intervals for RTEs.

Figure 3.3.2

Performance on the Verbal IQ task at each measurement point in the music classes



Note. (A) Boxplots showing the changes in performance on the WISC-IV Vocabulary subtest from T0 to T2. The asterisk displays a significant difference between the groups. *p < .05. (B) Relative treatment effects (RTEs) for each measurement point by groups. Error bars show the 95% confidence intervals for RTEs.

Thesis 3. *Incorporating different types of movement into classroom music education results in similar improvements in music-related and non-musical cognitive abilities during the first two years of primary school.*

3.4. STUDY 4−5: Longitudinal associations between musical abilities and reading-related competencies in the first and second school years

Studies 4 and 5 aimed to examine potential longitudinal correlations between musical abilities, phonological processing skills, and word reading in the first and second school years, respectively. The findings of Study 1 revealed a highly specific relationship between melody perception and phoneme awareness. As questions were raised about whether the type of tasks influenced the formation of music-reading relations in second-grade children, musical abilities were assessed using a different measurement tool in these studies. The studies aimed to determine if the relationships between the sub-components of musical abilities and reading-related cognitive abilities remained stable or changed during the first and second years of formal reading and music instruction. Study 4 examined the patterns of relations at the beginning of schooling and at the end of the first school year. It also explored the developmental relations between musical and reading-related abilities during this period. Additionally, Study 5 investigated the music-reading relationship at the end of the first and second school years, as well as the potential parallels between improvements in musical abilities and reading-related skills over the second school year.

Children recruited for Studies 2 and 3 were pooled together in these studies. The final sample size was 85 participants for Study 4 and 80 participants for Study 5. Measures of general intelligence, musical abilities (discrimination, auditory-visual connection), phoneme awareness, reading fluency, rapid automatized naming, and general cognitive abilities (working memory, verbal, and non-verbal IQ) were selected based on tests administered at T0 and T1 in Study 4 and at T1 and T2 in Study 5.

Regarding cross-sectional correlations, the only significant association found was between Tempo Discrimination and Reading Fluency at school entry. At the end of first grade, Phoneme Deletion was found to be related to both Melody Discrimination and Rhythm Connection. Reading Fluency showed a unique relationship with Pitch Discrimination at the end of first grade, whereas it was specifically related to Melody Discrimination at the end of second grade. In conclusion, the relationships between musical and reading-related abilities show specific associations throughout the first years of primary school, as indicated by the patterns observed at all assessment points.

The results of repeated measures correlations showed significant longitudinal associations between improvements in phonological processing and musical audiovisual

processing abilities during the first school year. Specifically, increases in Melody Connection were related to improvements in PA and RAN, but not reading. Furthermore, there was a specific association between increases in Rhythm Connection and rapid naming of pictures. In contrast to these selective relations, several relations were detected between improvements in subcomponents of music discrimination and phonological processing during the second school year. Enhancements in Melody and Rhythm Connection were generally associated with improvements in PA and RAN. Additionally, Reading Fluency had significant longitudinal relationships with all music discrimination abilities, except for Rhythm Discrimination (Figure 3.4.1). The studies suggest that the associations between the development of musical abilities, phonological processing, and reading become less specific during the first two years of primary school.

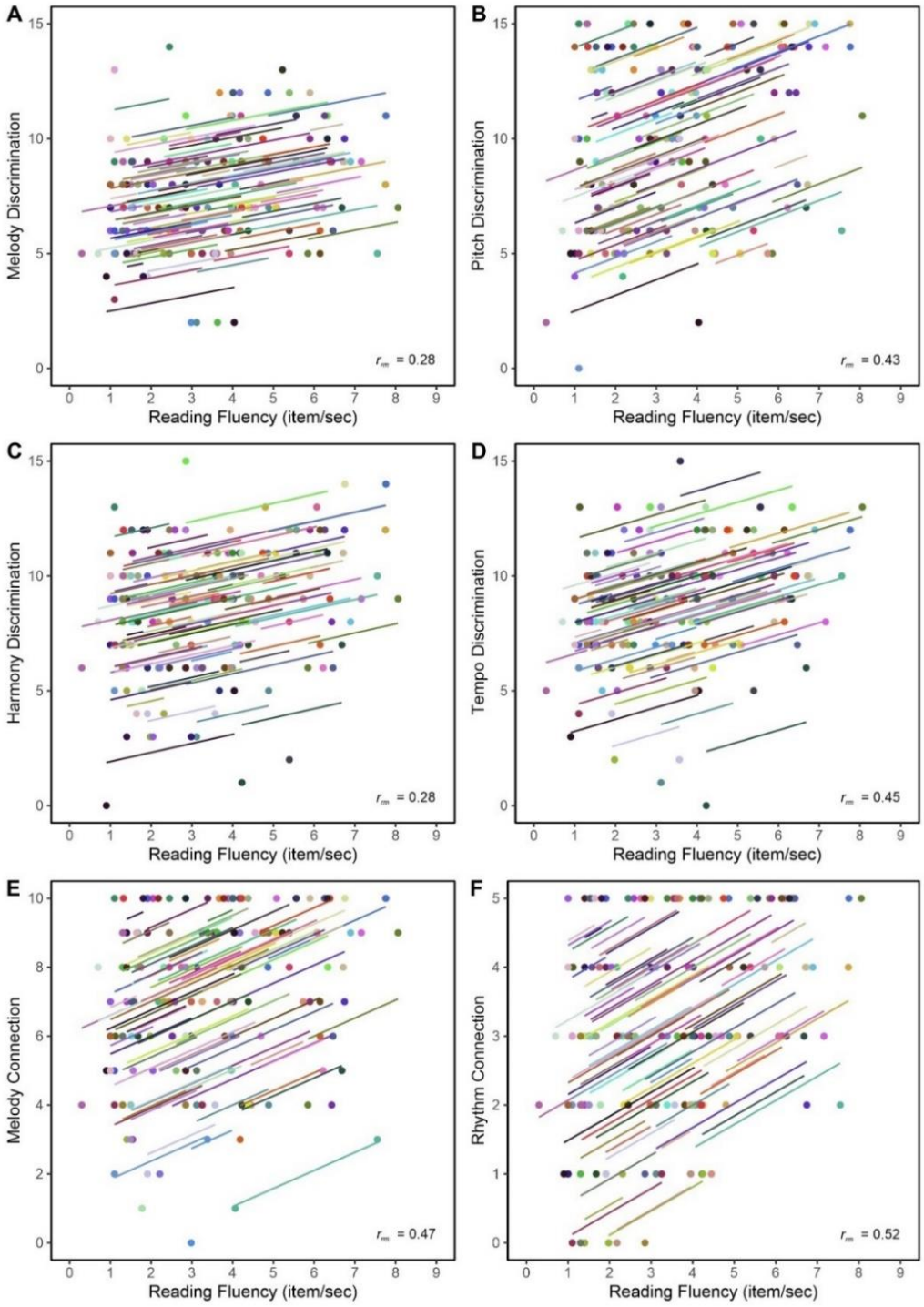
Investigating the unique contribution of each musical ability to word reading development in second grade, results showed that improvements in Pitch Discrimination made a significant contribution to reading development beyond the improvements in PA and numeric RAN. These results indicate that the acquisition of fluency in word reading during the second school year is specifically influenced by the development of pitch perception ability, in addition to the development of the cognitive precursors of reading.

***Thesis 4**. The relationship between musical abilities and reading, as well as its cognitive indicators, is highly specific. The patterns of these relationships differ across all assessments during the first two years of school.*

***Thesis 5**. The relationship between the development of musical competencies and reading-related cognitive abilities is selective, with different patterns of association in the first and second school years.*

Figure 3.4.1

Scatterplots of the significant repeated measures correlations between musical abilities and reading in second grade



Note. Panels display the significant longitudinal relations of Reading Fluency to Melody (A), Pitch (B), Harmony (C), and Tempo Discrimination (D) as well as to Melody (E) and Rhythm Connection (F). For the musical measures, the number of correct responses is illustrated.

4. DISCUSSION

The findings of the dissertation suggest that one year of participation in comprehensive music instruction, varying in intensity, is associated with similar performance levels in music perception, phoneme awareness, reading, and general intelligence among second graders. Furthermore, different classroom music learning programs that incorporate various body movement elements can lead to comparable improvements in music-related abilities, early literacy skills, executive functions, and general intelligence during the first two years of primary school. The developmental trajectories do not support the superiority of any specific music learning program. Several factors linked to the context, content of music learning, and the period during which music lessons occurred may have contributed to the absence of broader movement-related cognitive advantages.

When examining the relationship between musical competencies and reading-related abilities, their highly specific and somewhat varying nature can be observed over the first 18 months of primary school. Moreover, there appears to be a parallel development of musical abilities and reading-related skills, with more extensive longitudinal associations between the domains observed in the second school year. There may be moderate changes in the patterns of cross-domain associations during the early years of formal reading and music acquisition, which could impact the role of music in supporting early reading acquisition.

This dissertation contributes to the literature of music-induced transfer by conducting a thorough investigation into the impact of classroom music learning on children's cognitive development within the school context. The doctoral work also enhances our understanding of the role of movement in supporting cognitive improvements during the early years of primary school. Furthermore, this dissertation is distinctive in revealing parallels between the development of musical and reading-related abilities. These findings underline the importance of conducting further longitudinal studies over extended periods to investigate whether the influence of movement-based music education and the relationship between music and reading development change in later years of primary school.

5. REFERENCES

Besson, M., Chobert, J., & Marie, C. (2011). Transfer of training between music and speech: Common processing, attention, and memory. *Frontiers in Psychology, 2:94*. https://doi.org/10.3389/fpsyg.2011.00094

Bolduc, J., & Lefebvre, P. (2012). Using Nursery Rhymes to Foster Phonological and Musical Processing Skills in Kindergarteners. *Scientific Research*, *3*(4), 495–502. https://doi.org/10.4236/ce.2012.34075

Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How people learn: Brain, mind, experience, and school*. Washington, DC: National Academy Press.

Bugos, J. A., & DeMarie, D. (2017). The effects of a short-term music program on preschool children's executive functions. *Psychology of Music*, *45*(6), 855–867. https://doi.org/10.1177/0305735617692666

Cooper, P. K. (2019). It's all in your head: A meta-analysis on the effects of music training on cognitive measures in schoolchildren. *International Journal of Music Education*, *38*(3), 321–336. https://doi.org/10.1177/0255761419881495

Degé, F., Kubicek, C., & Schwarzer, G. (2015). Associations between musical abilities and precursors of reading in preschool aged children. *Frontiers in Psychology, 6:1220*. https://doi.org/10.3389/fpsyg.2015.01220

Degé, F., & Schwarzer, G. (2011). The effect of a music program on phonological awareness in preschoolers. *Frontiers in Psychology, 2:124*. https://doi.org/10.1177/002242940505300302

Douglas, S., & Willats, P. (1994). The Relationship Between Musical Ability and Literacy Skills. *Journal of Research in Reading*, *17*, 99–107. https://doi.org/10.1111/j.1467-9817.1994.tb00057.x

Forgeard, M., Schlaug, G., Norton, A., Rosam, C., Iyengar, U., & Winner, E. (2008). The Relation Between Music and Phonological Processing in Normal-Reading Children and Children With Dyslexia. *Music Perception: An Interdisciplinary Journal*, *25*(4), 383–390. https://doi.org/10.1525/mp.2008.25.4.383

Gooding, L., & Standley, J. M. (2011). Musical Development and Learning Characteristics of Students: A Compilation of Key Points From the Research Literature Organized by Age. *Update: Applications of Research in Music Education*, *30*(1), 32–45. https://doi.org/10.1177/8755123311418481

Ilari, B. S., Keller, P., Damasio, H., & Habibi, A. (2016). The Development of Musical Skills of Underprivileged Children Over the Course of 1 Year: A Study in the Context of an El Sistema-Inspired Program. *Frontiers in Psychology, 7:62*. https://doi.org/10.3389/fpsyg.2016.00062

Jaschke, A. C., Honing, H., & Scherder, E. J. A. (2018). Longitudinal Analysis of Music Education on Executive Functions in Primary School Children. *Frontiers in Neuroscience*, *12:103*. https://doi.org/10.3389/fnins.2018.00103

Jentschke, S. (2018). The relationship between music and language. In S. Hallam, I. Cross, & M. H. Thaut (Eds.), *The Oxford Handbook of Music Psychology* (2nd Editio, pp. 343–

355). Oxford, UK: Oxford University Press.

Lewis, B. E. (1988). The Effect of Movement-Based Instruction on First- and Third-Graders' Achievement in Selected Music Listening Skills. *Psychology of Music*, *16*, 128–142. https://doi.org/10.1177/0305735688162003

Loui, P., Kroog, K., Zuk, J., Winner, E., & Schlaug, G. (2011). Relating pitch awareness to phonemic awareness in children: Implications for tone-deafness and dyslexia. *Frontiers in Psychology*, *2:111*. https://doi.org/10.3389/fpsyg.2011.00111

Maróti, E., Barabás, E., Deszpot, G., Farnadi, T., Nemes, L. N., Szirányi, B., & Honbolygó, F. (2019). Does moving to the music make you smarter? The relation of sensorimotor entrainment to cognitive, linguistic, musical, and social skills. *Psychology of Music*, *47*(5), 663–679. https://doi.org/10.1177/0305735618778765

Miendlarzewska, E. A., & Trost, W. J. (2014). How musical training affects cognitive development: Rhythm, reward and other modulating variables. *Frontiers in Neuroscience*, *7:279*. https://doi.org/10.3389/fnins.2014.00279

Moreno, S., & Bidelman, G. M. (2014). Examining neural plasticity and cognitive benefit through the unique lens of musical training. *Hearing Research*, *308*, 84–97. https://doi.org/10.1016/j.heares.2013.09.012

Moreno, S., Marques, C., Santos, A., Santos, M., Castro, S. L., & Besson, M. (2009). Musical training influences linguistic abilities in 8-year-old children: More evidence for brain plasticity. *Cerebral Cortex*, *19*(3), 712–723. https://doi.org/10.1093/cercor/bhn120

Moritz, C., Yampolsky, S., Papadelis, G., Thomson, J., & Wolf, M. (2013). Links between early rhythm skills, musical training, and phonological awareness. *Reading and Writing*, *26*(5), 739–769. https://doi.org/10.1017/CBO9781107415324.004

Patel, A. D. (2011). Why would musical training benefit the neural encoding of speech? The OPERA hypothesis. *Frontiers in Psychology*, *2:142*. https://doi.org/10.3389/fpsyg.2011.00142

Patel, A. D. (2014). Can nonlinguistic musical training change the way the brain processes speech? The expanded OPERA hypothesis. *Hearing Research*, *308*, 98–108. https://doi.org/10.1016/j.heares.2013.08.011

Rautenberg, I. (2015). The effects of musical training on the decoding skills of German-speaking primary school children. *Journal of Research in Reading*, *38*(1), 1–17. https://doi.org/10.1111/jrir.12010

Roden, I., Grube, D., Bongard, S., & Kreutz, G. (2014). Does music training enhance working memory performance? Findings from a quasi-experimental longitudinal study. *Psychology of Music*, *42*(2), 284–298. https://doi.org/10.1177/0305735612471239

Roden, I., Kreutz, G., & Bongard, S. (2012). Effects of a school-based instrumental music program on verbal and visual memory in primary school children: A longitudinal study. *Frontiers in Psychology*, *3:572*. https://doi.org/10.3389/fpsyg.2012.00572

Rohwer, D. (1998). Effect of Movement Instruction on Steady Beat Perception, Synchronization, and Performance. *Journal of Research in Music Education*, *46*(3), 414–424. https://doi.org/10.2307/3345553

Schellenberg, E. G. (2004). Music lessons enhance IQ. *Psychological Science*, *15*(8), 511–514. https://doi.org/10.1111/j.0956-7976.2004.00711.x

Slater, J., Strait, D. L., Skoe, E., O'Connell, S., Thompson, E., & Kraus, N. (2014). Longitudinal effects of group music instruction on literacy skills in low-income children. *PLoS ONE*, *9*(11). https://doi.org/10.1371/journal.pone.0113383

Steinbrink, C., Knigge, J., Mannhaupt, G., Sallat, S., & Werkle, A. (2019). Are temporal and tonal musical skills related to phonological awareness and literacy skills? - Evidence from two cross-sectional studies with children from different age groups. *Frontiers in Psychology*, *10:805*. https://doi.org/10.3389/fpsyg.2019.00805

Tervaniemi, M., Tao, S., & Huotilainen, M. (2018). Promises of Music in Education? *Frontiers in Education*, *3:74*, 1–6. https://doi.org/10.3389/feduc.2018.00074

Trainor, L. J., & Corrigall, K. A. (2010). Music Acquisition and Effects of Musical Experience. In M. Riess-Jones & R. R. Fay (Eds.), *Springer Handbook of Auditory Research: Music Perception* (pp. 89–128). Heidelberg: Springer. https://doi.org/10.1007/978-1-4419-6114-3

Yazejian, N., & Peisner-Feinberg, E. S. (2009). Effects of a Preschool Music and Movement Curriculum on Children's Language Skills. *NHSA Dialog*, *12*(4), 327–341. https://doi.org/10.1080/15240750903075255

Ziegler, J. C., & Goswami, U. (2005). Reading acquisition, developmental dyslexia, and skilled reading across languages: a psycholinguistic grain size theory. *Psychological Bulletin*, *131*(1), 3–29. https://doi.org/10.1037/0033-2909.131.1.3