Journal of Educational Psychology

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Online First Publication, June 24, 2019. http://dx.doi.org/10.1037/edu0000376

American Psychological Association

Journal of Educational Psychology

0022-0663/19/$12.00

http://dx.doi.org/10.1037/edu0000376

A Population-Level Analysis of Associations Between School Music Participation and Academic Achievement

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The present study employed population-level educational records from 4 public school student cohorts (n = 112,916; Grades 7–12) in British Columbia (Canada) to examine relationships between music education (any participation, type of participation, music achievement, and engagement level) and mathematics and science achievement in Grade 10 as well as English achievement in Grades 10 and 12, while controlling for language/cultural background, Grade 7 academic achievement, and neighborhood socioeconomic status. Music participation was related to higher scores on all 4 subjects and these relationships were stronger for instrumental music than vocal music (Cohen's d range: .28 to .44 [small-medium effect sizes] and .05 to .13 [null-small effect sizes]). School music achievement positively related to scores on all subjects; such relationships were stronger for achievement in instrumental music compared with vocal music. Higher levels of music engagement (number of courses) was related to higher exam scores on all subjects; this pattern was more pronounced for very high engagement in instrumental music (d range: .37 to .55; medium effect sizes) compared with vocal music (d range: .11 to .26; small effect sizes). The effect sizes of these group differences are greater than the effect sizes corresponding to average annual gains of students' academic achievement during high school—in other words, highly engaged instrumental music students were, on average, academically over 1 year ahead of their peers. The findings suggest that multiyear engagement in music, especially instrumental music, may benefit high school academic achievement. Findings and implications are discussed within the broader interdisciplinary literature on music learning.

Educational Impact and Implications Statement

This large-scale study identified evidence of positive relationships between school music participation and high school exam scores in English, mathematics, and science using population-level educational records for over 110,000 students in British Columbia, Canada. Participation in school music (especially instrumental music) was related to higher exam scores, and students with higher levels of school music engagement had higher exam scores. The positive relationships between music engagement and academic achievement were independent of students' previous (Grade 7) achievement, sex, cultural background, and neighborhood socioeconomic status, and were of considerable magnitude: The group differences observed in our study were greater than average annual gains in academic achievement during high school. In other words, students highly engaged in music were, on average, academically over 1 year ahead of the peers not engaged in school music. In light of this study (the largest of its kind to date), as well as supporting evidence suggesting music learning in childhood may foster competencies (e.g., executive functioning) that support academic achievement, educators may consider the potential positive influence of school music on students' high school achievement.

Keywords: music making, school music, audiation, academic achievement, adolescents, population-level

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This research was supported by an Insight Grant (Peter Gouzouasis 15R09570) from the Social Sciences and Humanities Research Council, Canada. We thank the BC Ministry of Education, Victor Glickman, and Colleen Hawkey for providing the educational records used in this research, and graduate students who assisted with data preparation at an early stage of the project: Queenie Siu, Kate Twohig, and Ivan Cepeda. This study featured analyses of secondary, administrative, educational school records and was approved by the University of British Columbia Behavioural Research Ethics Board, and by the BC Ministry of Education. Peter Gouzouasis is the principal investigator of this article.

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In public education systems in North America, arts courses, including music courses, are commonly underfunded in comparison with what are often referred to as academic courses,[1] including those that teach numeracy and literacy skills (Major, 2013). An argument often used to justify limited support for the arts in public education is an opportunity cost hypothesis: It is believed that students who spend school time in arts classes rather than in further developing their skills in mathematics, science, and English classes will underperform in those disciplines (Elpus, 2013). While many studies have examined the relationships between arts-based learning and students' academic and social development (Deasy, 2002; Foster & Jenkins, 2017), findings have been mixed. The empirical situation is similarly mixed for music, specifically (for recent reviews see Benz, Sellaro, Hommel, & Colzato, 2016; Dumont, Syurina, Feron, & van Hooren, 2017; Sala & Gobet, 2017); the topic on which this study focuses. The variability of empirical findings may also partly reflect the inherently complex nature of the phenomenon of music, in that there are many varied ways of music-making, music engagement, and music education. Also, the complexity of musical activities and their potential to affect children's social, emotional, and cognitive experiences together make it challenging to formulate a theoretical framework that accounts for such complexity while coherently explaining the existing body of empirical findings. Yet, a better understanding about how and which forms of music training are related to children's development in the social, emotional, and cognitive domains—including educational achievement—are important for evidence-informed discussions and decision-making pertaining to the role that music may play in children's development and education.

This study aims to expand the existing empirical literature on the associations between high school students' music education and achievement in English, mathematics, and science, by drawing from a multiyear, representative, population-level data linkage. Many prior studies relating music education with academic achievement have lacked statistical power to consider specific forms of music education, including music type (e.g., instrumental, vocal), excellence/achievement in music, and duration (level) of engagement with music. The use of smaller, unrepresentative sample sizes has prevented examination of such variation in music participation, which ultimately has rendered it difficult to elucidate relationships between music education and academic achievement as well as how such relationships vary according to factors such as type of music participation and level of engagement with music.

Mechanisms Linking Music Making to Educational Achievement

Various mechanisms/pathways have been theorized to relate music training and academic achievement. Psychologists have referred to the concept of *transfer* (Barnett & Ceci, 2002), which in the present context refers to theories of how cognitive, motivation-related, and social-personal aspects related to music education and practice may positively affect learning in academic subjects such as mathematics, English, and science.

Executive Functioning

Purposeful and extended engagement with music-making in childhood and adolescence may impact cognition in various ways. One emergent hypothesis (Degé, Kubicek, & Schwarzer, 2011; Jaschke, Honing, & Scherder, 2018; Slevc, Davey, Buschkuehl, & Jaeggi, 2016) relates music training to academic achievement via a set of competencies termed *executive functions* (EFs; Diamond, 2013). These cognitive abilities focus on control and regulation of behaviors and thoughts. Neurological bases of EFs have been identified whereby the frontal lobe is hypothesized to be particularly salient in EFs (Miyake et al., 2000; Stuss & Alexander, 2000); relatedly, music training in childhood and/or early adolescence have been found to be related to lasting changes to neurological regions, including the corpus callosum, superior temporal gyrus, and middle temporal gyrus (e.g., Steele, Bailey, Zatorre, & Penhune, 2013; Schlaug, Norton, Overy, & Winner, 2005). EFs are wide-ranging and interrelated, yet the core competencies typically include: *inhibition* (i.e., self-regulation), *updating* (i.e., information monitoring and relations with working memory), and *switching/shifting* (i.e., flexibility of changing between tasks; Diamond, 2013). Music-making often entails numerous EF-related processes, including anticipation, planning, memory, synchronization with other musicians; instrumental music-making especially entails shifting between mental or physical tasks (e.g., rearranging one's fingers to perform the same and different patterns), recalling and audiating[2] from working memory different pieces of music and pattern sets, and substantial control or mastery over one's expressive behaviors. An example of "*updating*" is the process musicians use to simultaneously read musical notation, and coordinate and anticipate finger movements to play the correct melodic patterns.

Of educational importance, EFs can be modified—hence they are a focus of programs geared at boosting children's cognitive outcomes (Diamond & Lee, 2011). Based on a sample of 88% instrumental and 12% vocal musicians, musicians have been shown to outperform nonmusicians on various EFs, including shifting/switching (Moradzadeh, Blumenthal, & Wiseheart, 2015), and cognitive flexibility and working memory (Zuk, Benjamin, Kenyon, & Gaab, 2014). Evidence of memory benefits imbued by musical ability and/or music training have been documented several times (Bergman Nutley, Darki, & Klingberg, 2014; Oechslin, Van De Ville, Lazeyras, Hauert, & James, 2013; Roden, Grube, Bongard, & Kreutz, 2014). A long-term/multiyear involvement in music education/training may be especially important for cognitive benefits to more strongly manifest. For instance, longer durations/histories of music training were positively related to performance on EF tasks (Degé et al., 2011), while Chan, Ho, and Cheung (1998) found evidence of higher verbal memory scores among

[1] For convenience and brevity, the term "academic achievement" will be used throughout this article to refer to achievement in math, science, and English courses. This is not meant to imply that achievement in other disciplines, including arts courses in particular, is not comparably rigorous, valuable, and important and thus also "academic." Arguments supporting the study of music as an academic discipline have been made in the U.S. since the first introduction of music into Boston public schools in 1837 and were notably reinforced by Allen Perdue Britton in the 1960s (Heller, 2001).

[2] Music audiation involves the internal, conceptual processing of music when the sound is not necessarily physically present, and also involves conceiving and performing musical patterns (e.g., playing from memory, playing along with recordings, improvising). Audiation also involves the auditory processing of what was heard in the past with what is heard in the present, and predicting what will be heard in the immediate future during the performance of music (for additional discussion, see Gouzouasis, 1993).

adults who had received music training from an earlier age (before age 12) relative to those who began at a later stage. Crucially, EFs are positively correlated with academic scores (Best, Miller, & Naglieri, 2011; Slevc et al., 2016; Visu-Petra, Cheie, Benga, & Miclea, 2011) and hence represent a plausible pathway relating music training to academic achievement.

Motivation-Related Characteristics

A second suggested pathway concerns motivation-related characteristics, including learning discipline, self-efficacy, and mastery-oriented learning experiences. The process of music training—which often includes hours of practice, typically in solitude, and a commitment to music training in light of competing curricular and extracurricular activities—may foster motivation-related characteristics (Evans, 2015; Evans & Liu, 2019). Developmentally, students who learn that repeated music practice can lead to the mastery of complex skills and achieving desired outcomes such as high grades (i.e., a mastery-focused learning approach; Degé & Schwarzer, 2017) may internalize a sense of self-efficacy, which may then be applied to nonmusic areas. In fact, Bandura (2006) suggests, "although efficacy beliefs are multifaceted, social cognitive theory identifies several conditions under which they may co-vary even across distinct domains of functioning" (p. 308). Specifically, self-efficacy that a person may develop as a function of learning music could generalize to other areas of learning to the extent that "the different spheres of activity are governed by similar sub-skills" (Bandura, 2006). For example, self-regulatory skills developed through music performance may be useful in other areas of learning, so that a student's sense of perceived self-efficacy may thus generalize to those domains. Other pathways that may lead to a person's generalizations of perceived self-efficacy have been suggested. These include codevelopment of self-efficacy in multiple domains if the learning of competencies is socially structured in similar ways (e.g., learning multiple subjects in schools), and "powerful mastery experiences" that may "produce a transformational restructuring of efficacy beliefs" (p. 308, Bandura, 2006).

Such transfer of self-efficacy or other motivation-related characteristics may be plausible in light of key parallels between music education and traditional academic subjects taught in school. Music learning and practice resemble school-like activities (Schellenberg, 2006) as the process entails instruction and feedback (Degé & Schwarzer, 2017) and—in the case of school music—is a subject for which grades and course credits are awarded. It has been found that a sense of self-efficacy is associated with achievement (Caprara, Vecchione, Alessandri, Gerbino, & Barbaranelli, 2011), and that mastery and self-efficacy codevelop in an iterative, mutually reinforcing manner (McPherson & Renwich, 2011).

Few studies have examined any particular motivation-related characteristic as a pathway relating music training to academic achievement, but the handful of studies across various related concepts (academic motivation, self-esteem, and self-concept) do suggest positive relationships between music training and motivation-related characteristics. A review of projects concerned with engaging vulnerable youth in music found evidence that participation was associated with heightened motivation to engage in education, attain qualifications as well as a more positive attitudes toward learning in general (Qa Research, 2012). Similarly, music-based intervention programs have observed improvements in self-esteem, confidence, discipline, and motivation among youth (Creech, Hallam, McQueen, & Varvarigou, 2013; Uy, 2010; Wald, 2011). Students involved in music appear to show high levels of intrinsic motivation (Diaz, 2010), while adolescents learning music describe their musical competence and practice motivation as stemming from intrinsic motivation (Schmidt, 2005). Students randomly assigned to weekly piano lessons over the course of 3 years demonstrated gains in self-esteem (especially the academic dimension of self-esteem), whereas the control group showed no such gains (Costa-Giomi, 2004). Relatedly, a quasi-experimental design revealed that students assigned to a group whereby they received a higher number of music lessons over several years reported gains in academic self-concept that were unmatched by those in a comparison group (Rickard et al., 2013). Higher music engagement positively relates to stronger academic self-concept (i.e., the cognitive appraisal of one's academic abilities), both in cross-sectional work (Degé, Wehrum, Stark, & Schwarzer, 2014) and longitudinal work comparing children who participated in an extended music curriculum versus those who did not (Degé & Schwarzer, 2017). Relatedly, even after adjusting for sociodemographic background and IQ, positive associations existed between the amount of music lessons taken and academic self-concept (Degé et al., 2014).

Social-Personal Development

A third hypothesized pathway is of a social-personal nature. Students engaging in musical activities as part of a group may experience bonding and the sense of team accomplishment (Adderley, Kennedy, & Berz, 2003). Also, ensemble music-making is collaborative and generally noncompetitive, an aspect of music that has been found to be associated with enhanced school climate and social interactions within school contexts (Bastian, 2000; Gouzouasis & Henderson, 2012). Students' experiences of positive academic and disciplinary school climate, in turn, are related to academic achievement and decreased school drop-out (Rumberger & Lim, 2008).

A Conceptual Framework for Studying Music Learning and Academic Achievement

It must be acknowledged that the various aforementioned mechanisms may well occur in tandem and/or in an interdependent and iterative manner. Also, the different mechanisms that may be underlying an association between music learning and academic achievement may occur to different degrees for different types of music-making, for students with different personalities and characteristics, and within different contexts. For example, the motivational pathway may be strong for students who perform in school ensembles, or for students that are growing up in a context in which the performing arts are very highly valued. The degree to which relational and motivation-related aspects play a role may also depend on the ways in which music is learned and taught. Finally, it may be that not all areas of academic achievement are affected equally strongly by the potential cognitive, emotional, and social impacts that music-making and learning may have on children.

From an overarching conceptual and methodological standpoint, Bronfenbrenner's *bio-ecological model* (Bronfenbrenner & Morris, 2006) is useful for guiding our analyses of the association between (prolonged) music learning and academic achievement, as its propositions, the *process-person-context-time* (PPCT) model, and the concept of *developmental science in discovery mode* provide a path for

systematically testing hypotheses with regard to how the *proximal process* of music learning affects developmental outcomes. Specifically, the model postulates how any developmental effects of proximal processes—in our case, prolonged music learning—reflect a function of the "proximal process" happening with increasing complexity, on a "fairly regular basis over extended periods of time" (p. 797, Bronfenbrenner & Morris, 2006), and may "vary systematically as a joint function of the characteristics of the developing person, the environment—both immediate and more remote— in which the processes are taking place, [and] the nature of the developmental outcomes under consideration" (p. 798, Bronfenbrenner & Morris, 2006). Methodologically, this implies statistical examination of theoretically relevant interaction effects (e.g., is the developmental effect of music learning moderated by type of music learning, level of engagement, and/or the learning domain).

Empirical Review

Music Education and Academic Achievement

Numerous studies have found school music participation associated with higher scores on standardized academic achievement tests (dos Santos-Luiz, Mónico, Almeida, & Coimbra, 2016; Fitzpatrick, 2006; Kinney, 2008), as well as on assessments of academic-related cognitive competences (such as visual and auditory competencies; Benz et al., 2016; Degé, Wherum, Stark, & Schwarzer, 2011; Moreno, Friesen, & Bialystok, 2011; Roden, Kreutz, & Bongard, 2012). Similar patterns have been found among secondary school students for standardized mathematics exams (Catterall, 1997; Catterall, Chapleau, & Iwanaga, 1999; Miksza, 2010) and for exam scores in Grade 12 English, mathematics, and biology (Gouzouasis, Guhn, & Kishor, 2007). However, findings in this area have been mixed—particularly regarding the impact of music intervention programs on children's cognitive and/or academic achievement (Sala & Gobet, 2017). Many of the intervention studies were based on brief music training, and significant variation in the quality of training and instruction occurred (Dumont et al., 2017; Foster & Jenkins, 2017; Sala & Gobet, 2017). Nevertheless, in the largest observational analysis ($n > 13{,}000$) to date, Elpus (2013) found no differences on several standardized college entrance test scores between those who had taken music courses in high school and those who had not (Elpus, 2013). Notably, these analyses adjusted for many sociodemographic factors, time use, recent academic achievement, and attitudes/motivation about school. Elpus (2013) did not, however, adjust for earlier academic achievement; whereas other studies (e.g., Catterall, 1997; Gouzouasis et al., 2007; Miksza, 2010) adjusted for only a handful of potentially confounding variables. Failure to adjust for potential sociodemographic and prior achievement variables may distort results through omitted variable bias, while small, unrepresentative samples may provide unreliable results. Conversely, other well-adjusted analyses of large-scale data sets have in fact shown positive associations of music education and educational outcomes (e.g., Miksza, 2010; Southgate & Roscigno, 2009; Yang, 2015). Thus, one aim of the present study was to further our understanding of how music participation related to academic achievement within the context of representative population-level data that adjusted for an array of sociodemographic confounders as well as early academic achievement. Findings may help us understand better how music participation may impact academic achievement in high school, by elucidating whether such relationships are independent of various important confounding factors.

Type of Music Education and Academic Achievement

Music learning can take many forms, including music composition and theory, vocal music (e.g., singing), and instrumental music (e.g., learning and playing an instrument). The different forms of music-learning and -making may reflect different processes—in particular, learning and practicing a music instrument entails activities (e.g., learning to read music, hand-eye and spatial coordination for physically playing the instrument) distinct from the likes of vocal music (e.g., choral singing).[3] Such activities may impact pathways such as EFs or motivation-related characteristics differently and this may have implications for how and to what extent music learning may affect other areas of learning, including achievement in mathematics, science, and English. Few studies have examined how *type* of music education (e.g., participation in instrumental or vocal or other forms of music) may impact academic achievement. In fact, prior work has commonly considered one form of music compared against a no-music group, such as comparing academic scores of students taking instrumental/ensemble courses with those taking no music (Fitzpatrick, 2006; Miksza, 2010). In contrast, Kinney (2008) considered multiple forms of music education in elementary school, finding positive associations between instrumental music participation and academic achievement tests, but a null association for choir students. Thus, an aim of the present study was to expand upon the limited evidence regarding different forms of participation in school music and their relationships with academic achievement.

Music Achievement and Academic Achievement

Higher level of music achievement (e.g., higher grades in music courses) may reflect higher motivation for music, greater discipline, and/or higher musical skill. Scarce large-scale, representative research has examined the relationship of music achievement and academic achievement. An exception is the study by Gouzouasis et al. (2007), which found a positive relationship between music achievement in Grade 11 and academic achievement in Grade 12 courses among a representative dataset comprising over 50,000 secondary school students in British Columbia. Importantly, however, that study did not consider any potentially confounding factors. It is important to know whether the pattern observed was not an artifact of potential confounding factors related to both music achievement and academic achievement (e.g., prior academic achievement, sex, and/or SES). The present study therefore aimed to identify whether evidence supports a positive relationship between higher music achievement and aca-

[3] In British Columbia schools, instrumental music learning typically entails learning to read and perform music as early as Grade 5; hand-eye and spatial coordination for physically playing and reading music; performing in ensembles while reading notational scores; learning techniques, practicing, and rehearsing in homogenous and heterogeneous instrument settings; and hours of practice at home. With few exceptions, choral music does not entail learning those types of skills and activities, and in most circumstances involves reading lyrics and rote learning one's individual part of the music score in school. Choral students rarely, if ever, practice vocal techniques and music reading outside of school.

demic achievement, independent of various sociodemographic and prior achievement variables.

Engagement in Music Education and Academic Achievement

Some evidence has suggested a dose-response pattern of associations between duration of music training (e.g., number of music lessons accumulated) and higher cognitive outcomes (general IQ: Schellenberg, 2006) and higher academic achievement outcomes (Rodrigues, Loureiro, & Caramelli, 2013). Elpus (2013) found positive correlations between number of Carnegie units acquired in music and academic outcomes on a college entrance exam; however, those associations became insignificant when additional covariates were added to the models. Theoretically, higher engagement in music, indicated by a multiyear history of engagement, may reflect sustained dedication in music-making as well as enhanced exposure to cognitive benefits (e.g., EFs) that may be conferred by learning and practicing music. An aim of this study was therefore to elucidate how various levels of engagement in music—as well as engagement in different types of music—may impact academic achievement.

Subject-Specific Associations Between Music Education and Academic Achievement

Some studies have found that music may relate to certain cognitive/academic domains but not others. For instance, some have found musical training related to improvements in verbal but not visual memory (Ho, Cheung, & Chan, 2003) while a popular belief (and area of considerable inquiry) has assumed a specific relationship between music and mathematical/quantitative skills specifically (Vaughn, 2000). Music education has, however, been shown to positively relate to a broad range of measures of academic-related cognitive, visual, and auditory competencies (Benz et al., 2016; Degé et al., 2011; Moreno et al., 2011; Roden et al., 2012). Understanding whether music education has a general or domain-specific association with diverse academic subjects can help extend understandings of how and why music training can impact academic achievement. Thus, the present study considered three forms of academic achievement—English, mathematics, and science—to help clarify how music education relates to different domains of academic achievement.

To summarize, most (but not all) previous research suggests positive correlations between music participation and school achievement in mathematics, science, and English. What previous studies have typically *not* done is draw from multiyear representative (population-level) student cohort databases, which (a) facilitate consideration of (i.e., controlling for) early achievement; (b) make it possible to control for demographic and socioeconomic variables; (c) provide differentiated information on the nature of students' school music involvement; and (d) allow for examination of multiple subject-specific outcomes.

Examining whether a history of music training relates to high school academic achievement independent of early achievement, in addition to controlling for sociodemographic differences, helps to factor out possible individual and contextual differences that may confound relations between music participation and academic achievement. Moreover, this study is important in providing detail on music participation without the limitations of (a) examining these associations cross-sectionally, (b) being restricted to a small/unrepresentative/homogenous sample, and/or (c) relying on a broad, imprecise assessment of music participation. Moreover, understanding differences between types of music participation (e.g., instrumental music), levels/histories of engagement (e.g., several music courses rather than one), and multiple indicators of learning outcomes is important as it provides detail on how different forms of music participation may matter to different areas of academic achievement.

The Present Study

The present study extended previous research in this area by using multiyear population-level data from British Columbia (Canada) to examine associations between public secondary school students' sustained engagement in school music classes and their secondary school exam grades in math, science, and English, while also taking into account demographic and socioeconomic background characteristics and controlling for elementary school achievement in numeracy and reading.

The purpose of this study was to address the following research questions, testing theoretically pertinent main effect and interaction hypotheses:

Research Question 1: Is there a significant mean difference between school music participation versus no music participation with regard to academic learning outcomes in secondary school? Does this difference remain significant after controlling for previous academic achievement, socioeconomic status, gender, and cultural background? The theoretical literature suggests a positive association between music learning and academic achievement in other domains, but the empirical literature provides mixed evidence, possibly due to using different measures of music learning, indicators of academic learning and achievement, and taking into account different confounding variables (e.g., previous academic achievement, socioeconomic status). It was hypothesized that positive associations with high school academic achievement would be observed, even after controlling for previous academic achievement and socioeconomic status.

Research Question 2: Is the association between music learning and academic achievement moderated by the type of music-making (instrumental vs. vocal music)? Previous research indicates that instrumental music—arguably due to the additional layer of complexity added by learning an instrument as opposed to training/building one's voice—is relatively more strongly connected to enhancements in EF-related skills. Therefore, the hypothesis was that positive associations between music and academic achievement would be more pronounced for instrumental music.

Research Questions 3 and 4: Is the association between music learning and academic achievement moderated by indicators of students' excellence in music achievement or level of music engagement? Do these associations differ for vocal and instrumental music? The literature indicates a dose-response relationship between music learning and developmental benefits, such as enhanced EF and/or increased (and more generalized) self-efficacy. Accordingly, it was hypothesized that indicators of musical excellence and of long-term engagement

(using music grades and music courses, respectively, as proxies) would be positively associated with learning outcomes in other domains.

Research Question 5: Do the patterns of associations between type of music education and academic achievement vary by subject area (math, science, English)? The literature has proposed multiple pathways for a connection between musical learning and (a) domain-specific skills, such as spatial reasoning or pattern recognition as well as for (b) general learning skills, such as EF and self-efficacy. The empirical evidence is mixed, suggesting that either pathways are at play to different degrees in different contexts, or that different measures of (domain-specific or general) learning and achievement have been used in previous analyses. Our analyses aimed to provide some exploratory empirical findings with regard to these different, and possibly complementary hypotheses.

Method

Data Source

School records of students in all school districts (n = 60) in British Columbia (BC), Canada were obtained from the provincial Ministry of Education. They contained student-level public school data from Kindergarten to Grade 12, linked to neighborhood-aggregated census data indicating socioeconomic status. For the music courses, specifically, the educational databases provided information not solely on whether one took a school music course or not, but also on specific participation (i.e., concert band, jazz band, concert choir) and engagement trajectories of students (i.e., duration, number, and type of music courses taken).

Participants

The study sample was a combined set from four cohorts of students (total n = 112,916) from public secondary schools in all school districts across BC, Canada. Of all public secondary school students in the dataset (n = 134,238), 15.8% were omitted from analyses due to missing data on required variables or failure to meet inclusion criteria (see Figure 1). Inclusion criteria were that students: (a) began Grade 1 in 2000, 2001, 2002, or 2003; (b) attended a public secondary school (as listed by the BC Ministry of Education: http://www.bced.gov.bc.ca/); (c) had completed high school or completed at least 3 years of Grades 10, 11, 12 (whether in succession or not); (d) completed at least one of the four course exams (Grade 10 English, Math, Science, and Grade 12 English,); and (e) had data present on the

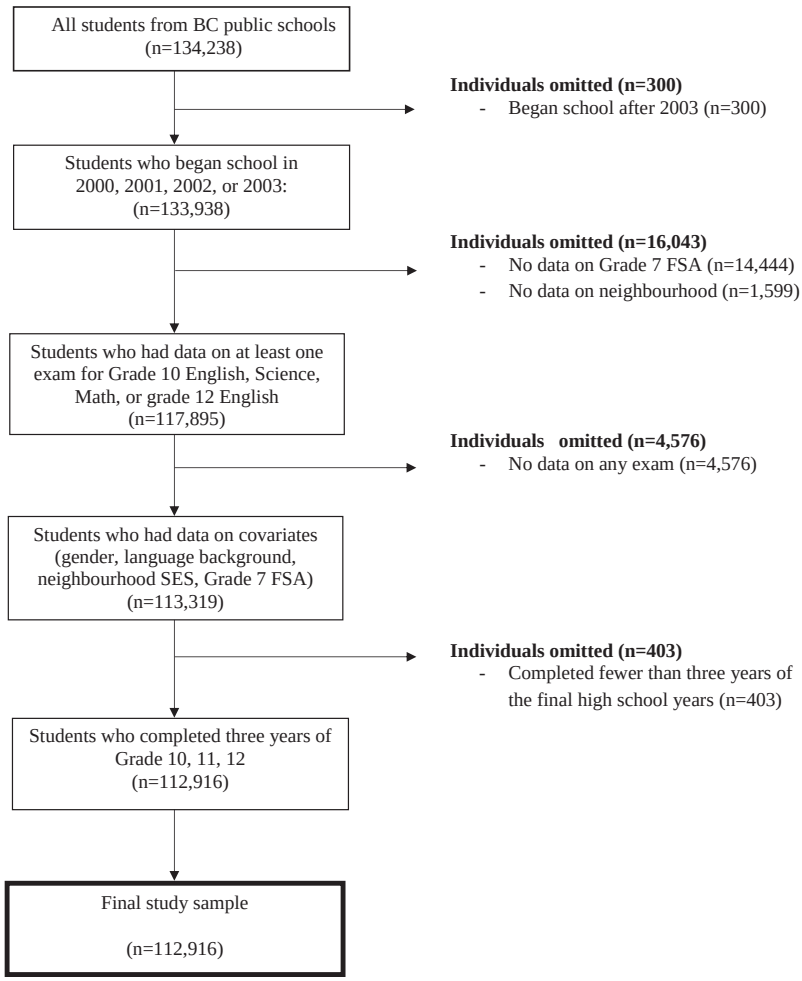

Figure 1. Refinement of the analytic sample.

covariates of interest. In BC, children attend elementary school from Kindergarten to Grade 7 and secondary school from Grades 8 to 12. In addition to secondary school course information, the dataset included information used as covariates: sex, home language, standardized Grade 7 numeracy and reading achievement scores, and neighborhood SES.

Table 1 characterizes the analytic sample, which was evenly distributed in terms of sex (male: 50.5%), and year entering school (2000: 27.8%, 2001: 25.5%, 2002: 23.7%, 2003: 23.0%). Approximately one quarter of the sample had a non-English language background, and the commonest language backgrounds mirrored the commonest visible minority groups in BC: South Asian (Punjabi), Chinese (Mandarin, Cantonese), and Filipino (Tagalog). Approximately half of the students studied in school districts in the Greater Vancouver area—BC's most populous region—which is home to a similar proportion of BC's overall population (Statistics Canada, 2017).

Measures

Music courses. Secondary school graduation requirements for BC require students to complete at least one arts (music, drama, dance, or visual arts) or applied skills (e.g., business education, home economics) course during Grades 10–12. Students may take combinations of courses (e.g., music *and* visual arts). For analyses, school music courses were identified. When assessing whether students had taken music courses, Grades 10–12 were considered as a whole rather than each grade separately.

Music participation. For Research Question 1, a binary music participation variable (yes/no) was derived to indicate whether

Table 1
Description of Analytic Sample of Public Secondary School Students (n = 112,916)

Variable	Overall		No school music participation	School music participation
	Count	%	(*n* = 97,433; 86.3%)	(*n* = 15,483; 13.7%)
Gender				
Male	57,024	50.5	51.5	44.0
Female	55,892	49.5	48.5	56.0
Year started school				
2000	31,342	27.8	27.6	28.7
2001	28,795	25.5	27.6	26.1
2002	26,812	23.7	23.9	22.9
2003	25,967	23.0	23.1	22.4
School district location				
Greater Vancouver area	55,799	49.4	48.5	55.0
Other areas	57,117	50.6	51.5	45.0
Language background				
English	85,954	76.1	76.8	71.6
Punjabi	8,038	7.1	8.0	1.5
Chinese±	7,890	7.0	5.6	15.7
Tagalog	1,509	1.3	1.2	2.1
Others or multiple non-English languages	9,525	8.4	8.3	9.0
Neighborhood socioeconomic status				
Household income*	112,916	$78,812 ($15,133)	$78,812 ($15,123)	$78,815 ($15,191)
% with posthigh education*	112,916	63.0 (9.3)	62.7 (9.2)	65.0 (9.1)
Grade 7 Foundation Skills Assessment*				
Numeracy	111,640	481.8 (99.4)	476.1 (97.5)	517.4 (103.5)
Reading	112,210	494.6 (99.7)	488.9 (98.6)	530.4 (99.4)
Exam grade*				
English 12	74,550	71.0 (12.2)	70.1 (12.1)	75.5 (12.0)
English 10	111,607	72.1 (13.4)	71.2 (13.3)	77.7 (12.3)
Math 10	89,388	68.2 (17.1)	67.0 (17.0)	74.7 (16.4)
Science 10	111,289	68.8 (13.1)	67.8 (12.8)	75.3 (12.9)
Exam grade*				
Overall for all Grades 10 to 12 music courses	14,808	n/a	n/a	88.0 (9.7)
Overall for all Grades 10 to 12 vocal music courses	3,786	n/a	n/a	86.6 (10.9)
Overall for all Grades 10 to 12 instrumental music courses	7,037	n/a	n/a	89.0 (8.7)

* Values represent means (standard deviation); except neighborhood income, where values represent the median (standard deviation). ±Chinese referred to Mandarin, Cantonese, or another Chinese language as spoken in the household.

or not a student took at least one school music course in Grades 10, 11, or 12. Eligible credit for school music courses comprised courses in concert band, conservatory, orchestra, jazz band, concert choir, and vocal jazz. Course credit for general music or guitar was not considered eligible, because general music typically does not per se entail music-making or practice, and the guitar course in secondary school does not require a certain skill level, and students can choose this course without prior music experience.

For our context, associations between high school music participation and high school academic achievement, although all measured via Grades 10–12 courses grades, may be conceptualized as associations between multiyear engagement with music and high school achievement in Grades 10–12. To receive Grades 10–12 course credits for instrumental music, a student will have completed numerous prior years of engagement, practicing, and participation in music both in and outside of school. Hence, receipt of Grades 10–12 course credit is evidence and often culmination of a multiyear prior trajectory of engagement that likely started several years prior to Grade 10 (middle school or earlier). Such a prior engagement with music before Grades 10–12 would have occurred for virtually all instrumental courses (as prerequisites and certain baseline skill levels are typically required for permission to enroll) whereas receipt of Grades 10–12 vocal music course credit may or may not have entailed such a multiyear prior engagement.

Instrumental versus vocal music courses. For Research Questions 2, 3, and 4, the music courses were classified into two categories: instrumental and vocal. Students who solely took any of the following school music courses were grouped into the instrumental category: concert band, orchestra, jazz band, and/or conservatory (piano, violin). Students who solely took any of the following courses were grouped into the vocal category: concert choir and/or vocal jazz. For Research Question 2, analyses were performed to compare mean exam grades on Grade 10 math, science, and English, and Grade 12 English, between those who took at least one instrumental school music course with those who took no school music courses, as well as between those who took at least one vocal school music course with those who took no school music courses. Similarly, for Research Questions 3 and 4, the analyses were conducted for the instrumental and vocal music groups, separately. This was done based on the notion that taking vocal versus instrumental music courses commonly reflects different pathways of music engagement. Specifically, in BC, learning to play a band instrument generally starts in Grades 5 or 6. For example, students enrolled in Grade 10 concert band, orchestra, and/or jazz band are expected to play at a Grade 10 skill level, equivalent to a level that reflects 5 years of prior band instrument experience and practice. Students who receive external course credits in conservatory music undertake their studies privately, away from school; however, they may choose to be examined at Grade 8 or higher levels (reflecting 8 or more years of piano study) to receive graduation course credit in school Grades 10–12. In other words, conservatory, like school Grades 10, 11, and 12 instrumental ensemble courses, involves a multiyear trajectory of music training and engagement.

Music course grades. For Research Question 3, music course grades—expressed in percentages (ranging from 0 to 100)—were used. Overall school music grades were derived by averaging the course grades received for all Grades 10–12 level music courses taken by a student.

Music engagement. For Research Question 4, music engagement was operationalized as the total number of either instrumental or vocal music courses (as defined above) taken during Grades 10–12. Then, students were grouped into four levels of music engagement: *no engagement* (those who took no music), *engagement* (those who took one or two music courses), *high* engagement (those who took three or four music courses), and *very high engagement* (those who took five or more music courses).

Academic courses. As per graduation requirements, all BC secondary school students were required to complete the same Grade 10 English and Grade 10 science courses, but could choose their required Grade 10 math course and Grade 12 English course. The most commonly taken math course, Foundations of Mathematics and Precalculus (taken by almost 80% of students in the analytic sample—hereafter referred to as Math 10), was used in this study. Similarly, the English course most commonly taken in Grade 12: English 12 (taken by approximately 65% of students in the analytic sample) was chosen to represent Grade 12 English. Provincial examination grades for each course were chosen as the specific outcome for each of the three academic subjects because examination grades are not compromised by teacher effects or variations in the coursework/nonexam components of each course. Past educational research has meaningfully employed provincial exam grades as an outcome variable to measure relationships to school music (e.g., Gouzouasis et al., 2007). Like music course grades, exams grades for math, science, and English are recorded as percentages (ranging from 0 to 100).

Previous academic achievement. Grade 7 (final year of elementary school in BC) academic achievement was used a covariate in the adjusted analyses, to control for students' previous academic achievement; it was measured via "Numeracy" and "Reading" scores on the Foundation Skills Assessment (FSA), a standardized test completed by most British Columbian students each year (British Columbia Ministry of Education, 2019). Significant zero-order (pairwise) Pearson correlations were observed between Grade 7 FSA reading scores and exam grades for English 10, $r(110{,}925) = .57$, and English 12, $r(74{,}199) = .48$, as well as between Grade 7 FSA numeracy scores and exam grades for Math 10, $r(88{,}706) = .54$, and Science 10, $r(110{,}068) = .60$.

Sociodemographic control variables. Variables indicative of students' sex, language/cultural background, and neighborhood SES were used as covariates in all adjusted analyses. The variables were operationalized in the following ways:

Sex was included as a binary variable (male, female), taken from administrative school records.

Cultural background was inferred from the parent-reported language spoken in each student's home each school year from Kindergarten through secondary school. No other direct or indirect measures of cultural background, immigration, or ethnicity were available in the dataset. Home language is a key aspect of ethnocultural background, and prior Canadian-based behavioral research (e.g., Emerson, Mâsse, Ark, Schonert-Reichl, & Guhn, 2018; Guhn, Milbrath, & Hertzman, 2016) has found children's language background to exhibit patterns consistent with studies that employed more direct measures of culture. Students whose parents consistently solely listed English were coded as having an English home language background, whereas students who reported a non-English language (e.g., Punjabi) at least once were categorized as that (non-English) language background. Students were grouped

into the three largest non-English language groups, in addition to English, while other languages and children with multiple home languages reported over the course of their education were combined into an "other" category.

Neighborhood socioeconomic status (SES) was derived using 2011 Canadian census data to assign the median household income and the proportion of adults with postsecondary education associated with the neighborhood in which students lived. These measures serve as useful proxy for SES in the absence of household-level data (Mustard, Derksen, Berthelot, & Wolfson, 1999). For this study, neighborhood boundaries custom-developed for the purposes of child development research (Kershaw, Forer, Irwin, Hertzman, & Lapointe, 2007) were employed. Students in the analytic sample were then assigned to their residential neighborhoods based on their residential postal codes recorded on administrative education records, linked to neighborhood boundaries via geo-coded linkage files (Guhn et al., 2016).

Analytic Approach

Mean exam grades (percentage scores) in Math 10, Science 10, English 10, and English 12 were the outcome variables in all analyses. First, intraclass correlation coefficients (ICCs) were calculated for all outcome variables to estimate the proportion of variance in exam grades due to between-school differences. ICCs were .18 for Math 10, .21 for Science 10, .17 for English 10, and .16 for English 12. Given the size of the ICCs, as recommended by Cohen, Cohen, West, and Aiken (2003), analyses were conducted with multilevel regression models to take into account the nestedness of the data (i.e., students nested within schools).[4]

Analyses were adjusted by controlling for four factors that are related to both academic achievement and school music participation: Grade 7 FSA reading and numeracy scores, sex, cultural background, and SES. Additionally, analyses adjusted for cohort (i.e., the year in which students began Grade 1). All analyses were calculated for the combined cohort of students (who began Grade 1 in 2000–2003), and employed multilevel analyses, using school attended in 2011 as the grouping variable, to account for the nestedness of the data (i.e., children within schools). Means and 95% confidence intervals were reported; to better characterize mean differences, Cohen's *d* values were estimated (Nakagawa & Cuthill, 2007). All data were analyzed using mixed models (Albright & Marinova, 2010) in SPSS Version 23 (IBM Corp, 2014). The following sets of analyses, corresponding to the research questions, were performed.

(1) School music participation versus no school music participation and academic achievement. Multilevel mixed models (via the MIXED command) were used to compare mean exam grades between those who took school music courses and those who did not (unadjusted), and to compare mean exam grades for these groups adjusting for students' previous (Grade 7) academic achievement and socioeconomic and demographic confounders.

(2) Type of music engagement (i.e., instrumental vs. vocal ensemble music classes) and academic achievement. Multilevel mixed models were conducted, similar to the analyses in (1), but for the instrumental and vocal school music groups. Namely, analyses compared mean exam grades for those who (a) took solely instrumental music courses or (b) solely vocal music courses relative to those who took no music courses, adjusting for previous academic achievement and confounders. To assess whether differences between students who took no music courses and those who took music varied according to the type of music courses taken (i.e., solely vocal or solely instrumental), the interaction *music participation * type of music* was tested.

(3) Grades in vocal music classes and instrumental music classes and academic achievement. Two separate multilevel regression analyses were performed to examine whether students' (a) mean vocal school music grade or (b) mean instrumental music grade predicted academic achievement in Grade 10 math, science, and English, and Grade 12 English, adjusting for previous academic achievement and confounders. To assess whether associations of music grades with academic achievement exam scores differed by type of music courses taken (i.e., solely vocal or solely instrumental), the interaction term *music grade * type of music* was tested.

(4) Level of music engagement (cumulative number of courses) in vocal music and instrumental music and academic achievement. Multilevel mixed models were used to examine mean differences in academic achievement associated with varying levels of music engagement (i.e., no engagement = zero school music courses taken; engagement = one or two school music courses taken; high engagement = three or four school music courses; and very high engagement = ≥5 school music courses taken) in (a) vocal music or (b) instrumental music, adjusting for Grade 7 academic achievement and confounders. To assess whether associations between level of engagement in school music and academic achievement differed by type of music courses taken (i.e., solely vocal or solely instrumental), the interaction *level of music engagement * music type* was tested.

(5) Associations between music education and academic grades by subject area. All aforementioned analyses (1–4) were conducted for multiple indicators of students' high school achievement—Math 10, Science 10, English 10, and English 12—and the extent to which the pattern and magnitude of the effect sizes (e.g., null-small-medium) differed by the learning outcomes under consideration was explored.

Results

School Music Participation Versus No Music Participation and Academic Achievement

Table 2 displays results of the multilevel mixed models comparing exam mean grades of those who took school music courses (n = 15,483) with those who took none (n = 97,433). Across all four courses, students who took school music courses had significantly higher mean exam grades than students who took no music courses. Unadjusted mean differences ranged from +4.69 (English 12) to +6.41 (Science 10), and Cohen's *d* effect sizes ranged from 0.36

[4] Regression analyses assume "independence of residuals" (or uncorrelated errors) across observations. The present study examined data of students that are grouped within classrooms and schools. Significant intraclass correlations suggested students within schools share more similarities than students across schools, violating the statistical assumption of independence. In such case, it is recommended to conduct multilevel models, which cluster students in schools, and thus control for non-independent (correlated) residuals (Cohen, Cohen, West, & Aiken, 2003).

Table 2
Unadjusted and Adjusted Mean Exam Grade Differences Between Public Secondary School Students Who Took School Music and Those Who Took No School Music

School music participation	English 12	English 10	Math 10	Science 10
		Unadjusted Analyses		
No participation in school music				
n	63,131	96,216	95,873	75,616
Mean [95% CI]	67.97 [67.45, 68.48]	68.74 [68.19, 69.28]	63.62 [62.87, 64.38]	64.62 [64.03, 65.22]
Participation in school music				
n	11,419	15,391	15,416	13,772
Mean [95% CI]	72.66 [72.11, 73.21]	74.46 [73.88, 75.04]	70.02 [69.23, 70.82]	71.03 [70.41, 71.65]
Mean difference (Cohen's *d*)	+4.69* (.36)	+5.73* (.40)	+6.40* (.36)	+6.41* (.46)
		Adjusted Analyses		
No participation in school music				
n	63,131	96,216	75,616	95,873
Mean [95% CI]	69.71 [69.30, 70.13]	70.87 [70.47, 71.27]	67.03 [66.47, 67.58]	67.23 [66.83, 67.62]
Participation in school music				
n	11,419	15,391	13,772	15,416
Mean [95% CI]	72.18 [71.74, 72.63]	73.59 [73.15, 74.02]	70.75 [70.16, 71.34]	70.99 [70.56, 71.41]
Mean difference (Cohen's *d*)	+2.47* (.22)	+2.72* (.23)	+3.72* (.25)	+3.76* (.34)

* Statistically significant ($p < .05$). Analyses performed using multilevel models accounting for nestedness of students within schools and adjusted for covariates. Reported *n* values denote total number of participants with scores on each exam.

(Math 10 and English 12) to 0.46 (Science 10). Results from the multilevel model, after adjusting for previous (Grade 7) academic achievement and sociodemographic covariates (sex, cohort, language/cultural background, and neighborhood SES), showed that exam grade means across all four academic subjects were significantly higher for those who took music relative to students who took no music. Adjusted mean differences in grades ranged from +2.47 (English 12) to +3.76 (Science 10), and the standardized Cohen's *d* effect sizes ranged from 0.22 (English 12) to 0.34 (Science 10). (Cohen's *d* is presented as standardized effect size for all mean comparisons, to facilitate comparisons across analyses.)

Type of Music (i.e., Instrumental vs. Vocal Music Classes) and Academic Achievement Throughout Secondary School (Grades 10–12)

Results indicated that differences between exam means of students who took no school music and those who took school music significantly differed by type of school music—in fact, a significant interaction term for *music participation * type of music* was observed for all four outcomes (English 12: $F = 50.84$, $p < .001$; English 10: $F = 75.17$, $p < .001$; Science 10: $F = 253.13$, $p < .001$; Math 10: $F = 237.16$, $p < .001$). Among students who took music courses, students who took instrumental music courses had significantly higher exam mean scores than students who took vocal music courses, across all four academic subjects (Table 3). Again, the analyses controlled for Grade 7 academic achievement and for sociodemographic covariates. Mean differences ranged from +1.42 (English 12) to +4.96 (Math 10) grade percentage points, with corresponding Cohen's *d* effect sizes ranging from 0.12 (English 12) to 0.31 (Math 10). The instrumental-vocal music differences in mean exam grades appeared particularly pronounced for Math 10 and Science 10 (Cohen's *d*: 0.31, 0.30, respectively) compared with English 10 and English 12 (Cohen's *d*: 0.13, 0.12, respectively).

Additionally, compared with students who took no music, students who took vocal music as well as students who took instrumental music had, on average, significantly higher exam means

Table 3
Adjusted Mean Exam Grade Differences Between Public Secondary School Students Who Took Vocal Music Courses And Those Who Took Instrumental Music Courses

School music participation	English 12	English 10	Math 10	Science 10
Participation in vocal school music				
n	2,728	3,766	3,198	3,769
Mean [95% CI]	74.90 [74.24–75.57]	77.08 [76.51–77.66]	72.04 [71.14–72.94]	73.03 [72.39–73.67]
Participation in instrumental school music				
n	5,749	7,652	6,994	7,665
Mean [95% CI]	76.33 [75.72–76.93]	78.64 [78.12–79.17]	77.00 [76.18–77.83]	76.82 [76.23–77.40]
Mean difference (Cohen's *d*)	+1.42* (0.12)	+1.56* (0.13)	+4.96* (0.31)	+3.78* (0.30)

* Statistically significant ($p < .05$). Analyses performed using multi-level models accounting for nestedness of students within schools and adjusted for covariates. Reported *n* values denote total number of participants with scores on each exam.

Table 4
Adjusted Mean Exam Grade Differences Between Public Secondary School Students Who Took No School Music Courses and (A) Those Who Took Vocal Music Courses, and (B) Those Who Took Instrumental Music Courses

School music participation	English 12	English 10	Math 10	Science 10
	Adjusted Analyses			
No participation in school music				
n	63,131	96,216	95,873	75,616
Mean [95% CI]	69.59 [69.17, 70.00]	70.68 [70.26, 71.07]	66.79 [66.22, 67.35]	66.94 [66.54, 67.34]
Participation in vocal school music				
n	2,728	3,766	3,198	3,769
Mean [95% CI]	70.63 [70.07, 71.19]	71.89 [71.37, 72.42]	67.59 [66.85, 68.32]	68.35 [67.83, 68.86]
Mean difference (Cohen's *d*)	+1.04* (.09)	+1.23* (.11)	+.80* (.05)	+1.40* (.13)
	Adjusted Analyses			
No participation in school music				
n	63,131	96,216	75,616	95,873
Mean [95% CI]	69.59 [69.17, 70.01]	70.69 [70.28, 71.10]	66.98 [66.42, 67.54]	67.23 [66.83, 67.63]
Participation in instrumental school music				
n	5,749	7,652	6,994	6,994
Mean [95% CI]	72.69 [72.20, 73.18]	74.11 [73.64, 74.58]	72.09 [71.45, 72.73]	72.01 [71.55, 72.46]
Mean difference (Cohen's *d*)	+3.10* (.28)	+3.42* (.30)	+5.11* (.34)	+4.78* (.44)

* Statistically significant ($p < .05$). Analyses performed using multilevel models accounting for nestedness of students within schools and adjusted for covariates. Reported *n* values denote total number of participants with scores on each exam.

(Table 4). The vocal music students had exam means that were between +0.80 and +1.40 higher than students who took no music. Students who took instrumental music had exam means that were between +3.10 (English 10) and +5.11 (Math 10) higher than students who took no music. Cohen's *d* effect sizes characterizing these mean exam differences tended to be higher for the instrumental music group (ranging from 0.28, for English 12, to 0.44, for Science 10) than for the vocal music group (ranging from 0.05, for Math 10, to 0.13, for Science 10).

Grades in Vocal and Instrumental School Music Classes Predicted Academic Achievement

Regression results indicated significant and positive linear associations between grades in vocal and instrumental school music classes and academic grades, adjusting for covariates (Table 5). Raw (unstandardized) coefficients are shown, so they can be interpreted in terms of percentage grades. Results indicated that associations of music grades with academic achievement exam scores significantly varied by type of school music (i.e., solely vocal or solely instrumental music courses)—as the interaction *music grades * type of music* was again significant for all four subjects (English 12: $F = 9.42$, $p = .002$; English 10: $F = 7.08$, $p = .008$; Science 10: $F = 19.80$, $p < .001$; Math 10: $F = 10.56$, $p = .001$). For vocal music, each one-unit increase in overall mean music vocal grade was associated with predicted increases in exam means in all four subjects, ranging from +0.19 (English 10) to +0.38 (Math 10). Such associations between music grades and academic exam scores were significantly higher (i.e., had a larger coefficient) for overall mean instrumental music grades, with coefficients ranging from +0.26 (English 10) to +0.50 (Math 10).

Table 5
Regression Results (Raw Coefficients, Pertaining to Percentage Grade Units) for Relationship Between Mean Music Grades and Exam Grades, Adjusted for Covariates

School music grades	English 12	English 10	Math 10	Science 10
Coefficient for mean grades in vocal music courses				
n	2,724	3,760	3,194	3,763
Coefficient [95% CI]	.22 [.18, .26]	.19 [.16, .22]	.38 [.33, .42]	.25 [.22, .28]
SE	.02	.02	.03	.02
F value	113.42	145.44	225.00	251.86
Coefficient for mean grades in instrumental music courses				
n	5,218	7,000	6,393	7,012
Coefficient [95% CI]	.32 [.28, .35]	.26 [.24, .29]	.50 [.46, .53]	.35 [.32, .38]
SE	.02	.01	.02	.01
F value	329.06	346.70	232.87	661.52

Note. Vocal and instrumental music grade coefficients were statistically significantly different ($p < .05$). Analyses performed using multilevel models accounting for nestedness of students within schools and adjusted for covariates. SE = standard error.

Level of Vocal and Instrumental School Music Engagement and Academic Achievement

Higher music engagement tended to be associated with higher exam means; however, the patterns differed slightly when considering type of music engagement (see Figures 2a and 2b).

Regarding vocal music engagement, those in the *engaged* vocal music group had higher exam means than those in the *no music* group for all subjects except Math 10. Similarly, students in the *highly engaged* vocal music engagement group had significantly higher exam means than those in the *engaged* vocal music group for all subjects except Math 10. Exam means of students in the *very highly engaged* and *highly engaged* vocal music groups did not significantly differ.

For instrumental music engagement, relative to students in the *no music* group, those in the *engaged* instrumental group (i.e., those with one or two courses) and the *highly engaged* instrumental group (i.e., those with three or four courses) had significantly higher exam means. Also, students in the *very highly engaged* instrumental music group had significantly higher exam means than those in the *engaged* or *highly engaged* instrumental music groups.

Interactions Between Music Engagement and Music Type

Given the different, nonlinear patterns of associations between level of music engagement and academic achievement, for the vocal and instrumental music groups, the interaction analyses focused on testing whether the difference between no music and any of the three levels of music engagement was significantly higher for the instrumental group than for the vocal group—which they were. Given the large number of comparisons, only select results for the *engaged* and *very highly engaged* groups are presented, to illustrate the pattern of results: Mean differences between the *engaged* and *no music* groups were significantly larger for instrumental than for vocal music engagement: +2.89 vs. +0.56 for English 12, $F = 33.99$, $p < .001$; +3.26 vs. +0.92 for English 10, $F = 38.69$, $p < .001$; +4.13 versus +0.97 for Science 10, $F = 92.35$, $p < .001$; and + 4.81, versus + 0.53, for Math 10, $F = 92.74$, $p < .001$. For the comparisons between the *very highly engaged* and *no music* groups, the differences were even more pronounced: +4.04 versus +1.34 for English 12, $F = 7.78$, $p = .005$; +4.54 versus +1.69 for English 10, $F = 9.18$, $p = .002$; +5.97 versus +2.83 for Science 10, $F = 23.33$, $p < .001$;

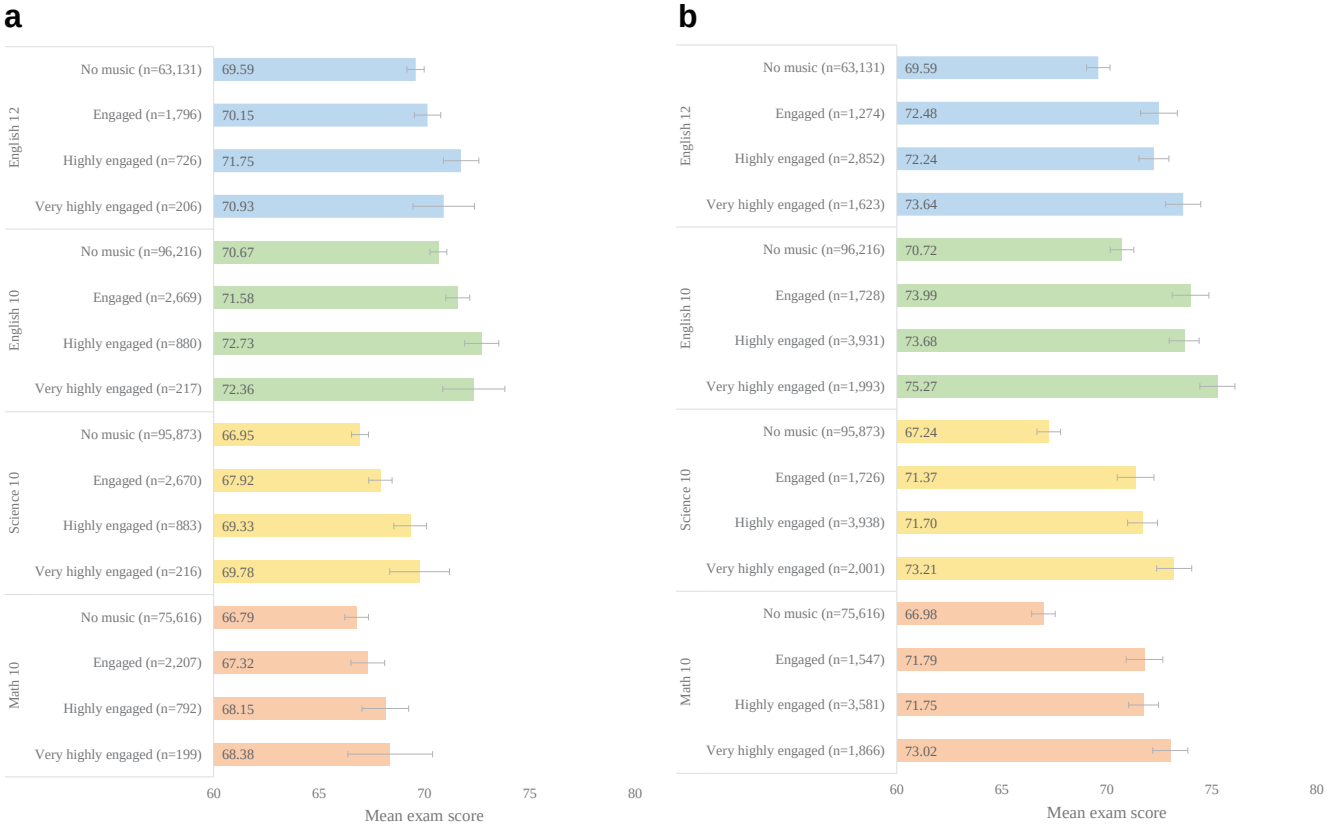

Figure 2. (a) Mean exam grades by level of vocal school music engagement (adjusted). (b) Mean exam grades by level of instrumental school music engagement (adjusted). Analyses performed using multilevel models accounting for nestedness of students within schools and adjusted for covariates. Error bars represent 95% confidence intervals. The *x*-axis represents the range within which the majority (>75%) of all exam scores fell. See the online article for the color version of this figure.

and +6.04 versus +1.59 for Math 10, $F = 33.99$, $p < .001$. Corresponding effect sizes were of small-to-medium magnitude for those who took instrumental music (Cohen's *d* values of 0.37, 0.40, 0.55, and 0.40, respectively), whereas they were small for those who took vocal music (Cohen's *d* values of 0.13, 0.15, 0.26, and 0.11, respectively).

Discussion

The present investigation examined associations between engagement in school music courses and provincial examination grades among over 110,000 public secondary school students in British Columbia, Canada, and represents the largest study of its kind. This study examined whether participation and engagement in school music was associated with academic outcomes in other subjects, by employing a population-level database and using standardized measures of music course participation and English, math, and science high school grades. It extended prior research by considering various forms of music education and controlling for several influences (including students' prior Grade 7 academic achievement and sociodemographic backgrounds) that are likely to confound relationships between music involvement and academic achievement in high school. Findings of this study revealed higher academic outcomes for students who took school music courses relative to those who took none, contravening beliefs that participation in school music may detract from and undermine achievement in core academic subjects such as English, mathematics, and science (i.e., the "opportunity cost" hypothesis). In addition, the greater achievement in high school math, science, and English remained after adjustment for various potential confounders—suggesting music has positive influences on school outcomes rather than being a result of individual differences in early academic achievement, demographics, and/or socioeconomic advantage. Finally, the effect sizes observed when comparing exam grades of students with *very high* engagement in instrumental music compared with those without any school music engagement were of substantive magnitude (Bloom, Hill, Black, & Lipsey, 2008).

Interpreting the Overall Association Between Music Participation and Academic Achievement

Music engagement and opportunity cost. Findings demonstrated that public secondary school students who took school music courses, on average, outperformed their peers who took no school music courses, in standardized exams on English, mathematics, and science. Also, higher levels of school music course engagement corresponded to higher levels of academic achievement. These findings contradict notions of an opportunity cost conferred by taking music courses, which is commonly communicated in school policy debates (Fiske, 1999; Gouzouasis, 2014; Scripp, 2002)—purporting that more time spent on music and less time spent on "basic academic courses" (e.g., math, science, English) undermines achievement in those courses.

Sociodemographics and earlier academic achievement. Relative to students of lower SES backgrounds, those of higher SES backgrounds are more likely to take music (within and outside school) and tend to attain higher academic scores (Elpus, 2013; Sirin, 2005). Accordingly, analyses controlled for children's SES background via holding constant the median household income and the postsecondary education level of students' neighborhoods. Analyses also controlled for students' prior academic achievement via standardized Grade 7 assessments in numeracy and reading skills. The positive associations between school music participation and exam grades remained after consideration of SES, earlier achievement, and other potential demographic confounders (sex, cultural/language background)—suggesting associations between music and academic achievement were not solely an artifact of a certain demographic of students selecting school music courses.

Interpreting the Moderation by Music Type, Music Excellence, and Level of Engagement

Moderation by music type (instrumental vs. vocal). Taking school music courses was generally positively related to academic achievement; however, participating in instrumental music appeared to be particularly beneficial, as evidenced by significantly larger mean exam score differences as well as larger effect sizes relative to those who were engaged solely with vocal school music. Such a pattern cohered with assumptions underlying the present investigation that participation in instrumental music is likely associated with different social, motivation-related, emotional, and cognitive activities relevant for academic achievement than the activities commonly involved in vocal music participation. Although vocal music participation was associated with comparatively smaller mean differences in exam scores and generally exhibited weaker associations with academic achievement (see subsequent subsections), it was still positively related to academic achievement. Vocal music engages different activities and processes than instrumental music (e.g., it generally does not require comparable levels of learning/practicing, a musical instrument is not learned, musical notation is commonly not learned). Yet, both vocal music and instrumental music participation both entail various processes that may aid academic achievement—including social activities (teamwork, interpersonal skills, learning to cooperate with others and awareness of comusicians' perspectives) as well as motivation-related activities (e.g., performing music, being evaluated/graded for such activities).

Important to note in this context is that vocal and instrumental music also differ in terms of the amount of time expended in learning, practicing, and engaging with the form of music. Vocal music, for the majority of high school students in British Columbia, does not generally come with the expectation for a comparable level of practice hours relative to students who participate in instrumental courses. Additionally, vocal music courses typically do not require as many prerequisites as instrumental music courses and vocal music courses do not require learning or practicing an instrument, and may not require learning music notation. Overall, instrumental music learning thus requires and develops a different set of skills—including some directly related to EFs (Slevc et al., 2016)—compared with vocal music participation; and it seems that those skills may be particularly beneficial and transferable to other areas of learning and academic achievement.

Moderation by music excellence/achievement and music type. Higher achievement on both vocal and instrumental music courses was significantly related to higher predicted mean exam scores in English, math, and science. Higher music achievement (grades) may indicate a higher dedication and/or competence in

musical activities, and hence students with higher music achievement may be exposed more thoroughly to the various cognitive, social, emotional, and motivation-related experiences hypothesized to support academic achievement. The observed pattern agreed with findings by Gouzouasis et al. (2007) by demonstrating positive, predictive relationships between music course grades and academic achievement in English, mathematics, and science. Additionally, achievement in instrumental music was more strongly related to exam scores than was achievement in vocal music. Such an interaction between music achievement and type of music may suggest that higher achievement in instrumental music was reflective of a higher level of exposure to a range of musical activities (e.g., executive functions, learning/practicing an instrument) that occur more commonly or uniquely in instrumental rather than in vocal music-making.

Moderation by level of music engagement and music type. The indicators of music engagement (number of courses) generally suggested that higher level of engagement and sustained engagement in music education was associated with higher exam grades in English, math, and science. This pattern echoes prior findings relating higher levels of music engagement with higher general IQ scores (Schellenberg, 2006) and higher academic achievement outcomes (Rodrigues et al., 2013). A high level of sustained engagement in music may represent a positive multiyear trajectory of involvement, commitment to, and dedication for learning and performing music—which in turn may support higher academic achievement through greater development of skills such as motivation, persistence, as well as executive functioning. Moreover, higher levels of sustained engagement in instrumental music was more strongly associated with higher exam scores in English, math, and science than was higher sustained engagement in vocal music.

Associations Between Music Participation and Academic Achievement Across Subject Areas

Overall, associations between various forms of music engagement and academic achievement did not vary substantively across exam subjects (English, science, math). That pattern of a similar, general association of music education is in consonance with several seminal studies of music education and cognitive outcomes (Miksza, 2010; Schellenberg, 2004, 2006; Southgate & Roscigno, 2009). Music participation has been shown to relate to positive outcomes across different academic domains such as in reading and math assessments (Southgate & Roscigno, 2009), language and science courses (dos Santos-Luiz et al., 2016), quantitative and verbal IQ scores (Schellenberg, 2006), spatial-temporal reasoning (Rauscher et al., 1997), as well as course grades in literature, language, history, and mathematics (Wetter, Koerner, & Schwaninger, 2009). Thus, the present study findings—in conjunction with prior evidence—suggest music participation in childhood may relate to cognitive competencies more generally rather than pertaining to any one specific school subject. Such a pattern coheres with theory suggesting music impacts academic achievement through enhancing broad competencies, such as executive functions (Slevc et al., 2016), including working memory, self-regulation, and information processing, that are integral to various academic subjects.

Contextualizing the Magnitude of Effect Sizes

The observed effect sizes, particularly regarding instrumental music, were substantive.[5] In fact, the effect sizes observed when comparing those in the *very highly engaged* instrumental music group with the *no music* group (even after adjustment for numerous confounders) were of a magnitude greater than the average annual gains in reading, science, and math that are seen during the high school years in the U.S. context (Bloom et al., 2008). In other words, students in the present study sample that were highly engaged in instrumental music were, on average, over 1 year ahead in their math, English, and science skills, compared with those peers not engaged in school music. As mentioned, the effect sizes reflect associations after controlling for socioeconomic background variables and previous academic achievement. Thus, an important point to consider is the extent to which other important confounding factors, such as student motivation, social and emotional factors, as well as family/parental factors that were missing in the present analyses, would have potentially accounted for the present findings.

Interdisciplinary Connections

Music aptitude, IQ, learning transfer, and the developing brain. In recent decades, neuroscientists have refined their understanding of music learning in relation to brain processes. For the interpretation of results, it may be useful to draw from that body of work, as it seems plausible that the kinds of skills gained through learning to play an instrument, including auditory, audiation, reading, and executive skills on different instruments (e.g., keyboard, string, percussion, and wind instruments), could positively impact auditory and motor regions of the brain (Hyde et al., 2009). Such changes, in turn, may positively affect other areas of students' understanding, such as in understanding mathematical concepts (see Rogenmoser, Kernbach, Schlaug, & Gaser, 2018; Schlaug & Bangert, 2008; Schneider et al., 2005).

Corroborating this hypothesis, Schneider et al. (2002, 2005) observed that increases in gray matter volume in the Heschl's gyrus (HG) of musicians, as compared with nonmusicians, were linked to greater musical aptitude and audiation (Gordon, 1979; Gouzouasis, 1993), which involves complex internal musical processing, memory, and anticipation; and these cognitive processes overlap with EF. Seither-Preisler, Parncutt, and Schneider (2014) also noted that children who had musical training possessed a considerably larger HG morphology. A study found musical training associated with functional neurological changes (evidenced by particular event-related potentials responses concerning auditory processing) 1 year after training in early childhood (Moreno, Lee, Janus, & Bialystok, 2015). Other researchers also have linked differences in brain morphology to instrumental music learning (Herholz & Zatorre, 2012; Pantev & Herholz, 2011; Schlaug, Jäncke, Huang, Staiger, & Steinmetz, 1995; Schlaug, 2015; Wan & Schlaug, 2010). The present study findings are consistent with the theory that prolonged engagement with (school) instrumental music learning processes may impact brain structure and function

[5] According to the United States Department of Education What Works Clearinghouse (2014), effect sizes of .25 or larger are considered as "substantively important" (p. 26) in educational settings.

(Benner et al., 2017; Tervaniemi, 2009) in ways that may enhance capacity for some aspects of learning as well as cognitive processing, and may thus positively influence academic achievement.

Learning to play an orchestral or band instrument involves cumulative learning over a period of time, and students interested in instrumental music typically begin learning, practicing, and playing in upper elementary grades (i.e., Grades 5 and 6) in BC schools. Becoming successful at playing an instrument, specifically at the secondary school level (starting in Grade 8), takes years of dedication and requires hours of practice and rehearsal time if it is to lead to achievement in musical performance (Sloboda, Davidson, Howe, & Moore, 1996). Students who are engaged in conservatory accredited music lessons (e.g., piano, violin) typically start learning at an even younger age; if these students receive credits for graduation course credit in Grades 10–12, it reflects that they have reached an advanced skill level in music performance. Musically engaged students spend hours practicing music and refining perceptual, cognitive (e.g., audiation-based), and motor skills that enable them to acquire skills to achieve the complex tasks involved in an ensemble or solo musical performance.

In the present study, positive associations between school music courses and exam grades were in the same effect size range across the different subjects (English, math, science) within the instrumental music group (small-to-medium effect sizes) and the vocal music group (small effect sizes). It is plausible that multiple pathways, occurring in parallel, underlie these seemingly general associations—for example, music-specific self-efficacy beliefs may generalize to other areas of learning (Bandura, 2006) and music learning may enhance EFs and audiation, which in turn may benefit learning capacity broadly. Our analyses could not test these pathways, but previous research suggests that even though music-related cognitive gains may to some extent be domain-specific (e.g., verbal but not visual memory; Ho et al., 2003), they commonly relate to various cognitive domains (Forgeard, Winner, Norton, & Schlaug, 2008; Schellenberg, 2004). A pathway that may be able to explain the general effect on academic achievement may lie in the long-term impact that music engagement and achievement have on student's overall EFs, including their cognitive flexibility, working memory, processing speed, and planning (Zuk et al., 2014). Audiation may represent an underlying mechanism via which differences in executive function abilities as well as various facets of instrumental music learning are connected. Thus, we concur with Zuk, Benjamin, Kenyon, and Gaab (2014) in that it is important to develop a better understanding of the connections between audiation abilities, music learning, morphology of specific auditory related areas of the brain, and complex cognitive processing such as those involved in executive functioning (Wengenroth et al., 2014).

Motivation, social context, and (school) music participation. A complex interplay of internal and external factors may influence a learner's motivation to participate in and continue long-term engagement with school music-making (Eccles & Wigfield, 2002), and shape an adolescent's self-concept of musical ability and task value (Sichivitsa, 2007). Intrinsic factors may be influenced by, for example, the sense of competence learners gain from performing well in a musical setting, the enjoyment they receive from the musical activity, the importance they place on the musical task and its potential impact on future music goals, the sacrifices they must make to achieve a musical outcome, and their interests in various kinds of music.

Children's perception of, and engagement in, school music may also be affected by numerous extrinsic factors pertaining to the musical context; for example, the music teacher's communication and choice of music style (e.g., including popular music; see Prendergast, Gouzouasis, Leggo, & Irwin, 2009); the degree to which music band is perceived as a culture, a place of belonging, and/or a social activity (Adderley, Kennedy, & Berz, 2003); the ways in which parents, teachers, and peers discourage engagement in school (Gouzouasis, Henrey, & Belliveau, 2008); and exposure to, or interaction with, other, highly skilled performing artists (Austin, 1988; Gouzouasis & Henderson, 2012). Furthermore, adolescents' musical identity may be context-specific, and be different in school and out of school contexts (Rideout, Foehr, & Roberts, 2010).

Children's music experiences may, in turn, impact their motivation and socioemotional well-being in school more broadly. A study with students who participated in band festivals (Gouzouasis & Henderson, 2012) found students valued instrumental music and participation in band festivals as a positive, rich *educational* experience, and experienced a sense of accomplishment after a good performance. Other research suggests that music-making can satisfy personal needs, build positive self-identity, and help develop effective learning routines (Hallam et al., 2016), and that learning to play an instrument or to sing seems to contribute to higher motivation in other subjects (e.g., language, mathematics, and science; see McPherson & O'Neill, 2010). Finally, a recent literature review (Creech et al., 2013) concluded that music engagement may contribute to enhanced social affirmation, personal development and empowerment, may help recovery from depression, and may support maintenance of personal well-being. In sum, motivational and social-emotional pathways may underlie the observed associations between music learning and learning in other subjects.

Limitations

Operationalization of variables. The dataset lacked information on parental educational achievement and family level socioeconomic status. Therefore, a proxy for family level socioeconomic standing was employed, by using neighborhood-level median household income and proportion of residents with postsecondary education. Aggregate SES data may mask within-group variability; however, previous studies have found that neighborhood SES variables, in the Canadian context, can serve as a valid proxy for household SES, especially when modeling SES as a control variable rather than a primary explanatory or outcome variable in analyses (Mustard et al., 1999).

Cultural background was approximated via language spoken at home (as listed on children's educational files). Language is an important, but incomplete, marker of cultural background because children of diverse cultures may primarily speak English at home; hence, misclassification likely occurred in some instances. Nevertheless, Canadian studies have found children's language background to exhibit patterns of results (for socioemotional functioning) comparable to patterns from studies employing direct measures of cultural background (Emerson et al., 2018; Guhn et al., 2016).

To control for children's previous academic achievement, reading and numeracy scores on a standardized Grade 7 assessment were used as covariates. Some children likely began music training prior to Grade 7 and cognitive benefits of music training have indeed been documented among children prior to Grade 7 (Schellenberg's, 2004 study featured 6-year-olds); for those children, including Grade 7 test scores in the analyses may have led to overcontrolling. Our choice of controlling for Grade 7 test scores was guided by Southgate and Roscigno (2009) who adjusted for Grade 8 test scores when assessing how school music related to Grade 12 achievement. Also, adjusting for Grade 7 achievement scores enabled examination of the impact of sustained involvement in music that occurred from Grade 7 onward, allowing us to test the hypothesis that *a multiyear involvement in instrumental music learning/practicing* is required for cognitive and academic achievement benefits to more prominently emerge.

Data regarding music engagement were only available in terms of secondary school (Grades 10–12) music course participation. As such, this study did not account for the participation and level of engagement in music outside of Grades 10–12 courses (e.g., private lessons, conservatory music, music courses taken before Grade 10). Accordingly, a proportion of students who took school music courses may have had additional out-of-school engagement in music; and some of the students who took no school music courses may have had, nonetheless, formal exposure to music outside of the school context. Additionally, virtually all studies in the related research literature, including this study, lacked measures reflecting specific music teaching content or style. Moreover, various facets of what constitutes an outstanding music program and music environment—for example, musicianship, the teaching and learning materials teachers use and develop, teacher personalities (which has an impact on motivation), home environment (supportive environment and parents)—were not controlled.

Omitted variables and observational nature of study. Given some conceptually important covariates were not included in our dataset and the study represents an observational design, the findings cannot establish cause-effect relationships. Factors missing from the analyses may have confounded the relationship between school music and academic achievement. For example, children's conscientiousness and openness to new experiences, as well as family context, such as parental involvement in music at home, attitudes about music, and parenting style, have been found to play a role in children's willingness to begin, and remain in, music lessons, and these factors commonly also predict academic achievement (Corrigall & Schellenberg, 2015; Corrigall, Schellenberg, & Misura, 2013; Dell et al., 2014–2015). Also, parental involvement can have both positive and negative influence on interest in music-making. Some research indicates that positive parental involvement enhances learner's motivation and success in music (Hallam, 2002; Holtz, 2001; Hurley, 1995; Sichivitsa, 2007), while other research (Hallam, 2001) finds parental influences (e.g., reminders to practice) as a negative factor. There is also evidence that children in the U.S. are more likely to initiate music education (enrolment in band class in Grade 6) if they are higher academic achievers, are from two-parent families, generally have a higher SES background, and/or are female (Kinney, 2008).

While dispositional factors are doubtless important to childhood activities, research suggests it is unlikely that they can fully explain the academic achievement differences observed in our study. Several experimental designs have found cognitive benefits for children who were randomly assigned to music instruction over children assigned to nonmusic control groups (Jaschke et al., 2018; Moreno et al., 2011; Schellenberg, 2004). Additionally, analysis of over 7,000 high school students yielded evidence of positive associations between music lessons and reading test scores even after adjustment for a host of individual difference variables including cultural background, family SES, sex, prior academic (reading) achievement in Grade 8, and number of books read (Southgate & Roscigno, 2009). Indeed, a recent meta-analysis of factors/experiences that promote IQ in childhood concluded that learning a musical instrument was one approach (Protzko, 2017). Regarding claims that students who take music were already more open to new experiences, some argue that music-making—a process that often entails personal challenge and exposure to novel stimuli—may, in fact, impact personality, specifically openness to new experiences (Hille & Schupp, 2015). Thus, some ostensible, predisposing, individual differences in traits of children who take music compared with those who take no music may in fact be influenced by the very process that separates them—music-making.

Finally, the correlational nature of the study prevented testing specific cause-effect relationships, particularly regarding direction, temporal precedence, and specific causal pathways relating music education to academic achievement. It should be noted, however, that the multiyear prior engagement in instrumental music does provide some index of temporal precedence in the sense that most musical activity/training occurred prior to the English, math, and science exams taken in Grades 10 or 12. Moreover, several experimental designs have found assignment to music training was related to subsequent improvements in academic or cognitive domains (Jaschke et al., 2018; Moreno et al., 2011; Schellenberg, 2004).

Representativeness and Generalizability of Findings

The study was conducted with a population-wide administrative dataset, including all students in all public schools in the province of British Columbia. However, it is noteworthy that the analytic sample did not include private/independent schools, who tend to have higher socioeconomic status and a higher likelihood of school music participation. Also, it is important to acknowledge jurisdictional variability in music education (e.g., course offerings, graduation requirements) that may contribute to differences in school music participation. In our study, the proportion who took vocal or instrumental music was about 14%. This is lower than the proportion of students with *at least one high school music course* that were considered in a representative sample in the U.S. (Elpus, 2013); however, our study excluded several music courses (e.g., guitar, general music), whereas all music courses were included in the U.S. study by Elpus (2013). For the BC context, the estimate of vocal and instrumental music participation is likely an accurate estimate for public high schools due to the recency, scale, and representativeness of our population-level administrative dataset.

Other social and cultural factors may limit generalizability to other contexts beyond the BC public school system. For example, instrumental school ensemble music, such as jazz band and orchestra, have a long, valued tradition in North American culture and schools—whereas other music traditions may be more prominent in other societies' cultures and their school systems. We

anticipate that studies in other contexts would find similar results to our study—as long as such studies are based on a measure of "musical engagement" that serves as an equally valid proxy for children's multiyear engagement in musical learning. After all, to be developmentally beneficial, music learning arguably needs to represent the characteristics of a *proximal process* in the Bronfenbrennerian sense (Bronfenbrenner & Morris, 2006); that is, a process that occurs regularly, over an extended period of time, with increasing complexity, and embedded within reciprocal interaction with the social and cultural environment in which the child grows up. In our study, engagement and achievement in band or orchestra in high school reflects a multiyear, increasingly complex process of music learning.

Future Research

Future inquiry in the intersection of music education and academic achievement may extend present study findings by four main approaches. First, future studies may benefit from knowledge of participants' level of music participation both within and outside of school to gain a more refined estimate of associations between music participation, music engagement and academic grades. Second, additional measures of potential confounders in associations of music education with academic achievement would offer greater precision when estimating relationships. In particular, it would be useful to adjust analyses for variables such as household-level SES, parental involvement in students' school life, students' academic motivation, and personal characteristics (e.g., conscientiousness). Third, inclusion of factors theorized as pathways relating music education to academic achievement—such as executive functioning, socioemotional functioning, audiation, and brain imaging—would enable evaluation of how such factors may represent mechanisms relating music education to academic achievement.

In line with Bronfenbrenner's bioecological model, and his propositions to examine the extent to which developmental effects of proximal processes vary as a function of their regularity, intensity, and growing complexity, our analyses tested for some pertinent interaction effects; for example, whether associations between music and academic achievement were moderated by the type and level of music engagement (e.g., the no music vs. very highly engaged instrumental vs. vocal music engagement groups). A further extension of Bronfenbrenner's propositions would be to not only control for previous academic achievement and the sociodemographic factors mentioned above (SES, gender, cultural background)—but to examine to what extent associations between the "proximal process" of music-making and developmental outcomes may "vary systematically as a joint function of the characteristics of the developing person [e.g., gender, previous academic achievement, efficacy beliefs], the environment—both immediate [e.g., family poverty] and more remote [e.g., societal valuing of music/the arts]—in which the processes are taking place, [and] the nature of the developmental outcomes under consideration [e.g., high school completion, well-being, mental health]" (Bronfenbrenner & Morris, 2006, p. 798).

Conclusions and Implications

The work of researchers in cognitive science and neuroscience over the past quarter century has suggested possible pathways and mechanisms that may apply to the results of the present study. For instance, two recent longitudinal studies of elementary schoolchildren (Holochwost et al., 2017; Jaschke et al., 2018) considered both executive functions and academic achievement, finding improvements in both cognitive domains while the former study observed evidence that music participation related to academic achievement via executive functions.

In light of the literature that has shed light on possible mechanisms between music learning and cognitive, social, and emotional development, this study concludes by reiterating the "call for school music" made by Zuk et al. (2014), who argue that degrading or eliminating school music programs may, in fact, have detrimental outcomes on math, science, and language skills, as well as on cognitive development overall. In extending the literature, the results of this study seem to indicate that music engagement sustained from childhood into adolescence—and more of it, particularly instrumental music—may lead to doing better in school.

References

Adderley, C., Kennedy, M., & Berz, W. (2003). A home away from home: The world of the high school music classroom. *Journal of Research in Music Education, 51,* 190–205. http://dx.doi.org/10.2307/3345373

Albright, J. J., & Marinova, D. M. (2010). *Estimating multilevel models using SPSS, Stata, SAS, and R.* Retrieved from http://www.iub.edu/_statmath/stat/all/hlm/hlm.pdf

Austin, J. R. (1988). The effect of music contest format on self-concept, motivation, achievement, and attitude of elementary band students. *Journal of Research in Music Education, 36,* 95–107. http://dx.doi.org/10.2307/3345243

Bandura, A. (2006). Guide for constructing self-efficacy scales. In F. Pajares & T. Urdan (Eds.), *Self-efficacy beliefs of adolescent* (pp. 307–337). Greenwich, CT: Information Age Publishing.

Barnett, S. M., & Ceci, S. J. (2002). When and where do we apply what we learn? A taxonomy for far transfer. *Psychological Bulletin, 128,* 612–637. http://dx.doi.org/10.1037/0033-2909.128.4.612

Bastian, H. G. (2000). *Musik(erziehung) und ihre Wirkung. Eine Langzeitstudie an Berliner Grundschulen* [Music (education) and its effect. A long-term study at Berlin elementary schools]. Mainz: Schott Musik International.

Benner, J., Wengenroth, M., Reinhardt, J., Stippich, C., Schneider, P., & Blatow, M. (2017). Prevalence and function of Heschl's gyrus morphotypes in musicians. *Brain Structure & Function, 222,* 3587–3603. http://dx.doi.org/10.1007/s00429-017-1419-x

Benz, S., Sellaro, R., Hommel, B., & Colzato, L. S. (2016). Music makes the world go round: The impact of musical training on non-musical cognitive functions—A review. *Frontiers in Psychology, 6.* http://dx.doi.org/10.3389/fpsyg.2015.02023

Bergman Nutley, S., Darki, F., & Klingberg, T. (2014). Music practice is associated with development of working memory during childhood and adolescence. *Frontiers in Human Neuroscience, 7.* http://dx.doi.org/10.3389/fnhum.2013.00926

Best, J. R., Miller, P. H., & Naglieri, J. A. (2011). Relations between executive function and academic achievement from ages 5 to 17 in a large, representative national sample. *Learning and Individual Differences, 21,* 327–336. http://dx.doi.org/10.1016/j.lindif.2011.01.007

Bloom, H. S., Hill, C. J., Black, A. R., & Lipsey, M. W. (2008). Performance trajectories and performance gaps as achievement effect-size benchmarks for educational interventions. *Journal of Research on Educational Effectiveness, 1,* 289–328. http://dx.doi.org/10.1080/19345740802400072

British Columbia Ministry of Education. (2019). *Foundational skills assessment.* Retrieved from https://www2.gov.bc.ca/gov/content/

education-training/k-12/administration/program-management/assessment/foundation-skills-assessment

Bronfenbrenner, U., & Morris, P. A. (2006). The bioecological model of human development. In R. M. Lerner (Ed.), *Handbook of child psychology: Vol. I. Theoretical models of human development* (6th ed., pp. 793–828). Hoboken, NJ: Wiley.

Caprara, G. V., Vecchione, M., Alessandri, G., Gerbino, M., & Barbaranelli, C. (2011). The contribution of personality traits and self-efficacy beliefs to academic achievement: A longitudinal study. *The British Journal of Educational Psychology, 81,* 78–96. http://dx.doi.org/10.1348/2044-8279.002004

Catterall, J. S. (1997). Involvement in the arts and success in secondary school. *Americans for the Arts Monographs, 1,* 1–11.

Catterall, J. S., Chapleau, R., & Iwanaga, J. (1999). Involvement in the arts and human development: General involvement and intensive involvement in music and theater arts. In E. B. Fiske, (Ed.) *Champions of change—The impact of the arts on learning* (pp. 1–18). Washington, DC: Arts Education Partnership & President's Committee on the Arts and the Humanities.

Chan, A. S., Ho, Y. C., & Cheung, M. C. (1998). Music training improves verbal memory. *Nature, 396,* 128. http://dx.doi.org/10.1038/24075

Cohen, J., Cohen, P., West, S. G., & Aiken, L. S. (2003). *Applied multiple regression/correlation analysis for the behavioral sciences*. New York, NY: Routledge.

Corrigall, K. A., & Schellenberg, E. G. (2015). Predicting who takes music lessons: Parent and child characteristics. *Frontiers in Psychology, 6*. http://dx.doi.org/10.3389/fpsyg.2015.00282

Corrigall, K. A., Schellenberg, E. G., & Misura, N. M. (2013). Music training, cognition, and personality. *Frontiers in Psychology, 4*. http://dx.doi.org/10.3389/fpsyg.2013.00222

Costa-Giomi, E. (2004). Effects of three years of piano instruction on children's academic achievement, school performance and self-esteem. *Psychology of Music, 32,* 139–152.

Creech, A., Hallam, S., McQueen, H., & Varvarigou, M. (2013). The power of music in the lives of older adults. *Research Studies in Music Education, 35,* 87–102. http://dx.doi.org/10.1177/1321103X13478862

Deasy, R. J. (Ed.), (2002). *Critical links: Learning in the arts and student academic and social development*. Washington, DC: Arts Education Partnership. Retrieved from https://eric.ed.gov/?id=ED466413

Degé, F., Kubicek, C., & Schwarzer, G. (2011). Music lessons and intelligence: A relation mediated by executive functions. *Music Perception, 29,* 195–201. http://dx.doi.org/10.1525/mp.2011.29.2.195

Degé, F., & Schwarzer, G. (2017). The influence of an extended music curriculum at school on academic self-concept in 9-to 11-year-old children. *Musicae Scientiae, 22,* 305–321. http://dx.doi.org/10.1177/1029864916688508

Degé, F., Wehrum, S., Stark, R., & Schwarzer, G. (2014). Music lessons and academic self-concept in 12-to 14-year-old children. *Musicae Scientiae, 18,* 203–215. http://dx.doi.org/10.1177/1029864914523283

Degé, F., Wherum, S., Stark, R., & Schwarzer, G. (2011). The influence of two years of school music training in secondary school on visual and auditory memory. *European Journal of Developmental Psychology, 8,* 608–623. http://dx.doi.org/10.1080/17405629.2011.590668

Dell, C., Rinnert, N., Yap, C. C., Keith, T., Zdzinski, S., Gumm, A., . . . Russell, B. (2014–2015). Musical home environment, family background, and parenting style on success in school music and in school. *Contributions to Music Education, 40,* 71–90. Retrieved from https://www.jstor.org/stable/24711072

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64,* 135–168. http://dx.doi.org/10.1146/annurev-psych-113011-143750

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4 to 12 years old. *Science, 333,* 959–964. http://dx.doi.org/10.1126/science.1204529

Diaz, F. M. (2010). Intrinsic and extrinsic motivation among collegiate instrumentalists. *Contributions to Music Education, 37,* 23–35. Retrieved from https://www.jstor.org/stable/24127266

dos Santos-Luiz, C., Mónico, L. S., Almeida, L. S., & Coimbra, D. (2016). Exploring the long-term associations between adolescents' music training and academic achievement. *Musicae Scientiae, 20,* 512–527. http://dx.doi.org/10.1177/1029864915623613

Dumont, E., Syurina, E. V., Feron, F. J. M., & van Hooren, S. (2017). Music interventions and child development: A critical review and further directions. *Frontiers in Psychology, 8*. http://dx.doi.org/10.3389/fpsyg.2017.01694

Eccles, J. S., & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53,* 109–132. http://dx.doi.org/10.1146/annurev.psych.53.100901.135153

Elpus, K. (2013). Is it the music or is it selection bias? A nationwide analysis of music and non-music students' SAT scores. *Journal of Research in Music Education, 61,* 175–194. http://dx.doi.org/10.1177/0022429413485601

Emerson, S. D., Mâsse, L. C., Ark, T. K., Schonert-Reichl, K. A., & Guhn, M. (2018). A population-based analysis of life satisfaction and social support among children of diverse backgrounds in British Columbia, Canada. *Quality of Life Research, 27,* 2595–2607. http://dx.doi.org/10.1007/s11136-018-1922-4

Evans, P. (2015). Self-determination theory: An approach to motivation in music education. *Musicae Scientiae, 19,* 65–83. http://dx.doi.org/10.1177/1029864914568044

Evans, P., & Liu, M. Y. (2019). Psychological needs and motivational outcomes in a high school orchestra program. *Journal of Research in Music Education, 67,* 83–105.

Fiske, E. (1999). *Champions of change: The impact of the arts on learning*. Washington, DC: The Arts Education Partnership and the President's Committee on the Arts and Humanities. Retrieved from https://eric.ed.gov/?id=ED435581

Fitzpatrick, K. R. (2006). The effect of instrumental music participation and socioeconomic status on Ohio fourth-, sixth-, and ninth-grade proficiency test performance. *Journal of Research in Music Education, 54,* 73–84. http://dx.doi.org/10.1177/002242940605400106

Forgeard, M., Winner, E., Norton, A., & Schlaug, G. (2008). Practicing a musical instrument in childhood is associated with enhanced verbal ability and nonverbal reasoning. *PLoS ONE, 3*(10), e3566. http://dx.doi.org/10.1371/journal.pone.0003566

Foster, E. M., & Jenkins, J. V. (2017). Does participation in music and performing arts influence child development? *American Educational Research Journal, 54,* 399–443. http://dx.doi.org/10.3102/0002831217701830

Gordon, E. E. (1979). Developmental music aptitude as measured by the Primary Measures of Music Audiation. *Psychology of Music, 7,* 42–49. http://dx.doi.org/10.1177/030573567971005

Gouzouasis, P. (1993). Music audiation: A comparison of the music abilities of kindergarten children of various ethnic backgrounds. *The Quarterly Journal of Music Teaching and Learning, 4,* 70–76. https://openmusiclibrary.org/article/182329/

Gouzouasis, P. (2014). What matters most: Using contemporary research to support music education policies in schools (a performative autoethnography). In P. Gouzouasis (Ed.), *Policy and media in and for a diverse global community*. Proceedings of the commission on music policy: Culture, education, and media of the International Society for Music Education (pp. 60–71). Natal, Brazil: Commission on Music Policy: Culture, Education, and Media.

Gouzouasis, P., Guhn, M., & Kishor, N. (2007). The predictive relationship between achievement in music and achievement in core Grade twelve academic subjects. *Music Education Research, 9,* 81–92. http://dx.doi.org/10.1080/14613800601127569

Gouzouasis, P., & Henderson, A. (2012). Secondary band student perspectives on musical and educational outcomes from participation in band festivals. *Music Education Research, 14,* 479–498. http://dx.doi.org/10.1080/14613808.2012.714361

Gouzouasis, P., Henrey, J., & Belliveau, G. (2008). Turning points: A transitional story of grade seven music students' participation in high school band programmes. *Music Education Research, 10,* 75–90. http://dx.doi.org/10.1080/14613800701871397

Guhn, M., Janus, M., Enns, J., Brownell, M., Forer, B., Duku, E., . . . Raos, R. (2016). Examining the social determinants of children's developmental health: Protocol for building a pan-Canadian population-based monitoring system for early childhood development. *British Medical Journal Open, 6,* e012020. http://dx.doi.org/10.1136/bmjopen-2016-012020

Guhn, M., Milbrath, C., & Hertzman, C. (2016). Associations between child home language, gender, bilingualism and school readiness: A population-based study. *Early Childhood Research Quarterly, 35,* 95–111. http://dx.doi.org/10.1016/j.ecresq.2015.11.003

Hallam, S. (2001). The development of expertise in youth musicians: Strategy use, knowledge acquisition and individual diversity. *Music Education Research, 3,* 8–23. http://dx.doi.org/10.1080/14613800020029914

Hallam, S. (2002). Musical motivation: Towards a model synthesising the research. *Music Education Research, 4,* 226–244. http://dx.doi.org/10.1080/1461380022000011939

Hallam, S., Creech, A., Papageorgi, I., Gomes, T., Rinta, T., Varvarigou, M., & Lanipekun, J. (2016). Changes in motivation as expertise develops: Relationships with musical aspirations. *Musicae Scientiae, 20,* 528–550. http://dx.doi.org/10.1177/1029864916634420

Heller, G. N. (2001). Allen Perdue Britton and "The study of music: An academic discipline." *Journal of Historical Research in Music Education, 22,* 94–110. http://dx.doi.org/10.1177/153660060102200202

Herholz, S. C., & Zatorre, R. J. (2012). Musical training as a framework for brain plasticity: Behavior, function, and structure. *Neuron, 76,* 486–502. http://dx.doi.org/10.1016/j.neuron.2012.10.011

Hille, A., & Schupp, J. (2015). How learning a musical instrument affects the development of skills. *Economics of Education Review, 44,* 56–82. http://dx.doi.org/10.1016/j.econedurev.2014.10.007

Ho, Y. C., Cheung, M. C., & Chan, A. S. (2003). Music training improves verbal but not visual memory: Cross-sectional and longitudinal explorations in children. *Neuropsychology, 17,* 439–450. http://dx.doi.org/10.1037/0894-4105.17.3.439

Holochwost, S. J., Propper, C. B., Wolf, D. P., Willoughby, M. T., Fisher, K. R., Kolacz, J., . . . Jaffe, S. R. (2017). Music education, academic achievement, and executive functions. *Psychology of Aesthetics, Creativity, and the Arts, 11,* 147–166. http://dx.doi.org/10.1037/aca0000112

Holtz, G. (2001). Evaluating the effectiveness of school instrumental programs. *Teaching Music, 9,* 40–43. Retrieved from https://eric.ed.gov/?id=EJ663629

Hurley, C. G. (1995). Student motivations for beginning and continuing/discontinuing string music instruction. *The Quarterly Journal of Music Teaching and Learning, 6,* 44–55. Retrieved from https://openmusiclibrary.org/article/182373/

Hyde, K. L., Lerch, J., Norton, A., Forgeard, M., Winner, E., Evans, A. C., & Schlaug, G. (2009). Musical training shapes structural brain development. *The Journal of Neuroscience, 29,* 3019–3025. http://dx.doi.org/10.1523/JNEUROSCI.5118-08.2009

IBM Corp. (2014). IBM SPSS Statistics for Windows, (Version 23.0) [Computer software]. Armonk, NY: IBM Corp.

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. http://dx.doi.org/10.3389/fnins.2018.00103

Kershaw, P., Forer, B., Irwin, L. G., Hertzman, C., & Lapointe, V. (2007). Toward a social care program of research: A population-level study of neighborhood effects on child development. *Early Education and Development, 18,* 535–560. http://dx.doi.org/10.1080/10409280701610929

Kinney, D. W. (2008). Selected demographic variables, school music participation, and achievement test scores of urban middle school students. *Journal of Research in Music Education, 56,* 145–161. http://dx.doi.org/10.1177/0022429408322530

Major, M. L. (2013). How they decide: A case study examining the decision-making process for keeping or cutting music in a K–12 public school district. *Journal of Research in Music Education, 61,* 5–25. http://dx.doi.org/10.1177/0022429412474313

McPherson, G. E., & O'Neill, S. A. (2010). Students' motivation to study music as compared to other school subjects: A comparison of eight countries. *Research Studies in Music Education, 32,* 101–137. http://dx.doi.org/10.1177/1321103X10384202

McPherson, G. E., & Renwich, J. M. (2011). Self-regulation and mastery of musical skills. In B. J. Zimmerman & D. H. Schunk (Eds.), *Handbook of self-regulation of learning and performance* (pp. 234–250). New York, NY: Routledge.

Miksza, P. (2010). Investigating relationships between participation in high school music ensembles and extra-musical outcomes: An analysis of the Education Longitudinal Study of 2002 using a bioecological development model. *Bulletin of the Council for Research in Music Education, Fall, 2010,* 7–25. Retrieved from https://www.jstor.org/stable/41110431

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: A latent variable analysis. *Cognitive Psychology, 41,* 49–100. http://dx.doi.org/10.1006/cogp.1999.0734

Moradzadeh, L., Blumenthal, G., & Wiseheart, M. (2015). Musical training, bilingualism, and executive function: A closer look at task switching and dual-task performance. *Cognitive Science, 39,* 992–1020. http://dx.doi.org/10.1111/cogs.12183

Moreno, S., Bialystok, E., Barac, R., Schellenberg, E. G., Cepeda, N. J., & Chau, T. (2011). Short-term music training enhances verbal intelligence and executive function. *Psychological Science, 22,* 1425–1433. http://dx.doi.org/10.1177/0956797611416999

Moreno, S., Friesen, D., & Bialystok, E. (2011). Effect of music training on promoting pre literacy skills: Preliminary causal evidence. *Music Perception, 29,* 165–172. http://dx.doi.org/10.1525/mp.2011.29.2.165

Moreno, S., Lee, Y., Janus, M., & Bialystok, E. (2015). Short-term second language and music training induces lasting functional brain changes in early childhood. *Child Development, 86,* 394–406. http://dx.doi.org/10.1111/cdev.12297

Mustard, C. A., Derksen, S., Berthelot, J. M., & Wolfson, M. (1999). Assessing ecologic proxies for household income: A comparison of household and neighbourhood level income measures in the study of population health status. *Health & Place, 5,* 157–171. http://dx.doi.org/10.1016/S1353-8292(99)00008-8

Nakagawa, S., & Cuthill, I. C. (2007). Effect size, confidence interval and statistical significance: A practical guide for biologists. *Biological Reviews of the Cambridge Philosophical Society, 82,* 591–605. http://dx.doi.org/10.1111/j.1469-185X.2007.00027.x

Oechslin, M. S., Van De Ville, D., Lazeyras, F., Hauert, C. A., & James, C. E. (2013). Degree of musical expertise modulates higher order brain functioning. *Cerebral Cortex, 23,* 2213–2224. http://dx.doi.org/10.1093/cercor/bhs206

Pantev, C., & Herholz, S. C. (2011). Plasticity of the human auditory cortex related to musical training. *Neuroscience and Biobehavioral Reviews, 35,* 2140–2154. http://dx.doi.org/10.1016/j.neubiorev.2011.06.010

Prendergast, M., Gouzouasis, P., Leggo, C., & Irwin, R. L. (2009). A haiku suite: The importance of music making in the lives of secondary school students. *Music Education Research, 11,* 303–317. http://dx.doi.org/10.1080/14613800903144262

Protzko, J. (2017). Raising, I. Q. among school-aged children: Five meta-analyses and a review of randomized controlled trials. *Developmental Review, 46,* 81–101. http://dx.doi.org/10.1016/j.dr.2017.05.001

Qa Research. (2012). *Young people not in education, employment or training (NEET) and music making*. London, UK: Youth Music. Retrieved from https://network.youthmusic.org.uk/file/2286/download?token=3lRui5TM

Rauscher, F. H., Shaw, G. L., Levine, L. J., Wright, E. L., Dennis, W. R., & Newcomb, R. L. (1997). Music training causes long-term enhancement of preschool children's spatial-temporal reasoning. *Neurological Research, 19,* 2–8. http://dx.doi.org/10.1080/01616412.1997.11740765

Rickard, N. S., Appelman, P., James, R., Murphy, F., Gill, A., & Bambrick, C. (2013). Orchestrating life skills: The effect of increased school-based music classes on children's social competence and self-esteem. *International Journal of Music Education, 31,* 292–309. http://dx.doi.org/10.1177/0255761411434824

Rideout, V. J., Foehr, U. G., & Roberts, D. F. (2010). *Generation M²: Media in the lives of 8 to 18-year-olds*. Menlo Park, CA: Henry J. Kaiser Family Foundation. Retrieved from https://files.eric.ed.gov/fulltext/ED527859.pdf

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,* 284–298. http://dx.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 Neuroscience, 3,* 572. http://dx.doi.org/10.3389/fpsyg.2012.00572

Rodrigues, A. C., Loureiro, M. A., & Caramelli, P. (2013). Long-term musical training may improve different forms of visual attention ability. *Brain and Cognition, 82,* 229–235. http://dx.doi.org/10.1016/j.bandc.2013.04.009

Rogenmoser, L., Kernbach, J., Schlaug, G., & Gaser, C. (2018). Keeping brains young with making music. *Brain Structure & Function, 223,* 297–305. http://dx.doi.org/10.1007/s00429-017-1491-2

Rumberger, R. W., & Lim, S. A. (2008). Why students drop out of school: A review of 25 years of research. *California Dropout Research Project, 15,* 1–3. Retrieved from https://www.issuelab.org/resources/11658/11658.pdf

Sala, G., & Gobet, F. (2017). When the music's over. Does music transfer to children's and young adolescents' cognitive and academic skills? A meta-analysis. *Educational Research Review, 20,* 55–67. http://dx.doi.org/10.1016/j.edurev.2016.11.005

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

Schellenberg, E. G. (2006). Long-term positive associations between music lessons and IQ. *Journal of Educational Psychology, 98,* 457–468. http://dx.doi.org/10.1037/0022-0663.98.2.457

Schlaug, G. (2015). Musicians and music making as a model for the study of brain plasticity. *Progress in Brain Research, 217,* 37–55. http://dx.doi.org/10.1016/bs.pbr.2014.11.020

Schlaug, G., & Bangert, M. (2008). Neural correlates on music learning and understanding. In W. Gruhn & F. Rauscher (Eds.), *Neurosciences in music pedagogy* (pp. 101–120). New York, NY: Nova Science Publishers, Inc.

Schlaug, G., Jäncke, L., Huang, Y., Staiger, J. F., & Steinmetz, H. (1995). Increased corpus callosum size in musicians. *Neuropsychologia, 33,* 1047–1055. http://dx.doi.org/10.1016/0028-3932(95)00045-5

Schlaug, G., Norton, A., Overy, K., & Winner, E. (2005). Effects of music training on the child's brain and cognitive development. *Annals of the New York Academy of Sciences, 1060,* 219–230. http://dx.doi.org/10.1196/annals.1360.015

Schmidt, C. P. (2005). Relations among motivation, performance achievement, and music experience variables in secondary instrumental music students. *Journal of Research in Music Education, 53,* 134–147. http://dx.doi.org/10.1177/002242940505300204

Schneider, P., Scherg, M., Dosch, H. G., Specht, H. J., Gutschalk, A., & Rupp, A. (2002). Morphology of Heschl's gyrus reflects enhanced activation in the auditory cortex of musicians. *Nature Neuroscience, 5,* 688–694. http://dx.doi.org/10.1038/nn871

Schneider, P., Sluming, V., Roberts, N., Scherg, M., Goebel, R., Specht, H. J., . . . Rupp, A. (2005). Structural and functional asymmetry of lateral Heschl's gyrus reflects pitch perception preference. *Nature Neuroscience, 8,* 1241–1247. http://dx.doi.org/10.1038/nn1530

Scripp, L. (2002). An overview of research on music and learning. In R. J. Deasy (Ed.), *Critical links: Learning in the arts and student academic and social development* (pp. 132–136). Washington, DC: Arts Education Partnership.

Seither-Preisler, A., Parncutt, R., & Schneider, P. (2014). Size and synchronization of auditory cortex promotes musical, literacy, and attentional skills in children. *The Journal of Neuroscience, 34,* 10937–10949. http://dx.doi.org/10.1523/JNEUROSCI.5315-13.2014

Sichivitsa, V. O. (2007). the influences of parents, teachers, peers and other factors on students' motivation in music. *Research Studies in Music Education, 29,* 55–68. http://dx.doi.org/10.1177/1321103X07087568

Sirin, S. R. (2005). Socioeconomic status and academic achievement: A meta-analytic review of research. *Review of Educational Research, 75,* 417–453. http://dx.doi.org/10.3102/00346543075003417

Slevc, L. R., Davey, N. S., Buschkuehl, M., & Jaeggi, S. M. (2016). Tuning the mind: Exploring the connections between musical ability and executive functions. *Cognition, 152,* 199–211. http://dx.doi.org/10.1016/j.cognition.2016.03.017

Sloboda, J. A., Davidson, J. W., Howe, M. J. A., & Moore, D. G. (1996). The role of practice in the development of performing musicians. *British Journal of Psychology, 87,* 287–309.

Southgate, D. E., & Roscigno, V. J. (2009). The impact of music on childhood and adolescent achievement. *Social Science Quarterly, 90,* 4–21. http://dx.doi.org/10.1111/j.1540-6237.2009.00598.x

Statistics Canada. (2017). *Census Metropolitan area of Vancouver, Focus on Geography Series, 2016 Census. Statistics Canada Catalogue* no. 98-404-X2016001. Ottawa, Ontario: Data products, 2016 Census. Retrieved from https://www12.statcan.gc.ca/census-recensement/2016/as-sa/fogs-spg/Facts-can-eng.cfm?Lang=Eng&GK=CAN&GC=01&TOPIC=1

Steele, C. J., Bailey, J. A., Zatorre, R. J., & Penhune, V. B. (2013). Early musical training and white-matter plasticity in the corpus callosum: Evidence for a sensitive period. *The Journal of Neuroscience, 33,* 1282–1290. http://dx.doi.org/10.1523/JNEUROSCI.3578-12.2013

Stuss, D. T., & Alexander, M. P. (2000). Executive functions and the frontal lobes: A conceptual view. *Psychological Research, 63,* 289–298. http://dx.doi.org/10.1007/s004269900007

Tervaniemi, M. (2009). Musicians—Same or different? *Annals of the New York Academy of Sciences, 1169,* 151–156. http://dx.doi.org/10.1111/j.1749-6632.2009.04591.x

Uy, M. (2010). *Positive behavioral and academic outcomes in students participating in two after school music programs: The Harmony Project and El Sistema,* Unpublished manuscript, Berkley's College of Letters and Sciences, University of California, Berkley, CA.

Vaughn, K. (2000). Music and mathematics: Modest support for the oft-claimed relationship. *Journal of Aesthetic Education, 34,* 149–166. http://dx.doi.org/10.2307/3333641

Visu-Petra, L., Cheie, L., Benga, O., & Miclea, M. (2011). Cognitive control goes to school: The impact of executive functions on academic performance. *Procedia: Social and Behavioral Sciences, 11,* 240–244. http://dx.doi.org/10.1016/j.sbspro.2011.01.069

Wald, G. (2011). Promoción de la salud integral a través del arte con jóvenes en situación de vulnerabilidad social: Estudio comparativo de dos orquestas juveniles de la Ciudad de Buenos Aires [Promotion of

integral health through art with young people in situation of social vulnerability: comparative study of two youth orchestras of the City of Buenos Aires]. Revista de Humanidades Médicas & Estudios Sociales de la Ciencia y la Tecnología [Journal of Medical Humanities & Social Studies of Science and Technology], *3*, 1–31. Retrieved from http://www.ea-journal.com/art3.1/Wald-Promocion-salud-integral-a-traves-del-arte.pdf

Wan, C. Y., & Schlaug, G. (2010). Music making as a tool for promoting brain plasticity across the life span. *The Neuroscientist, 16*, 566–577. http://dx.doi.org/10.1177/1073858410377805

Wengenroth, M., Blatow, M., Heinecke, A., Reinhardt, J., Stippich, C., Hofmann, E., & Schneider, P. (2014). Increased volume and function of right auditory cortex as a marker for absolute pitch. *Cerebral Cortex, 24*, 1127–1137. http://dx.doi.org/10.1093/cercor/bhs391

Wetter, O. E., Koerner, F., & Schwaninger, A. (2009). Does musical training improve school performance? *Instructional Science, 37*, 365–374. http://dx.doi.org/10.1007/s11251-008-9052-y

What Works Clearinghouse. (2014). *Procedures and standards handbook (Version 3.0)*. Washington, DC: U. S. Institute of Education Sciences. Retrieved from http://ies.ed.gov/ncee/wwc/DocumentSum.aspx?sid=19

Yang, P. (2015). The impact of music on educational attainment. *Journal of Cultural Economics, 39*, 369–396. http://dx.doi.org/10.1007/s10824-015-9240-y

Zuk, J., Benjamin, C., Kenyon, A., & Gaab, N. (2014). Behavioral and neural correlates of executive functioning in musicians and non-musicians. *PLoS ONE, 9*, e99868. http://dx.doi.org/10.1371/journal.pone.0099868

Received May 9, 2018
Revision received April 26, 2019
Accepted April 30, 2019 ■