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Is more time in general music class associated with stronger extra-musical outcomes in kindergarten?☆

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ABSTRACT

Prior research has suggested an association between increased musical training and extra-musical outcomes, but these studies are primarily correlational, focused on instrumental music, and provide limited information about the type of musical intervention. In the current study, we perform the first randomized controlled study investigating whether more time in general music in kindergarten results in better executive functioning, self-perception, and attitudes towards school. Control students received an average of 45 min of general music class per week while treatment students received 2–7 times more minutes per week. Both control and treatment students had applied to attend a school or program of intensive general music study serving primarily low-income students. Analyses from end-of-kindergarten data revealed no significant group differences on our outcome measures. Results fail to show an association between increased time spent in general music learning and stronger extra-musical outcomes.

1. Introduction

There is no known human culture without music, and musical instruments have been found from 45,000 years ago (Higham et al., 2012). All typically developing children respond to music and engage in spontaneous and frequent music-making both in and outside school (Goldstein, Lerner, & Winner, 2017). Understanding what children gain from music participation is important for our understanding of human development and learning.

Here we report an investigation of non-musical benefits from music education. We note that it is important to distinguish between intrinsic and extra-musical reasons for engaging children in music. The justification for music education should never, in our view, be based solely on potential extra-musical benefits. Music is one of humankind's most important (and ubiquitous) inventions. We believe that music education is intrinsically valuable even if it leads to no cognitive transfer effects. However, any potential transfer effects are added benefits, and certainly educators want to know about whether such effects exist and under which conditions.

Extra-musical benefits of music participation have been widely reported – in the popular press, in music education advocacy materials, and in empirical studies. Music education has been argued to improve cognition (e.g., IQ, standardized test scores, academic performance, executive functioning; Diamond, 2014; Holochwost et al., 2017; Schellenberg, 2004; Moreno et al., 2011), broad habits of mind (e.g., listening, imagining, and planning; Hodges, 2005; Hogan & Winner, in press), emotional functioning (e.g., empathy, motivation to attend school; Rabinowitch, Cross, & Burnard, 2013; Thomas, Singh, & Klopfenstein, 2015), social affiliation (Cirelli, Wan, Spinelli, & Trainor, 2017; Mehr & Spelke, 2017) and well-being (e.g., relief from depression and anxiety; Lally, 2009; Zanini & Leao, 2006; for reviews of transfer from music learning to other domains, see Hallam, 2015; McCarthy et al., 2001; Schellenberg & Weiss, 2013; and Winner, Goldstein, & Lancrin, 2013).

However, most of this research is correlational, not experimental, with self-selection into music participation being a significant weakness (Corrigall, Schellenberg, & Misura, 2013; Elpus & Abril,

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2011; Foster & Marcus Jenkins, 2017; Hille & Schupp, 2015; Winner et al., 2013). We note also that most of the research on music and extra-musical benefits has focused on instrumental training or listening experiences, with little work on general music instruction (sometimes called classroom music), classes in which children interact with music in a variety of ways – singing, playing simple unpitched percussion instruments, moving one's body to music, guided listening, describing music, and creating simple songs and soundscapes (Baldridge, 1984; Campbell & Scott-Kassner, 2013). General music, instrumental music, and listening experiences may well teach different kinds of skills. General music class has been understudied, despite the fact that this kind of class is nearly universal at the elementary level and forms part of the curriculum in 94% of United States elementary schools (Parsad & Spiegelman, 2012). In many cases, general music is the only music education that children receive, since elective ensemble courses are often a part of the curriculum for only select students in older grades. Because general music classes are compulsory, samples are not contaminated by self-selection.

We report here a randomized controlled study examining extra-musical outcomes (executive functions, self-perception, school liking) in kindergarteners as a function of amount of time spent in general music. Children in our treatment group (consisting of three separate classrooms) received between 90–315 min a week of general music, while those in our control group received only 45 min per week. Thus, treatment children received up to seven times more general music time than those in our control group, making it reasonable to consider whether so much additional time has an effect on cognitive and socio-emotional outcomes.

We focus here on three extra-musical outcomes: executive functioning, self-perception, and school-liking. We first briefly review what is known about the relation of music education of any kind to these three outcomes measures. Because nearly all research studies in music participation focus on instrumental playing rather than general music activities, we include these in our review.

1.1. Music and executive functioning

Executive functions (EFs) are seen by many as core skills critical for cognitive, social, and psychological development (e.g., Diamond, 2013; Jacques & Marcovitch, 2010; Moffitt et al., 2011; Zelazo, Carlson, & Kesek, 2008). They are important for daily life, and they are often more strongly associated with school readiness than are IQ or entry-level reading or math (e.g., Blair & Razza, 2007). Even when IQ, gender, social class, and family circumstances are controlled, better EFs in childhood predict better health, higher educational attainments, higher incomes and better jobs, and fewer arrests (Moffitt et al., 2011; Wong et al., 2010).

There are currently no conclusive answers about the effects of music training on EFs due to the small number of non-correlational studies and their mixed results. For example, a study by Schellenberg (2011) found that on most measures of EF, musically trained children showed no advantage. In contrast, Holochwost et al. (2017) found that on some measures of EF, musically trained children showed an advantage; and Degé et al. (2011) found that on all of the EF measures given, musically trained children showed an advantage. Degé et al. note several possible reasons for these conflicting results: studies did not all use the same EF measures, some of the measures may be more engaging or developmentally appropriate for young children than others, and studies differed in how music training was defined.

While core executive functions often work together, executive functioning is composed of three sub-functions: inhibitory control, working memory, and cognitive flexibility (Diamond, 2013; Huizinga, Dolan, & van der Molen, 2006; Miyake et al., 2000). We consider next what is known about the relationship of music training to each of these sub-functions.

1.1.1. Inhibitory control

Inhibitory control involves being able to override prepotent responses and direct one's attention, behavior, thoughts, and/or emotions to what is appropriate (Diamond, 2013). Joret, Germeys, and Gidron (2016) reported correlational findings that 9–12 year-olds who had begun Suzuki method instrumental lessons before the age of five had better inhibitory control in comparison to non-musicians as measured by the Simon task (Simon & Rudell, 1967). Consistent with this finding, adult musicians showed greater inhibitory control than non-musicians on the Simon task and an auditory Stroop task (Bialystok & DePape, 2009). Inhibitory control is an important aspect of playing music in large ensembles and chamber groups: playing parts that are not in unison requires focusing on one's own part (sometimes screening out others) and inhibiting playing at the wrong time (Jentzsch, Mkrtchian, and Kansal, 2014).

The relationship between inhibitory control and an early childhood music and movement program has been explored in one quasi-experimental study. Winsler, Ducenne, and Koury (2011) speculated that young children involved in music experiences may learn to regulate their behaviors as a result of continual practice in which they respond to changes in music (loud/soft, high/low, happy/sad). In their study of 3- and 4-year-olds involved in the early childhood music program, Kindermusik, which includes activities similar to those found in general music in elementary schools, they found that children in music classes performed better on self-regulation measures and were more likely to use singing or humming as a regulatory behavior when waiting.

1.1.2. Working memory

Working memory (both verbal and non-verbal) is most commonly defined as the ability to hold information in mind while mentally manipulating that information (e.g., doing mental math, re-ordering a to-do list, or relating one idea to another; Baddeley, 2012; Baddeley & Hitch, 1974; D'Esposito & Postle, 2015; Diamond, 2013).[1] Working memory is required for playing music from notation because one must play correct fingerings and bowings while reading ahead to the notes coming next (Meinz & Hambrick, 2010; Nutley, Darki, & Klingberg, 2014). Working memory has been positively related to music experience in numerous studies. In a correlational study by Franklin et al. (2008), undergraduate and graduate music students who had initiated instrumental training before the age of 10 were compared to a non-musical control group. Musicians scored significantly higher on two measures of verbal working memory-reading span and operation span. In a study following child and adult participants over two years, Nutley et al. (2014) found a positive correlation between weekly hours of instrumental music practice and working memory using the Dot Matrix from the Automated Working Memory Assessment (Alloway, 2007) and the Backwards Digit Span. (For similar findings, see Bugos, Perlstein, McCrae, Brophy, & Bedenbaugh, 2007; Degé, Kubicek, & Schwarzer, 2011; Ho, Cheung, & Chan, 2003; Pallesen et al., 2010; and Schellenberg, 2006).

[1] An alternative definition of working memory is holding information in mind while blocking or inhibiting other information from entering that active state (Engle & Kane, 2004; Unsworth & Engle, 2007) – or stated slightly differently, "the ability to keep a representation active, particularly in the face of interference and distraction" (Engle, Tuholski, Laughlin, & Conway, 1999, p. 309). This definition blurs the distinction between inhibitory control and working memory. For the purposes of our study and of what constitutes an appropriate measure of working memory, the difference between these two definitions of working memory is not relevant.

1.1.3. Cognitive flexibility

Cognitive flexibility (also called mental flexibility, set shifting, or task switching) is the ability to adjust flexibly to changed demands or priorities, switch perspectives, and come up with alternative ways to succeed when one's initial attempt is unsuccessful. Cognitive flexibility is dependent upon the other two core executive functions (Diamond, 2013). Music participation requires cognitive flexibility when changing time signatures, key, tempo, and dynamic level (Joret et al., 2016). Additional attentional set shifting is also ongoing while playing or singing in a group, as musicians must switch between listening to themselves (for personal intonation, timbre, etc) and the group (for group intonation, blend, dynamic level, etc.), and between watching the sheet music and the conductor's gestures (Loehr, Kourtis, Vesper, Sebanz, & Knoblich, 2013). Holochwost et al. (2017) showed that students in grades 2–8 admitted by lottery into an intensive orchestral program performed more rapidly on both a Stroop and a card-sorting task (which requires rule shifting), irrespective of the number of years in the program, compared to those not admitted to the program. Additional support for a relation between music participation and cognitive flexibility was reported by Bugos et al. (2007) and Degé et al. (2011).

1.2. Music and self-perception

In addition to executive functioning, there is reason to believe that simply participating in musical experiences may promote feelings of self-esteem and belonging. Few studies have investigated psychosocial benefits of music participation (Crooke, Smyth, & McFerran, 2016), but there are some promising correlational findings. Among disadvantaged South African adolescents with no prior formal training, those involved in an instrumental music intervention exhibited higher self-esteem, optimism, happiness and perseverance (Devroop, 2012). Parents reported that their children were more confident and happier as a result of participation in an intensive orchestral music program in Scotland (Scottish Government Social Research, 2011). Twelve-year-olds with at least six years of musical training showed higher global self-esteem than those without musical training (Hietolahti-Ansten & Kalliopuska, 1990) – consistent with a study showing that classically trained college music majors identified the development of a strong sense of self-esteem as a benefit of music making (Kokotsaki & Hallam, 2007). Finally, Rickard et al. (2013) showed that both general music influenced by the Kodály approach (Choksy & Kodály, 1981) and stringed instrument instruction in elementary students was associated with stability in global self-esteem, while lack of such instruction was associated with a decline in global self-esteem. Of note, Rickard et al. also found that self-esteem was associated with training in juggling, suggesting that such an outcome may not be specific to music but may rather result from feelings of mastery in any domain.

1.3. Music and school liking

The arts have been seen as a motivator for children and adolescents to attend school (Davis, 2011), but the evidence is correlational. In a small study of high school students who considered dropping out, 41% spontaneously mentioned the arts as a reason to stay, and 83% agreed, when directly asked, that the arts had influenced their decision to stay (Barry, Taylor, & Walls, 1990). In a correlational study of about 11,000 participants, students from low socio-economic backgrounds were less likely to drop out of school by 10th grade if they were involved in the arts (3.5%) compared to those not involved in the arts (6.5%; Catterall, Chapleau, & Iwanga, 1999). And following a sample of 175,000 9th graders longitudinally for five years, Thomas et al. (2015) found that students taking arts classes were less likely to drop out, even when controlling for course completion in required subjects. A review of *El Sistema*-inspired programs (intensive ensemble music programs) concluded that students in these programs developed positive attitudes towards school as measured by school attendance (Creech, Gonzalez-Moreno, Lorenzino, & Waitman, 2013). However, none of these studies were experimental in design.

2. Method

2.1. Participants

Two cohorts totaling 203 kindergarten children were recruited at the end of their kindergarten year during the spring of 2015 and 2016 (95 males, 108 females; $n_{treatment} = 111$, $n_{control} = 92$; $M_{age} = 6.2$ years, $SD = 0.39$). Treatment students attend three elementary schools in a New England city. They begin an intensive general music program in kindergarten in preparation for a stringed orchestral training program in Grade 1. Parents of both treatment and control children applied to be part of one of three intensive music programs/schools. Therefore both treatment and control parents desired a school or program with a musically intensive experience.

Sites 1 and 2 were public charter schools, where admission was by lottery, and hence truly random, per Massachusetts General Law for enrollment to charter schools. (Children who reside in the same city as the school, and siblings of current school attendees, are given preference however.) Charter schools are free public schools in the US that are not subject to the same curricular requirements of non-charter public schools and are able to set up their own special programs and curricula. Control participants for Sites 1 and 2 had applied to the schools but were not admitted (via randomly lottery) and thus attended other schools in the city. At Site 3, both control and treatment children attend the same school. Treatment children were those accepted to the music program on a first-come, first-served basis at the beginning of the year (again with the exception of siblings who are given preference). Control participants for Site 3 were recruited from the wait list for the music program at Site 3; that is, control participants had applied to the music program but were not admitted due to lack of space.

Treatment students were recruited through their programs. Control students were recruited from lottery losers (Sites 1 and 2) or program wait lists (Site 3) from those same schools via regular mail, email, and telephone. All parents/guardians received $10 for participation in our study during their child's kindergarten year.

Each of the school sites has a high incidence of low-income students (Site 1: 80.8%; Site 2: 65.1%; Site 3: 78.6%; "Massachusetts School and District Profiles," n.d.). Return rate of the parent/guardian demographic form was 92% from the treatment group and 93% from the control group. Chi-square analyses revealed that the treatment and control groups did not differ in socioeconomic status, racial, or ethnic composition, as shown in Table 1.

2.2. Intervention

Treatment students at each site participated in a general music program with 90 min or more of instruction per week. Time differed across sites as shown in Table 2. Control students attended various schools in the city (including some at Site 3), where the norm is to have no more than 45 min per week of general music instruction. Thus, students in the treatment group had at least twice as many minutes of general music class per week as the control students.

In the kindergarten year, treatment students at all three sites are in a preparatory year before beginning stringed orchestral training. Children receive general music training, the kind seen in any quality and systematic general music classroom. Curriculum maps shared by two sites (and verbally confirmed by the third site) show

Table 1
Demographic Information (in Percentages) for Treatment and Control Groups and Chi-Square Results Showing Group Non-Significant Differences between Groups.

Demographic Information	Treatment	Control
Single parent household	27	39
Neither parent/guardian post-sec education	14	19
Hispanic/Latino/a	39	49
African American/Black	46	47
Caucasian/White	28	31
Asian	15	13
American Indian/Alaska Native	2	1
Mixed Race	4	6
Declined Race Response	4	3

Notes: Chi square tests revealed no differences between groups in single parent households (2.51, $p = .11$), neither parent/guardian post-secondary education (0.02, $p = .88$), ethnicity (1.32, $p = .25$), or race (0.77, $p = .98$).

that children practice solfege (singing, holding sounds in one's short term memory, and recognizing pitch and rhythm patterns), develop a sense of steady beat, sing simple songs with movements, and learn to differentiate the instruments of the orchestra – learning goals consistent with general music in kindergarten in many environments (Campbell & Scott-Kassner, 2013). At two of the sites, teachers report using the Kodály concept, a systematic and structured approach to teaching pitch and rhythm patterns (Choksy & Kodály, 1981). This approach generally uses traditional folk songs for repertoire, emphasizes aural and other conceptual understandings (high/low, above/below, etc.) prior to written notation, and uses Curwen hand signs to help children kinesthetically connect with pitch contour.

At two of the treatment sites, treatment children receive some instrumental training at the end of their kindergarten year. At site 2, instrumental training is included 2x/week for 45 min on papier-mâché instruments (November–late April) and real stringed instruments (late April–June). At site 3, class times could incorporate papier-mâché instruments (November–February) and real violins (March–June). This is in preparation for future enrollment in an *El Sistema*-inspired orchestral ensemble program (Majno, 2012). However, the preponderance of this year in music class is exploratory and non-instrumental, and hence general music in nature. The distinctions between these is quite blurry in practice (for instance, singing a folk song with movements and then transferring that folk song to a violin), so therefore we have included all time in a music class in the minutes/week tally shown in Table 2.

There are no data to confirm that control students did not continue to seek out another music program outside of their regular school day. However, given the socio-economic status of our students (predominantly low-income, some living in motels or shelters where we tested them), we find this to be an unlikely confound since outside of school music participation typically requires money.

Table 2
Site Information.

Treatment Sites	N	Min/Wk	Matched Control Sites	N	Min/Wk
1 Public Charter	35	90	Public Traditional	29	45
2 Public Charter	64	297	Public Traditional	55	45
3 Public Traditional	15	315	Same School	7	45

Notes:
Site 1: Music class 3x/wk for 30 min.
Site 2: Music class 5x/week for 45 min (September and October), 7x/week for 45 min (November–June).
Site 3: Music class 3x/week for 90 min (before school day); 1x/week for 45 min (during school day).

2.3. Procedure

All parents/guardians signed IRB-approved consent forms and were given a demographic survey to complete. Children met individually with a tester for approximately 30 min. Treatment students were tested in a quiet area of the school. Control students were tested in their homes or our lab. Testing occurred during the end of the kindergarten school year and in early summer. All children attend English-speaking classrooms and were tested in English.

2.4. Measures

During each testing session, children were administered six measures in a set order: flanker/reverse flanker task (Diamond, Barnett, Thomas, & Munro, 2007), The Pictorial Scale of Perceived Competence and Social Acceptance for Young Children (Harter & Pike, 1984), school-liking measure (designed by the researchers), dot counting (Case, Kurland & Goldberg, 1982), category fluency (Benton, 1968) and backwards digit span (Wechsler, 2003). All of these measures were standardized, reliable measures except for the school-liking measure, designed by the researchers.

2.4.1. Executive function

Children were administered four measures of executive functioning: flanker/reverse flanker task, backwards digit span, category fluency, and dot counting.

Flanker/reverse flanker task. The flanker/reverse flanker task (Diamond et al., 2007) assesses all three core areas of EF: working memory, inhibition, and cognitive flexibility (Diamond, 2013). This task was administered using Presentation Software by Neurobehavioral Systems (Berkeley, CA) and included three blocks: standard flanker, reverse flanker, and a mixed block. Each block began with written and oral directions and practice trials (4 practice trials each for Blocks 1 and 2, and 8 practice trials for Block 3). Practice trials were repeated if children did not master the first practice round. Children responded by pressing keys on the far right and far left of the computer keyboard. Children received encouragement between blocks but not during practice or test trials. Neither testers nor the computer program provided feedback on performance. If children removed their fingers from the keyboard during a trial, they were reminded to place them back on the keyboard.

Children first received the standard flanker block with 5 blue fish all in a row, variously pointing left, right, up or down. Children were told that when the fish were blue, the hungry fish was in the middle. The task was to feed the hungry fish by pressing the arrow key facing in the same direction and on the same side of the keyboard as the middle (target) fish. Children had to attend to the direction in which the middle fish was facing while ignoring the outer fish. On 25% of trials, the fish in the middle and the four flanker fish (two on either side) were facing the same direction (congruent trials). On 25% of trials, the four flanker fish were facing the opposite direction as the middle fish (incongruent trials), requiring the child to ignore the conflicting information presented by these fish. On an additional 25% of trials, the four flanker fish were facing up or down, thus not facing in a direction associated with a response (neutral trials), and on the remaining trials, the middle fish was presented alone without any flanker fish (no distractor trials).

In the second block (reverse flanker), children saw only pink fish and had to learn a different rule. Now when the fish were pink, the hungry fish were on the *outside* and children were to attend to fish they had previously ignored (the four flanker fish). Again, children were presented all four types of trials: incongruent (middle fish facing opposite direction as flanker fish), congruent (middle fish facing same direction as flanker fish), neutral (middle fish facing up or down) and no distractor (no middle fish) intermixed during this block.

In the final, mixed block, children were presented with trials with pink (reverse flanker) fish and trials with blue (standard flanker) fish intermixed. Thus, throughout the block, children had to switch between the rules of selectively attending to the middle fish and selectively attending to the outer flanker fish, depending on the color of the fish. Again, children were presented all four types of trials for each color of fish (incongruent, congruent, neutral and no distractor).

In the standard flanker, children must attend to the task, remember the rule to look at the middle fish, and inhibit looking at the outside fish. This requires the executive function of selective attention (a component of inhibitory control). For the reverse flanker block, these same skills are required. In addition, children are called on to inhibit the rule they had been using and instead use cognitive flexibility to switch rules: now they must attend to the stimuli they had been ignoring [the outside fish] and ignore the stimulus they had been attending to [the middle fish]. In the mixed flanker block, children must remember twice as many rules, remember which rule applies based on the color of the fish, then apply that rule by focusing their attention on the appropriate fish and pressing the appropriate key (Diamond et al., 2007). This task is coming to be more and more widely used (e.g., Schonert-Reichl et al., 2015; Zaitchik, Iqbal, & Carey, 2014).

The flanker task calls upon all three core areas of executive functioning, working memory, inhibition, and cognitive flexibility, and thus may capture similar capacities of executive functioning used in general music instruction. For instance, children singing partner songs (two different songs sung simultaneously by two different people or groups) or rounds (when different groups sing the same song, but beginning at different times) must maintain attention only on their assigned part, similar to how the Flanker task requires attention to only the target-fish.

Three scores were computed. Two global switch cost scores, one for accuracy and one for response time, were computed by calculating the difference in accuracy and reaction time (RT) between performance in the mixed flanker block and average performance across the other two blocks. These scores reflect the performance cost of knowing that on some trial one must switch rules and attentional foci (Block 3) compared to those blocks requiring no switching (Blocks 1 and 2). Hence this score reflects cognitive flexibility. Lower scores reflect better performance, as they indicate less of a cost between rule switching. The third score, the RT flanker effect score, was calculated as the difference in RT on congruent and incongruent trials, divided by RT on congruent trials. This score assesses the effect on performance of having to inhibit the response to the non-target fish. On congruent trials, whether one selectively attends to the target or not, one should respond correctly. On incongruent trials, one must exercise more attentional control and inhibit any tendency to respond according to the non-target stimulus. The flanker effect reflects the toll in response time that doing that extracts.

Data from six participants were excluded due to computer malfunction. Fourteen additional children ($n_{treatment} = 7$, $n_{control} = 7$) were excluded because their overall accuracy score was below chance (50%) and thus we made the conservative assumption that they either did not understand the task or did not try. For the purposes of data analyses (and in line with previous studies), the first trial of every condition was excluded, as well as trials with reaction times below 250 ms, as this is too fast to be in response to the stimulus (Davidson, Amso, Anderson, & Diamond, 2006). This rate of exclusion is consistent with previous research (Cremone, McDermitt, & Spencer, 2017). Reaction times were calculated only for correct responses.

Backwards digit span. The backwards digit span task (Wechsler, 2003) was administered as a measure of verbal working memory (Diamond, 2013). Children were read sequences of digits at the rate of one digit/second. They were instructed to repeat the sequence in reverse order (e.g., if participants heard "5, 3", they should repeat back "3, 5"). Sequences began with two digits; if children were correct on two trials in a row, they were then presented two sequences with three digits. Depending on performance, children could hear up to eight digits. Children received two practice trials with tester feedback. No feedback was provided during test trials and no sequences were repeated. When children requested that a sequence be repeated, they were told just to do their best. After two incorrect trials in a row, the task was stopped. Working memory is called for in this task because children must retain the forward sequence in memory and manipulate that sequence to repeat it backwards. This is among the few relatively pure working memory tasks, as it does not tax the other two core executive functions (Diamond, 2013). A backwards digit span score was computed from the total number of entirely accurate sequences recalled (Wechsler, 2003), and thus a higher score is better.

Children in general music regularly engage the kind of working memory assessed in the backwards digit span task. Work with solfege pitch patterns (holding in mind and manipulating different pitches of notes, either in the context of a song or in exercises specifically created to practice working with pitches) is a common general music class activity. Similar work occurs with rhythmic patterns (the organization of note durations).

Data from five children were excluded from analyses of the backwards digit span task: one declined to participate, one ran out of time before completion, and three were excluded due to experimenter error. We noted a large percentage of "zero" scores ($n_{Treatment} = 17$, $n_{control} = 15$, or 16% of the total sample). Zero scores did not differ as a function of condition as calculated via chi square analysis (0.04, $p = .847$) at $p < .05$. We therefore interpret the results of this measure cautiously, because this measure may have been too difficult for this particular sample of children at this age.

Category fluency. In the category fluency task, children were asked to name as many animals as they could think of in the span of one minute. Prior to the start of the test trial, children were prompted with a practice category (foods) and were encouraged to name at least two food items before they were given the test category (animals; Riva, Nichelli, & Devoti, 2000). Encouragement and feedback were given during the practice trial. The only feedback during the test trial occurred if children paused for more than 15 s (they were then encouraged to keep going) or named three non-animal words (they were then reminded to think of animals).

Category fluency is considered by some to be a measure of all three core executive functions. This task requires cognitive flexibility because children must rethink ways of approaching this problem when they get stuck (e.g., switching their thinking from animals of the sea, once they have exhausted their knowledge of that list, to animals of the forest) but most empirical findings and theoretical accounts link the task to working memory updating (e.g., holding in mind what you have said so that you do not repeat a word you have already said, which children are instructed not to do; Rende, Ramsberger, & Miyake, 2002; Shao, Janse, Visser, & Meyer, 2014).[2]

The executive functioning mechanisms that are involved in category fluency have parallels in the general music environ-

[2] It should be noted that some researchers consider this task to primarily measure semantic long-term memory, which is not an executive function and does not depend on the same neural system as any of the executive functions; Corcoran & Upton, 1993; Hodges. Patterson, Oxbury & Funnell, 1992.

ment. For example, improvisation activities (which happen at an age-appropriate level in elementary general music, such as spontaneously playing an excerpt using only a small pitch set on a xylophone) force children to think through possibilities of what to play, similar to the task of category fluency.

Data from four children were excluded from analyses of the category fluency task: one declined to participate, one was excluded due to experimenter error, and two were excluded for continuing the category from the practice trial. A category fluency score was calculated from the total number of unique animals named, with a higher score reflecting better performance. If a child named two pronunciation variants of a single animal (e.g. kitten and the diminutive form kitty), credit was given only for a single animal. However, if a child named two phonologically-distinct words referring to a single animal (e.g., puma and cougar), credit was given for each animal named. The following examples were also scored as separate responses: adult and child names of the same animal (e.g., puppy and dog), male and female versions of the same animal (e.g., rooster and hen), male, female and sex-neutral names of animals (e.g., buck, doe, deer), names of different exemplars of a type of animal (e.g., hummingbird and robin), and animals and their superordinate class (e.g., whale and mammal). If an adjective and animal name could be compounded to form a distinct lexical or term (e.g., bluebird or polar bear), the animal was counted as a unique response. But if an adjective simply modified an animal name (e.g. "black cat" or "white bear"), these animals were counted as identical to the animal being modified (e.g., if a child said both "yellow bird" and "bird," the child received credit for just one). Words that referred to imaginary creatures (e.g. "unicorn" and "dragon") and proper names that clearly referred to an animal (e.g. "Clifford" or "Scooby Doo") were given credit (Isacoff & Stromswold, 2014).

Dot counting. The dot counting task is a simplified measure of verbal working memory from the NIH EXAMINER (Kramer et al., 2014). It is a complex span task modeled from the counting span task (Case et al., 1982; Conway et al., 2005). Children were presented with an 8.5" by 11" sheet of paper with an array of blue dots, and instructed to count all of the blue dots on the page one at a time and remember the final total. Next, a new sheet of paper was presented with a new array of blue dots which children were instructed to count. The number of different pages presented in each trial increased from 2 to 5 over four trials. After counting the blue dots on the second page, children were then asked to recall the total number of blue dots in both of the arrays they saw, in the order in which they were presented. Children were first presented 2 arrays on the first trial. On the second trial, children were presented 3 consecutive arrays before being asked to recall the number of dots in all three arrays. On the third trial, children were presented 4 arrays, and finally, on the fourth trial, children were presented 5 arrays. The task was stopped after two incorrect trials in a row. Children were given three practice trials involving 2 or 3 dot arrays, and those who failed all practice trials did not move on to the test trials (as it was assumed they did not understand the task). Children were given feedback and encouragement during practice trials but not during test trials. Working memory is called for in this task because children must hold in mind the numbers they have counted in one array while they count the numbers in the next array.

Children in general music employ working memory. Simplified written notation activities that are common in elementary general music instruction requires children to remember notation meanings while singing and to read ahead to upcoming notations, similar to remembering numbers in the dot counting task.

Data from 14 students were excluded from analyses of the dot counting task: 12 did not understand the practice round and thus were not tested in this task and two were excluded due to experimenter error. The dot counting score was calculated from the total number of individual dot arrays recalled across all sequences, with higher scores reflecting better performance. Partial credit was given for remembering the correct location of a digit within a sequence (for example, a response of 4-9-1 after seeing and counting 4-7-8 would receive 1 point; a response of 7-4-1 after seeing 4-7-8 would receive a zero score; and a response that repeated the entire sequence correctly received 3 points). If an array was counted aloud incorrectly, but the child recalled the number she had counted, this was considered correct (since this task measures working memory, not counting ability; Kramer et al., 2014).

2.4.2. Self-perception

Children were administered two subscales (Peer Acceptance and Cognitive Competency) of The Pictorial Scale of Perceived Competence and Social Acceptance for Young Children (Harter & Pike, 1984). They were shown pictures of two different children, matched in gender to themselves, who were described having distinct attributes. Children were asked first to pick the child that they were "more like" (e.g., "This girl is good at puzzles, and this girl is not very good at puzzles. Which girl are you more like?"). They were then asked to quantify by pointing to one of the two circles on the page that were verbally described (e.g., again shown "This girl is very good at puzzles," children were asked, "Are you *really good* at puzzles or *pretty good* at puzzles?"; for children who identified with, "This girl it not very good at puzzles," children were asked "Are you *sort of* good at puzzles or *not very good* at puzzles?"). Responses to each item were scored on a scale of 1–4, with scores of 4 being the response corresponding with the most positive self-perception. Two average response scores were computed for each of these scales.

2.4.3. School-Liking

We designed a simple measure of school liking: children were asked to show how they feel when they think about going to school, using a 7-point Likert scale of drawn faces that progressively ranged from very sad (low scores) to very happy (high scores). Responses were scored on a scale from 1 to 7, with higher scores indicating more happiness.

3. Results

Prior to data analysis, scores of participants that were above or below three standard deviations from the mean were modified to the value of three standard deviations from the mean (Winsorizing; as in Farah et al., 2008; Howard, Powell, Vasseleu, Johnstone & Melhuish, 2017; Kim, Park, Song, Koo, & An, 2011). The number of outliers found is as follows: Flanker Effect (4), Global Switch Cost Accuracy (3), Global Switch Cost Response Time (3), and Dot Counting (1).

All data were analyzed by ANCOVA, with group as the fixed effect, and gender, site, and cohort as covariates. The results reported here reflect all of the study's measures. We included these three covariates because although they were not of theoretical interest to us, they were predicted, a priori, to contribute to some of the variance in responses. Bonferroni corrections were applied as follows: Because there were three dependent variables in the Flanker task (Flanker Effect and Flanker Global Switch Cost [response time and accuracy]), we performed a Bonferroni correction by dividing 0.05 by 3, yielding a criterion alpha value of 0.017. Because there were two self-perception dependent variables (Cognitive Competency and Peer Acceptance), we performed a Bonferroni correction for analyses of these scales by dividing 0.05 by 2, yielding a criterion alpha value of 0.025.

Group means are shown in Table 3 and ANCOVA results are shown in Table 4. Our findings were clear. There was no main effect of group for any of the outcome variables. This is the key finding. The

Table 3
Means for Treatment and Control Groups.

Measure		Treatment		Control	
	Mean	*SD*	Mean	*SD*	
Flanker Effect	RT	0.12	0.14	0.10	0.17
Global Switch Cost	RT	−27.24	183.95	29.92	203.04
	Acc	0.14	0.14	0.11	0.12
Reverse Digit Span		2.66	1.55	2.69	1.82
Category Fluency		9.81	3.71	9.84	4.11
Dot Counting		4.61	3.07	4.35	2.74
Peer Acceptance		2.98	0.63	2.94	0.61
Cognitive Comp		3.55	0.35	3.59	0.36
School-liking		5.25	2.19	5.66	2.02

group receiving more hours of general music did not perform any better than the group receiving fewer hours of general music. Significant covariates (gender in Flanker Global Switch Cost Accuracy, and Site in school liking; located in Table 4), are not discussed here because there were no theoretical predictions for these variables. Additionally, because Site 3 has a first-come, first-served admissions process over a lottery admission, we ran all analyses without Site 3 participants. Our lack of a group effect remained unchanged.

The lack of a group effect was not due to inadequate power. We conducted a power analysis to check the sensitivity of the test of the group effect in the ANCOVA with group as the fixed effect and cohort, gender, and site as covariates (G*Power 3.1; Faul, Erdfelder, Buchner, & Lang, 2009). With the current sample size, the *F* test for the effect of group was able to detect an effect that is as small as effect size $\eta^2 = 0.04$, which corresponds to Cohen's $d = 0.42$, with 0.80 power. In the analyses reported above, the estimated effect size η^2 for the main effect of group was smaller than 0.01 for most measures.

4. Discussion

It is important to publish null findings alongside significant ones, particularly in the area of research on transfer of learning from the arts where findings have often been "over"-interpreted. Witness the large popular press reaction to the publication of a randomized-controlled study showing no extra-musical cognitive benefits of six weeks of early childhood music classes (Mehr, Schachner, Katz, & Spelke, 2013). This finding was covered in over 100 reports from over 40 countries (Mehr, 2015), perhaps because it defied public expectations that music "makes you smarter." Even music educators are inclined to believe myths about music learning. When music educators (practicing and in teacher-training) were presented with both factual psychological or neuroscientific findings about music learning and incorrect "neuromyths," they accepted an average of 40% of the neuromyths as true (Düvel, Wolf, & Kopiez, 2017). In short, confusion about the benefits of music participation is common, likely due to the heavy emphasis on positive findings in both the academic and popular literatures.

4.1. Weaknesses of prior research

The question of extra-musical outcomes of music education cannot be properly addressed without using a randomized-controlled design, without publication of null findings, and without clear information about the kind of music under investigation. We discuss each of these issues below.

4.1.1. Correlational rather than randomized-controlled designs

Correlational findings about the ancillary benefits of arts instruction are often erroneously used to suggest causal effects of that instruction (e.g., Catterall, Chapleau, & Iwanaga, 1999). Elpus and Abril (2011) demonstrated that high school music stu-

Table 4
ANCOVA Results Showing Covariate Effects for each Dependent Variable.

	Flanker Effect	Flanker Global Switch Cost (RT)	Flanker Global Switch Cost (Accuracy)	Reverse Digit Span	Category Fluency	Dot Counting	Cognitive Competency	Peer Acceptance	School-liking
Group	$F(1,182) = 0.805$, $p = .371$	$F(1,182) = 3.968$, $p = .048$	$F(1,182) = 1.222$, $p = .270$	$F(1,197) = 0.090$, $p = .764$	$F(1,182) = 0.104$, $p = .748$	$F(1,182) = 0.575$, $p = .449$	$F(1,202) = 0.864$, $p = .354$	$F(1,202) = 0.147$, $p = .702$	$F(1,202) = 3.056$, $p = .082$
Gender	$F(1,182) = 0.739$, $p = .391$	$F(1,182) = 0.011$, $p = .918$	$F(1,182) = 9.491$, $\mathbf{p = .002}^*$	$F(1,197) = 0.471$, $p = .493$	$F(1,198) = 0.555$ $p = .457$	$F(1,188) = 1.554$, $p = .214$	$F(1,202) = 1.787$, $p = .183$	$F(1,202) = 1.896$, $p = .170$	$F(1,202) = 0.021$, $p = .885$
Cohort	$F(1,182) = 0.197$, $p = .658$	$F(1,182) = 0.663$, $p = .417$	$F(1,182) = 0.001$, $p = .972$	$F(1,197) = 1.128$, $p = .290$	$F(1,198) = 0.000$, $p = .996$	$F(1,188) = 0.065$, $p = .799$	$F(1,202) = 0.078$ $p = .780$	$F(1,202) = 0.748$, $p = .388$	$F(1,202) = 0.159$, $p = .690$
Site Dummy 1	$F(1,182) = 0.189$, $p = .665$	$F(1,182) = 0.028$, $p = .867$	$F(1,182) = 2.690$, $p = 0.103$	$F(1,197) = 0.042$, $p = .837$	$F(1,198) = 3.008$, $p = .084$	$F(1,188) = 0.033$, $p = .856$	$F(1,202) = 0.043$, $p = .360$	$F(1,202) = 0.766$, $p = .383$	$F(1,202) = 5.306$, $\mathbf{p = .022}^*$
Site Dummy 2	$F(1,182) = 0.082$, $p = .775$	$F(1,182) = 0.516$, $p = .473$	$F(1,182) = 2.052$, $p = .154$	$F(1,197) = 2.319$, $p = .129$	$F(1,198) = 1.845$, $p = .176$	$F(1,188) = 2.341$ $p = .128$	$F(1,202) = 0.840$, $p = .360$	$F(1,202) = 1.623$, $p = .204$	$F(1,202) = 4.523$, $\mathbf{p = .035}^*$

Notes: With Bonferroni correction, $\alpha_{Bonferroni} = .017$ for Flanker tasks. $\alpha_{Bonferroni} = .025$ for Cognitive Competency and Peer Acceptance. $\alpha = .05$ for all other measures.
[*] Denotes significant results after Bonferroni correction. Site Dummy Variable 1 indicates the difference in dependent variables between Sites 1 and 3. Site Dummy Variable 2 indicates the difference in dependent variables between Sites 2 and 3.

dents are not representative of US high school students. Rather, the subset of students who continue to pursue music into high school significantly underrepresents males, English language learners, Hispanics, the lowest quartile of socioeconomic status, and children of parents with no post-secondary education. When these factors were statistically controlled, music students no longer outperformed non-music students. Several studies have examined this issue including Corrigall et al. (2013), Foster and Marcus Jenkins (2017), and Sala and Gobet (2017).

Correlational findings about music are repeatedly misinterpreted as providing evidence of causation in both the popular and academic press (Mehr, 2013, 2015; Sala & Gobet, 2017; Winner et al., 2013). A prominent example can be seen in a blog posting from the National Association for Music Education (NAFME, 2014), the professional organization for music educators in the United States, entitled "20 Important Benefits of Music in Our Schools" (2014). None of the assertions in the blog cite academic sources. While most of the benefits seem plausible, most are unproven or even disputable. Consider one touted benefit, "Better SAT scores: Students who have experience with music performance or appreciation score higher on the SAT. One report indicates 63 points higher on verbal and 44 points higher on math for students in music appreciation courses." While figures do show that high school students who take more music classes have higher SAT scores than those who take few or no music classes (Vaughn & Winner, 2000), it is misleading to call this a "benefit" of music education, because this is based on correlational data and are hence subject to selection effects.

The popular press is not the only culprit. Researchers sometimes suggest causal conclusions where none are warranted. For example, Ho et al. (2003) titled their paper, "Music training improves verbal but not visual memory: cross-sectional and longitudinal explorations in children." However, treatment and control groups were not randomized in this study and therefore the improvements observed in verbal memory may have been due to preexisting differences correlated with choosing to engage in music training.

4.1.2. Failure to publish null findings

As noted by Hartshorne and Schachner (2012), studies with significant effects are more likely to be published than those with null results. Because some journals wish to publish articles that are "newsworthy," results that are surprising (hence less likely to generalize) may overpopulate the research literature.

4.1.3. Lack of information about the music intervention

Reports about music education often lack adequate information about the pedagogical approach used (Hallam, 2015). There are many ways in which we interact with music – listening, singing, playing instruments, composing, improvising; alone or in groups; formally or informally – and each of these situations calls upon a different set of skills, dispositions, and behaviors (Reimer, 2004). Even differences within instrumental learning have been reported, including specific hemispheric advantages for keyboardists vs. stringed instrumentalists (Bangert & Schlaug, 2006) and differing processing of timbre for violinists vs. trumpeters (Pantev, Roberts, Schulz, Engelien, & Ross, 2001). Knowledge of the concepts, methods, and approaches involved in an intervention is essential to understanding why any reported effects occurred. This is particularly necessary in general music, where a considerable variety of philosophies and approaches can be found (Reimer, 1994).

4.2. Difficulties of demonstrating transfer effects

Transfer of learning from one domain to another is always difficult to demonstrate (Detterman & Sternberg, 1993). Limitations in rigorous attempts to demonstrate transfer from the arts are in no different a position from attempts to demonstrate other forms of transfer of learning (Barnett & Ceci, 2002; Bransford & Schwartz, 1999; Salomon & Perkins, 1989). For instance, a classic study on the difficulty of transfer comes from Woodworth and Thorndike (1901) who reported that, contrary to hypothesis, learning Latin (a difficult task) does not increase students' achievement in other areas of the curriculum. This is consistent with Sala and Gobet's (2017) meta-analysis on the relation between music participation and academic or cognitive skills (including executive functioning) showing only small or null effects.

People improve on what they practice and this generalizes to untrained tasks where the same skills they practiced are required. The transfers tend to be highly specific. For example, Cogmed computerized working memory training trains backward digit span but not forward (Simons et al., 2016). Training in analogical reasoning does not enhance spatial reasoning, nor does training in spatial reasoning enhance analogical reasoning (Diamond & Ling, 2016). Chess masters can recall the positions of all the chess pieces during a match with remarkable accuracy after viewing the board for only a few seconds, but their recall of other types of material is no better than most people's (Gobet & Simon, 1996). Athletes who can show brilliant executive functions on the field cannot necessarily demonstrate them in other areas of endeavor (). That benefits of training for any skill are *extremely* narrow has been emphasized by numerous experts for decades (Baltes & Lindenberger, 1988; Diamond & Ling, in press; Melby-Lervag, Redick, & Hulme, 2016; Noack, Lovden, Schmiedek, & Lindenberger, 2009; Shipstead, Hicks, & Engle, 2012; Simons et al., 2016).

4.3. Conclusions and limitations

Our finding that the treatment group did not perform significantly better than the control group does not allow the conclusion that general music confers no benefit on executive functioning, self-perception, or school-liking, given that both treatment and control children participated in general music instruction. It would have been very difficult to recruit a control group with no general music exposure because 94% of elementary schools in the United States offer some music instruction (Sparks, Zhang, & Bahr, 2015). Children in the 6% of schools that do not offer music are likely unrepresentative of US children (perhaps attending a school with a significantly lower budget, a specialized-mission towards a non-arts related domain, or a high-needs population that requires mental health and other specialists that could prohibit the hiring of a music teacher).

Our study, therefore, can only speak to the impact of different intensities of music instruction. Because we detected no reliable differences between treatment and control groups at the end of the kindergarten year, we found no support for the hypothesis that doubling (or more) the time per week that kindergarten children spend in general music classes affects our outcome measures. Both high and low dosages may help equally, or neither may help. There are precedents for differing dosages of an activity producing comparable benefits. For example, Davis et al. (2007) found that 20 min a day of aerobic activity for 30 weeks produced the same benefits on a treadmill endurance test as did 40 min a day. Chang, Tsai, Chen and Hung (2013) found no difference on the flanker task performance among children assigned to high- versus low-intensity soccer practice, concluding that both helped equally, but of course it's equally possible that neither helped.

It is important to note that we had no baseline assessment of our outcome measures. Although our participants were randomly assigned to treatment and control groups, we cannot know for sure that there were no pre-existing group differences at the beginning of the year. If the treatment group began kindergarten with significantly lower scores than the control group, the lack of a significant difference between groups at the end of the year would yield a different interpretation. Indeed, there are several precedents for exactly that – the treatment group starting behind the control group *despite random assignment*. This can result in the treatment group improving more than the control group, and treatment and controls performing equivalently at posttest (e.g., Hillman et al., 2014; Schmidt, Jäger, Egger, Roebers, & Conzelmann, 2015; Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2009).

Finally, findings from the backwards digit span task should be interpreted with caution, because, as mentioned, it is possible that a more sensitive measure may have been more appropriate for our sample.

4.4. Future directions

It is possible that the kind of learning that goes on in general music class may not be the kind most likely to challenge executive functioning. Diamond and Ling (2016) argue that for interventions to result in stronger executive functioning, they must challenge children to go beyond their comfort level, beyond their zone of proximal development (Vygotsky, 1978). Perhaps the expectations for excellence in general music are not as strong as expectations for performance in an instrumental ensemble. For instance, while young instrumentalists enjoy the challenge of continually learning the fingerings for new notes, and adding to their repertoire of pitches, no such parallel exists in singing, the predominant activity in general music. While kindergarten students can be encouraged to keep developing mastery over their voice, they may have trouble thinking of their voice as an instrument that they can work on. Future research could compare the effects of intensive singing versus instrumental learning over a span of multiple years and at different age ranges to investigate whether instrumental learning is more likely to challenge executive functioning than is vocal or general music training.

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