

Research Article

Evidence for a Musician Speech-Perception-in-Noise Advantage in School-Age Children

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ABSTRACT

Purpose: The objective of this study was to evaluate whether child musicians are better at listening to speech in noise (SPIN) than nonmusicians of the same age. In addition, we aimed to explore whether the musician SPIN advantage in children was related to general intelligence (IQ).

Method: Fifty-one children aged 8.2–11.8 years and with different levels of music training participated in the study. A between-group design and correlational analyses were used to determine differences in SPIN skills as they relate to music training. IQ was used as a covariate to explore the relationship between intelligence and SPIN ability.

Results: More years of music training were associated with better SPIN skills than fewer years of music training. Furthermore, this difference in SPIN skills remained even when accounting for IQ. These results were found at the group level and also when years of instrument training was treated as a continuous variable (i.e., correlational analyses).

Conclusions: We confirmed results from previous studies in which child musicians outperformed nonmusicians in SPIN skills. We also showed that this effect was not related to differences in IQ between the musicians and nonmusicians for this cohort of children. However, confirmation of this finding with a cohort of children from more diverse socioeconomic statuses and cognitive profiles is warranted.

Musicians, including children who are musicians, show superior auditory skills that fall outside skills that are directly targeted by music training when compared to individuals who do not have musical training (Kraus et al., 2012; Magne et al., 2006; Merten et al., 2021; Nie et al., 2018; Parbery-Clark et al., 2009). One of these enhanced skills that has received considerable attention is speech perception in noise (SPIN)—a complex, auditory listening skill that is vital to children’s learning both in and outside the classroom (see review by Coffey et al., 2017). As discussed in a recent review article on the topic, child and adult musicians demonstrate a SPIN advantage for a variety of target (e.g., words, sentences) and masker

conditions (e.g., speech-shaped noise, multitalker babble, Coffey et al., 2017). Music training has also been proposed as an effective intervention to improve listening difficulties in noise for children and adults, including clinical populations known to struggle with listening in noise (e.g., children with hearing loss; Kraus & Chandrasekaran, 2010; Lo et al., 2020; Merten et al., 2021; Whitton et al., 2017). However, most of the literature on the musician SPIN skill advantage has focused on adult musicians with only a few studies examining the musician SPIN advantage in children and adolescents (Nie et al., 2018; Strait et al., 2012; Torppa et al., 2018). Therefore, additional studies with child musicians and nonmusicians are necessary to increase our understanding of the relationship between music training, including different dimensions of training (e.g., years of training, type of training), and SPIN skills when both skills are still developing.

Many adult studies have shown that the number of years of music training is associated with SPIN skills; that

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is, the longer the musical training, the better the skills (Coffey et al., 2017; Parbery-Clark et al., 2009; Yoo & Bidelman, 2019). However, studies of nonmusicians with no formal musical training suggest that such training alone is not responsible for high-level SPIN skills (Boebinger et al., 2015; Mankel & Bidelman, 2018). That is, it is reasonable to assume that SPIN skills are influenced by other traits and experiences, or a combination thereof, that can support these skills. For example, some studies show that adult and child musicians outperform nonmusicians in indices of general intelligence (IQ; Schellenberg, 2011a, 2011b; Silvia et al., 2016). As a result, some researchers have hypothesized that the musician advantage in IQ could underlie the enhanced SPIN skills observed in this population as opposed to music training alone (Boebinger et al., 2015; Silvia et al., 2016). However, this hypothesis contradicts findings in the general population in which IQ does not predict SPIN skills (see Akeroyd, 2008, for a review). It is also possible and likely that other variables such as socioeconomic status, natural talent, or specific personality traits could predispose individuals to receive and persist at music training from early childhood. This could, ultimately, contribute to a gap between musicians and nonmusicians on SPIN skills.

The goal of this study was to evaluate whether there is a musician SPIN advantage in school-age children. Following previous studies with musician children (Strait et al., 2012), we used years of instrument training to delineate groups with different levels of music training; these included advanced musicians (> 3 years of training), beginner musicians (< 3 years of training), and nonmusicians (untrained, 0 years). This grouping also allowed us to connect our results to longitudinal data on the effects of music training on children's SPIN skills (Slater et al., 2015), which suggested that a minimum of 2 years of childhood training might be needed to improve SPIN skills. The study aims to determine (a) whether years of music training differentiates SPIN skills in school-age children and (b) whether years of music training is positively associated with SPIN skills and if IQ influences those findings. We hypothesized that, at the group level, children with more years of music training (advanced musicians) would show better SPIN skills than those with fewer years of music training (beginner musicians) and nonmusicians. In addition, we hypothesized that years of music training would be positively associated with SPIN skills even when controlling for IQ differences.

Method

Participants

In the general population, SPIN skills improve throughout a child's early school-age years and reach

adultlike performance during adolescence (Elliott, 1979; Fallon et al., 2000; Stollman et al., 2004). However, very few studies have explored the musician SPIN advantage in children. Therefore, participants for this study included 51 typically developing school-age children with normal hearing (30 girls) aged 8.2–11.9 years ($M = 10.2$, $SD = 1.0$). All children passed an air-conduction pure-tone screening at octave intervals from 250 to 4000 Hz at 20 dB HL in both ears. All children had typical cognitive skills as evidenced by standard scores no lower than 85 ($M = 116.3$, $SD = 14.8$) on the Kaufman Brief Intelligence Test–Second Edition (Kaufman & Kaufman, 2004) and used English as the primary language at home. We obtained informed assent from all children and written consent from their legal guardians. All procedures conformed to the protocol approved by the Vanderbilt University Institutional Review Board.

We recruited children from the Nashville area, with most of the children coming from the Vanderbilt community, including the Blair School of Music at Vanderbilt University. Caregivers provided information about the age of onset of instrument training, years of instrument training, and type(s) of training, using select questions from a music history questionnaire developed by Kraus and colleagues at Northwestern University (see Appendix). The number of years of instrument training was used to assign children (post hoc) to the advanced music (> 3 years), beginner music (≤ 3 years), or no music groups. Children in the advanced music group ($n = 17$) ranged in years of instrument training from 3.2 to 7.7 years with a mean of 5.0 years. Children in the beginner music group ($n = 16$) ranged in years of instrument training from 10 months to 3.0 years with a mean of 1.9 years. Note that our distinction between advanced and beginner musicians was determined solely on years of music training. Therefore, group membership is not intended to reflect differences in music skills but, rather, the amount of training. Children in the no music group ($n = 18$) did not have any current or past experience with an instrument. The three groups did not differ by age, $F(2, 48) = 2.42$, $p = .10$; sex ($\chi^2_2 = 1.23$, $p = .54$), or socioeconomic status as inferred from maternal education ($\chi^2_2 = 3.33$, $p = .19$). Maternal education was computed as the highest degree of education completed by the participant's mother. See Table 1 for detailed group demographic information.

Materials

Caregiver questionnaires. Caregivers completed a questionnaire in which they provided information about their child's and family's background, including maternal education. Following the common convention in the child development literature, maternal education was used as an index of socioeconomic status. Because all mothers except

Table 1. Demographic information for each of the groups as compared to the full data set of all participants.

Groups	<i>n</i>	Number of females	Age			Maternal education	Years of instrument training			Onset of instrument training			IQ scores		
			<i>M</i> (years)	<i>SD</i>	Range (years)	Percentage (college degree or higher)	<i>M</i> (years)	<i>SD</i>	Range (years)	<i>M</i> (years)	<i>SD</i>	Range (years)	<i>M</i>	<i>SD</i>	Range
No music	18	9	9.8	0.9	8.6–11.6	88.9%	NA	NA	NA	NA	NA	NA	109.7	12.2	87–129
Beginner music	16	11	10.6	0.9	8.8–11.8	81.3%	1.9	0.7	0.8–3.0	8.6	1.0	6.0–10.0	113.8	17.0	86–141
Advanced music	17	10	10.2	1.3	8.2–11.7	100.0%	5.0	1.4	3.2–7.7	5.2	1.6	3.0–8.0	125.7	8.35	110–143
All participants	51	30	10.2	1.1	8.2–11.8	91.3%	2.3	2.2	0.0–7.7	6.8	2.2	0.0–10.0	116.4	14.4	86–143

Note. *n* = number of participants; NA = not applicable.

one had at least an associate degree, education level was converted to a binary indicator (college degree versus no college degree) for the group comparisons (see Table 1). Caregivers also completed the music questionnaire that was used to group children (see Appendix).

Bamford–Kowal–Bench Speech-in-Noise Test. SPIN skills were evaluated using the Bamford–Kowal–Bench Speech-in-Noise Test (BKB-SIN; Etymotic Research, 2005). This test was selected because it uses first-grade reading level, phonetically balanced sentences (e.g., “The green tomatoes are small” or “They are watching the train”). Thus, it was an appropriate test to use with this cohort of school-age children. For this test, children repeat each sentence out loud and the administrator scores keywords (three to four per sentence) as correct or incorrect. The test presents sentences at a fixed level in the presence of a four-talker babble noise with signal-to-noise ratios (SNRs) decreasing in 3-dB steps from +21 dB to -6 dB. Based on the responses, the BKB-SIN determines a 50% correct threshold. That is, the SNR at which the child repeats half of the words correctly (SNR-50).

KBIT-2. Intelligence (IQ) was evaluated using the KBIT-2 (Kaufman & Kaufman, 2004). This test is standardized for individuals between 4 and 90 years of age, and it includes both verbal and nonverbal assessments. With the KBIT-2, the verbal scale contains a receptive language and a riddle subtest, which evaluate receptive and expressive vocabulary, respectively. Thus, the verbal scale assesses crystallized thinking (i.e., knowledge from prior experiences). The nonverbal scale includes a matrices subtest in which children recognize a logical pattern within an incomplete picture matrix. Thus, the nonverbal subtest evaluates fluid thinking. The KBIT-2 provides an age-normed verbal and nonverbal intelligence score. Additionally, the KBIT-2 derives an age-normed composite score (used as a proxy for IQ in this study) from both scales. Despite its relatively quick administration (approximately 20–30 min), the KBIT-2 has high reliability (.9) and validity, showing strong correlations (approximately .8) with other comprehensive intelligence tests such as the Wechsler Intelligence Scales for Children–Third Edition and the Kaufman Test of Educational Achievement–Second Edition (Bain & Jaspers, 2010).

Procedure

Immediately after obtaining consent for participation, we screened children’s hearing in a sound-proof booth to confirm normal-hearing thresholds while caregivers completed the demographic and music questionnaires. Next, we administered the BKB-SIN in the same soundproof booth. For each child, we administered three pairs of BKB-SIN lists randomly selected and equated on difficulty (10 sentences per list, 60 sentences total). We

averaged the two SNR-50 values within each list pair and across the three lists to obtain the final SNR-50 score used in the analysis. When administered with three pair lists, the BKB-SIN scores provide good test–retest reliability and good interlist equivalency (Schafer, 2010). Administration time was approximately 15 min. We delivered the sentences at 80 dBA (SPL) in sound field. Sentences and the four-talker babble masking noise emanated from the same front loudspeaker (Electro-Voice, EVID-3.2) located at 0° azimuth and 1 m from the child. Previous studies reported that differences between musicians and nonmusicians in SPIN skills are more likely to emerge when the target stimuli and the masker are spatially separated than when they are colocated (e.g., Strait et al., 2012). However, our pilot data consistently showed that differences emerged between musicians and nonmusicians in colocated conditions, similar to the adult sample in Parbery-Clark et al. (2009). Because we anticipated that if there were effects of general intelligence on SPIN that they would occur for more difficult listening situations (i.e., colocated) than at easier listening situations (i.e., spatially separated), we presented our children with the colocated condition only. Finally, either the first author or a qualified research assistant administered the KBIT-2 to each child according to published instructions in a quiet room. Administration time was approximately 30 min.

Data Analyses

We computed correlational analyses between years of instrument training and SPIN scores, controlling and not controlling for IQ. We also computed correlations between potential covariates (maternal education, age, and sex) and SPIN scores. We planned on including these variables as covariates in our main correlations of interest (years of instrument training relative to SPIN scores) only if they were related to our outcome measure (SPIN scores). Because we did not find normally distributed data for the years of instrument training variable, we calculated Spearman correlations. Correlation results reported herein reflect two-tailed *p* values. Finally, one participant from the beginner music group was removed from analyses involving IQ scores because we could not complete the assessment. The participant reported being fatigued and did not finish the assessment.

In addition to correlational analyses, we compared SPIN skills across the three groups (advanced music, beginner music, and no music) using a one-way between-group analysis of variance (ANOVA). We also implemented one-way between-group analyses of covariance (ANCOVAs) to analyze group differences in SPIN skills while controlling for IQ. For both the ANOVA and the ANCOVA, group served as the between-group variable, and SPIN, as the dependent variable. For the ANCOVA,

the IQ composite score served as the covariate. Irrespective of the ANOVA and ANCOVA outcomes, we followed up both analyses with planned post hoc pairwise contrasts to explore differences between groups, which were our main analyses of interest at the group level. Specifically, we implemented Tukey Tests to control for elevation of Type I error. ANOVA and ANCOVA results reported herein reflect two-tailed p values.

Results

When treating musical training as a noncategorical variable, we found a significant inverse correlation between years of instrument training and SPIN scores without controlling for IQ ($n = 51$, $\rho = -0.35$, $p = .01$) as well as when controlling for it ($n = 50$, $\rho = -0.30$, $p = .03$). Specifically, more years of training predicted lower (better) SNR-50 scores (see Figure 1). Table 2 displays correlations between all our variables including years of music training, SPIN scores, IQ scores, maternal education, age, and gender. Note that none of the potential covariates were related to SPIN scores, including IQ scores ($n = 50$, $\rho = -.26$, $p = .07$).

We followed correlational analyses with group-level analyses. We observed a main effect of group on SPIN skills before controlling for between-group differences in IQ, $F(2, 48) = 4.78$, $p = .01$, $\eta^2 = .17$. Tests of pairwise comparisons revealed that SPIN scores were significantly

lower (better) in the advanced music group ($M = +0.07$ SNR-50, $SD = 0.99$, range: $+1.33$ to -1.67) than the no-music group ($M = +1.46$ SNR-50, $SD = 1.48$, range: $+4.8$ to -0.5 ; $p = .01$). Additionally, a one-way ANOVA with IQ scores as the dependent variable showed a main effect of group, $F(2, 47) = 7.54$, $p = .001$, $\eta^2 = .24$. Tests of pairwise comparisons revealed higher IQ scores in the advanced music group than the beginner music group ($p = .02$) and the no-music group ($p = .001$). When controlling for IQ on SPIN, a main effect of group on SPIN was not observed, $F(2, 47) = 2.23$, $p = .12$, $\eta^2 = .09$. However, differences revealed by pairwise comparisons between the advanced music group and the no-music group remained significant ($p = .04$). In none of the aforementioned analyses did the beginner music group ($M = +1.08$ SNR-50; $SD = 1.57$, range: $+4.2$ to -0.1) differ from the other two groups on SPIN skills (for the ANOVA, beginner music group vs. advanced music group [$p = .07$], beginner music group vs. no-music group [$p = .68$]; for the ANCOVA, beginner music group vs. advanced music group [$p = .13$]; beginner music group vs. no-music group [$p = .87$]). Figure 2 displays a summary of the SPIN differences across groups. IQ scores across groups are reported in Table 1.

Discussion

This study evaluated SPIN skills of school-age children with different levels of music training and found

Figure 1. Scatter plot of the relationship between signal-to-noise ratio (SNR-50) scores from the Bamford–Kowal–Bench Speech-in-Noise Test and years of instrument training ($n = 51$). As plotted here, better speech-perception-in-noise skills (low SNR-50 scores) are related to more years of instrument experience. This relationship persists even when controlling for individual differences in IQ (not shown here, see Results section).

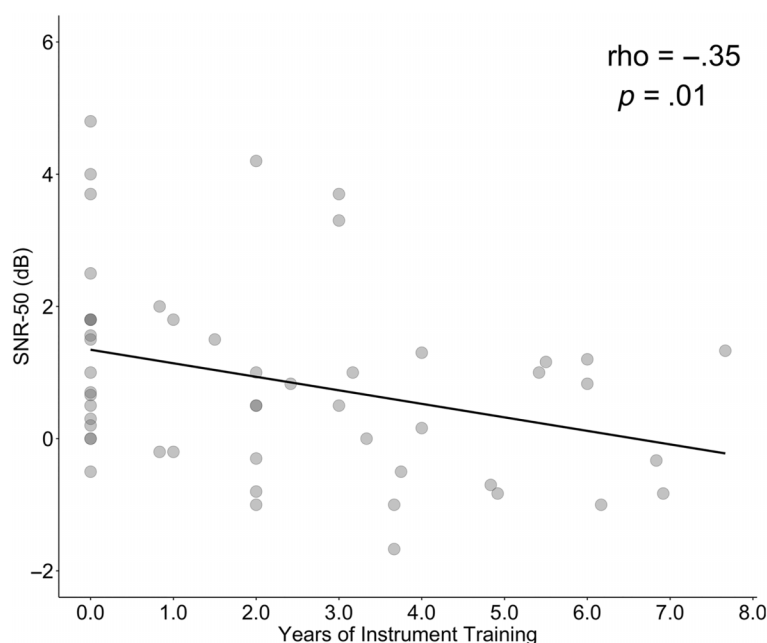


Table 2. Correlation matrix.

Variable	Years of music training	SPIN	IQ	Age	Maternal education	Sex
Years of music training	1	-.35 ^a	.42 ^{**a}	.23 ^a	-.25 ^c	-.08 ^c
SPIN		1	-.26 ^b	-.24 ^b	-.08 ^c	-.09 ^c
IQ			1	.02 ^b	-.30 ^{*c}	.32 ^{*c}
Age				1	-.13 ^c	.19 ^c
Maternal education					1	2.8 ^d
Sex						1

Note. For all correlations $n = 51$, except for correlations involving IQ scores ($n = 50$).

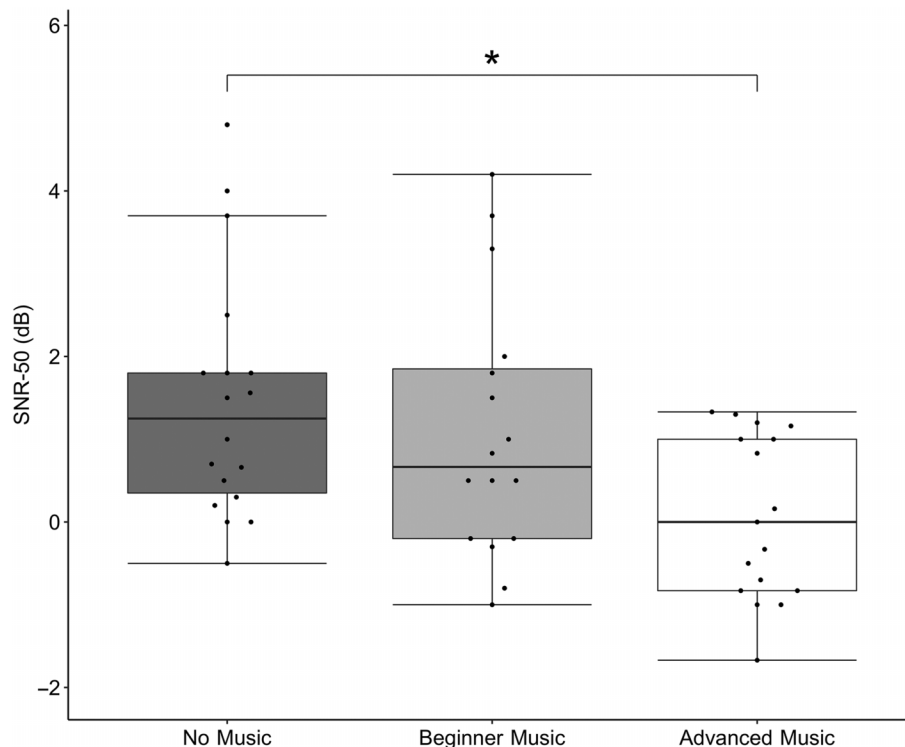
^aSpearman correlation (ρ). ^bPearson correlation (r). ^cPoint biserial (ρ). ^dChi-square test (χ^2).

* $p < .05$. ** $p < .01$.

further evidence that the SPIN musician advantage emerges before adulthood (Nie et al., 2018; Strait et al., 2012; Torppa et al., 2018). Our main findings can be summarized as follows: (a) The metric of years of instrument training was a predictor of SPIN skills in our cohort of children and (b) there was no impact of IQ on the relationship between music training and SPIN skills in this cohort. Specifically, we found that more years of instrument training relates to better SPIN skills, confirming our

hypothesis that children with higher levels of instrument training have better SPIN skills than those with no instrument training, even when controlling for IQ. For the advanced music group, we found that the 50% correct threshold was, on average, approximately 0 dB, which in lay terms corresponds to the point in the test where the speech is played at the same level as the noise. By contrast, for the no music group, the threshold was approximately 1.4 dB, indicating that the no-music group required the

Figure 2. Children with advanced music training had significantly greater speech-in-noise scores than children with no music training, even when controlling for between-group differences in IQ. The figure shows boxplots of signal-to-noise ratio (SNR)-50 scores from the Bamford-Kowal-Bench Speech-in-Noise Test for each of the study groups. The central horizontal line in each boxplot indicates the median SNR-50 score. The boxes show the interquartile range from the 25th (lower boundary) to the 75th percentile (upper boundary). The error bars extending from the boxes capture values falling within 1.5 times the interquartile range. Filled circles show data points > 1.5 times the interquartile range. Note that low SNR-50 scores represent enhanced speech-perception-in-noise skills. We also show individual data points for each group using a Swarm of Bees visualization. The star (*) indicates that significant differences were found between the advanced music group and the no-music group. SNR = signal-to-noise ratio. * $p < .05$.



speech to be 40% more intense with respect to the noise to achieve the same accuracy as the advanced music group. Interestingly, this approximately 1.4-dB difference is consistent with the group difference reported by Parbery-Clark et al. (2009) between young adult musicians and nonmusician controls. It also aligns with the magnitude of improvement observed after 2 years of child musical training in a previous study (Slater et al., 2015), and the changes that arose from short-term auditory training in younger and older adults (Anderson & Kraus, 2013; Song et al., 2012).

This study revealed a musician advantage in a colocated SPIN task, where the speech and the masker were delivered from the same loudspeaker positioned directly in front of the child. These findings align with at least a couple of previous studies with adults (Coffey et al., 2019; Parbery-Clark et al., 2009). However, findings differ from previous studies with children and adults in which differences between musicians and nonmusicians arose only in spatially separated conditions (i.e., speech and masker delivered from different locations) and not colocated conditions (Strait et al., 2012; Swaminathan et al., 2015). Researchers attributed the previous null results in colocated conditions to the greater complexity of that listening task relative to those in spatially separated conditions. Specifically, in a recent review of the SPIN advantage, it was speculated that difficult SPIN conditions “might allow compensatory mechanisms to mask relative weaknesses in nonmusicians at some levels of difficulty” (Coffey et al., 2017, p. 60), potentially leveling differences between musicians and nonmusicians. However, it is reasonable to consider that our use of a child-friendly test, the BKB-SIN, in the current study might have made the colocated condition easier than prior studies that used speech tests designed for adults. Nevertheless, our study shows that differences in SPIN skills can arise in colocated conditions between children with varying levels of music training.

Contrary to what has been hypothesized in the literature, we found that the SPIN musician advantage was evident even after controlling for IQ (Akeroyd, 2008; Boebinger et al., 2015; Silvia et al., 2016), most noticeably when the advanced music group was compared to the no music group. Also, in line with previous studies, SPIN skills were not related to IQ in this cohort of children although the three groups did differ with respect to IQ (see Akeroyd, 2008, for a review). The fact that the relationship between music training and SPIN skills was not explained by IQ suggests that enhanced cognitive skills in advanced musicians as compared to nonmusicians does not underlie the musician SPIN advantage, at least not in our cohort of children.

Therefore, collectively, these findings underscore that the relationship between years of music training and SPIN is complex and cannot be explained by a single general cognitive indicator (IQ). Lower order cognitive factors, such as

working memory and selective attention, as well as auditory sensory skills (e.g., pitch perception or temporal processing), have been previously associated with enhanced SPIN skills in adult musicians (Coffey et al., 2017; Meha-Bettison et al., 2018; Moradzadeh et al., 2015; Yoo & Bidelman, 2019). It is possible that, as previously suggested by others, the musician SPIN advantage found in our sample is a byproduct, at least partially, of the enhanced lower order cognitive abilities characteristic of this population rather than general intelligence (Bidelman & Yoo, 2020; Moradzadeh et al., 2015; Moreno & Bidelman, 2014; Patel, 2011; Yoo & Bidelman, 2019). However, it is also possible that a subgroup of these lower order cognitive abilities is associated with IQ (e.g., working memory; e.g., Giofrè & Mammarella, 2014). Future studies that focus on disentangling the relationship between SPIN skills, lower order cognitive factors, and IQ in young musicians could enhance our understanding in this area.

Our study was not designed to investigate genetic predispositions (including musical talent), or weigh the relative contributions of genetic predispositions versus training-related factors as they relate to SPIN skills in musicians. However, assuming that the brain is susceptible to plastic changes via experience and given that childhood represents a sensitive period when the influence of experience is heightened (e.g., Skoe & Kraus, 2013), our data, in combination with other recent studies in children (e.g., Strait et al., 2012), suggests that music training from an early age might have a positive impact on children’s ability to listen to speech in adverse listening conditions.

Enhanced SPIN skills have also been associated with increased language outcomes (Dubas et al., 2022; Kuhl et al., 2005; McCreery et al., 2017; Vance et al., 2009) and improved psychosocial skills (Slater et al., 2015). Therefore, musical training should perhaps be promoted to families and educators to improve children’s academic outcomes and children’s health (Slater et al., 2015). Our group comparisons suggest, similar to Slater et al. (2015), that a minimum amount of training might be needed to observe significant gains (i.e., the advanced musicians differed from the untrained controls but the beginner musicians, with less training, did not). That being said, the claim that musical training benefits SPIN is not without controversy (e.g., McKay, 2021). In fact, we also acknowledge the possibility that children with some level of natural musical talent might inherently have better auditory skills, including SPIN skills, than those who are not musically talented. As a result of their natural musical talent, they might be more likely to take music lessons and continue taking them for long periods of time. This alternative explanation is supported by previous findings from Swaminathan and Schellenberg (2020) who found that musical ability—with amount of training held constant—predicted children’s performance on phoneme discrimination tasks, but music training—with ability held constant—did

not, even though the simple association with training was significant. Longitudinal studies and randomized control trials analyzing the effects of music training programs on SPIN and other cognitive domains are necessary to evaluate further the extent to which innate factors and musical training (including years of training but also other dimensions of training such as the instructional method) interact when these skills are developing.

Limitations

Although a SPIN musician advantage emerged even when comparing groups having similar socioeconomic status—a variable that can influence access to music and other forms of auditory enrichment—the majority of children in our sample came from families that could be considered of higher-than-average socioeconomic backgrounds (most mothers had a college degree or higher). Thus, our sample did not represent a range of socioeconomic backgrounds representative of our region that would allow for generalization of our findings across socioeconomic groups. Our cohort also had higher-than-average IQ scores (note that all three groups had average IQ scores higher than the mean of 100 for typically developing children, although only the advanced music group had an average IQ score greater than 1 *SD* above the test normative data), which might make IQ a less meaningful variable in our analysis than in a study where IQ scores ranged more broadly. Future studies can explore whether results from this study can be extrapolated to school-age children from diverse socioeconomic backgrounds and cognitive profiles (e.g., Hoff, 2013).

We considered IQ as representative of possible cognitive factors underlying the musician SPIN advantage. However, it is important to note that we did not investigate specific cognitive factors, such as working memory, that might be at play in the musician advantage for SPIN. Working memory is critical to SPIN tests, especially when the test requires repeating key words or full sentences presented in noise (Bishop-Liebler et al., 2014; Boebinger et al., 2015; Donai & Jennings, 2016; Kraus et al., 2012; Meha-Bettison et al., 2018; Parbery-Clark et al., 2009; Ruggles et al., 2014; Zhang et al., 2021). Future exploration of whether other lower order cognitive factors underlie the musician SPIN advantage in children, and how they relate to higher order cognitive domains (IQ) is warranted.

Finally, bilingualism has been previously linked to reduced SPIN skills in children and adults when participants are tested in their second language (Krizman et al., 2017; Lucks Mendel & Widner, 2016; Schmidtke, 2016). However, in some cases, SPIN skills are actually enhanced when multilingual participants are tested in their primary language relative to monolingual participants (Coffey et al., 2019). Although we confirmed that English was the

primary language for all children in our cohort, we do not know whether other languages were spoken at home or in school. Therefore, we cannot rule out the possibility of second language exposure for the children in this study.

Conclusions

This study revealed that the SPIN musician advantage is evident in children of school age. The findings also suggest that the IQ- and the SPIN-advantage in musician children could be unrelated. However, other lower order sensory and cognitive factors (e.g., auditory discrimination, working memory, and attention) not necessarily related to IQ could underlie the SPIN advantage in musicians. Future longitudinal studies should explore the development of SPIN skills and lower order sensory and cognitive factors and their relationships to understand why child musicians might have an advantage on these tasks relative to nonmusicians.

Data Availability Statement

The data sets generated and/or analyzed during this study are available from the corresponding author upon reasonable request.

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Appendix (p. 1 of 3)**Music Questionnaire**

Subject #: _____

MUSIC QUESTIONNAIRE FORM: LISTENING IN NOISE STUDY

I. Participant Information

NAME (LAST) _____ (FIRST) _____ (MI) _____
DATE OF BIRTH ____/____/____ SEX ☐ MALE ☐ FEMALE AGE _____ GRADE _____
ADDRESS _____

PHONE (H) _____ (CELL) _____ (W) _____
EMAIL _____ PREFERRED CONTACT ☐ PHONE ☐ E-MAIL

II. Music Training

PLEASE ANSWER THE FOLLOWING QUESTIONS TO THE BEST OF YOUR ABILITY. OBSERVATIONS SHOULD INCLUDE BEHAVIOR AT SCHOOL AS WELL AS AT HOME. WHEN A RATING IS REQUESTED, PLEASE CIRCLE ONLY ONE NUMBER. MOST QUESTIONS ARE DIRECTED TOWARD YOUR CHILD'S CURRENT MUSICAL ABILITY AND INTEREST. PLEASE FEEL FREE TO WRITE IN THE SPACE PROVIDED WHEN ELABORATION IS REQUIRED.

1. Did your child participate in a preschool music program? ☐ YES ☐ NO

If yes, at what age did this program begin/end (years + months)? _____

If yes, approximately how many hours/week were spent in preschool music activities? _____

2. Does your child have perfect pitch? ☐ Yes ☐ No ☐ Undetermined

3. Please check the **highest** category that describes your child

- ☐ Is an excellent musician in both performing ability and knowledge of music theory
☐ Plays an instrument and has fair sight-reading abilities as well as general knowledge in music theory
☐ Plays an instrument but has not been trained in theory and cannot sight read (reproduce written music on an instrument)
☐ Enjoys singing and has a set of songs that are commonly sung or is a critical listener of songs on the radio or buys music and listens to it often
☐ Occasionally sings familiar melodies, such as nursery rhymes and popular songs, or sometimes listens to music on the radio/requests to listen to music
☐ Shows no interest & does not care to listen to or sing music
☐ Prefers not to listen to music/dislikes music

4. How much interest does your child show in music-related activities

1	2	3	4	5	6	7
NO INTEREST						EXTREME INTEREST

5. At what age did your child first show interest in music? _____

6. Please describe all of your child's **current** music-related activities. Please be as precise as possible (e.g., years + months).

	ACTIVITY	AGE BEGAN	WEEKLY FREQUENCY OF INVOLVEMENT
(HOURS/WEEK)			
1	_____	_____	_____
2	_____	_____	_____
3	_____	_____	_____
4	_____	_____	_____
5	_____	_____	_____

Appendix (p. 2 of 3)

Music Questionnaire

7. Please describe all of your child's **former** music-related activities. Please be as precise as possible (e.g., years + months).

	ACTIVITY	AGE BEGAN/ENDED	WEEKLY FREQUENCY OF INVOLVEMENT
(HOURS/WEEK)			
1	_____	_____	_____
2	_____	_____	_____
3	_____	_____	_____
4	_____	_____	_____
5	_____	_____	_____

8. Please indicate what instrument your child plays most frequently.

PRIMARY _____
 SECONDARY _____
 TERTIARY _____

9. At what age did your child start playing the above instrument(s) (years+months)? _____
 If different from the above age, at what age did your child begin playing an instrument consistently (years+months)? _____

10. Please indicate what type of training below:

- ☐ Group lessons
☐ Private training
☐ Suzuki training
☐ Other (specify): _____

11. Does your child practice on a daily basis? ☐ YES ☐ NO

If yes, how many hours/day? _____
 If not, how many hours/wk? _____

12. Does your child enjoy practicing? ☐ YES ☐ NO

13. How many hours per week would you estimate your child

PRACTICES PRIVATELY _____
 PLAYS WITH AN ENSEMBLE _____
 PERFORMS FOR A GROUP/AUDIENCE _____
 ENGAGES IN PRIVATE LESSONS _____
 ENGAGES IN OTHER MUSICAL ACTIVITIES (PLEASE EXPLAIN) _____

14. Are either parents or any siblings regularly-practicing musicians? ☐ YES ☐ NO

If yes, how many hours/week is the child exposed to the musical practice of family members?
 Which immediate family members are musicians? _____

15. Does your child participate in school music activities (band/orchestra, choir, or other musical group)?
☐ YES ☐ NO

Appendix (p. 3 of 3)**Music Questionnaire**

If so, please indicate below:

Or does your child participate in music activities outside of school (church choir, etc.)?

☐ YES

☐ NO

If so, please indicate activities below and average # hours spent weekly:

III. Musical Behavior

1. When your child actively listens to music (i.e., pays attention to it), how would you compare his or her level of expressed emotion with a typical child of the same age?

1	2	3	4	5	6	7
MUCH LESS EMOTION			SIMILAR EMOTION		MUCH MORE EMOTION	

2. When your child reproduces music (like singing a song he/she has learned), how accurate is it?

1	2	3	4	5	6	7
no accuracy			somewhat accurate		perfect	

3. How much of a song is your child able to reproduce?

Please mark one of the following:

- ☐ Reproduces a small portion
☐ Reproduces a lot of the piece
☐ Reproduces the entire piece

4. How frequently does your child reproduce music in comparison to a typical child of his or her age?

1	2	3	4	5	6	7
much less frequently			similar frequency		much more frequently	

5. How often does your child create music or songs of their own?

1	2	3	4	5	6	7
never creates		sometimes creates		similar frequency		creates extremely often

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