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Musical expertise and cognitive abilities: no advantage for professionals over amateurs

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Cognitive advantages in musicians are often attributed to far transfer from music training. If this causal interpretation is correct, greater musical expertise should generally predict larger cognitive gains. To test this prediction, we reanalysed data from the *Music Ensemble* project—a large-scale initiative including 33 laboratories across 15 countries. We compared 608 nonmusicians, 289 amateur musicians, and 352 professional musicians on measures of musical ability, cognition, and personality, controlling for demographic differences. As expected, musical abilities increased with expertise: professionals outperformed amateurs, who outperformed nonmusicians. Cognitive performance, however, showed a different pattern. Only short-term memory (STM) for melodies increased monotonically with expertise. Verbal STM was similar across groups. Other domains revealed nonlinear associations: both musician groups outperformed nonmusicians in visuospatial STM, vocabulary, and executive functions, but professionals did not exceed amateurs in any domain and even performed worse in nonverbal reasoning. Personality also differed: professionals scored higher on open-mindedness than both other groups, but lower on agreeableness than amateurs. Thus, despite superior musical abilities and distinctive personalities, professional musicians showed no cognitive advantage over amateurs. This dissociation questions the assumption that musicians' cognitive differences stem from training and points to alternative explanations such as selection effects.

1. Introduction

Expertise in any domain requires years of intensive training and consistent practice. Unsurprisingly, psychologists and neuroscientists often turn to experts to understand better the mechanisms of learning and plasticity. Across domains such as chess [1], spatial navigation [2,3], phonetic transcription [4] and music [5,6], experts show distinctive behavioural and neuroanatomical profiles. In music research, such differences are often attributed to training, even though most supporting evidence comes from cross-sectional comparisons rather than randomized controlled trials [7].

For some expertise-related differences, training provides a plausible account. For example, string players have enlarged cortical representations of their left hand [8] and heightened plasticity in the hand region of the motor cortex [9]. In many other cases, however, the causal direction remains unclear. Although music training is proposed frequently as a model for studying experience-dependent plasticity [6,10–12], this view understates the influence of preexisting factors in determining who pursues and persists in music learning [13].

Indeed, natural musical ability likely plays a foundational role in training trajectories. When measured with objective perceptual tasks, musical ability is remarkably stable over time and relatively unaffected by training [14,15]. Longitudinal evidence suggests further that musical ability predicts subsequent engagement in music training better than training predicts future ability [14]. When musical ability is statistically controlled, group differences that are often attributed to training—in cognitive ability [16], language [17], emotion recognition [18]—tend to disappear. Moreover, twin studies reveal substantial genetic influences on both music practice and the association between practice and ability [19,20].

A central question in training research is whether learning in one domain confers benefits in another domain, a phenomenon known as *transfer*. Transfer is typically categorized as *near* or *far*, depending on the similarity between the trained and untrained skills. Near transfer, such as improvements in fine-motor control following instrumental practice [15,21], is documented and theoretically grounded. By contrast, far transfer—generalization to distantly related cognitive domains, such as from music training to working memory—has proven to be elusive and contentious [19–21].

Robust evidence for far transfer remains scarce across different types of training. Meta-analyses provide little support for generalization beyond trained tasks following working-memory training [22,23], executive-function training [24] and even physical exercise after accounting for moderators and publication bias [25]. The literature on music training is similarly mixed. A recent meta-analysis of instrumental training in older adults [26] found small benefits for processing speed and some executive functions (inhibition, switching), but no effects for working memory, verbal memory or selective visual attention. Crucially, only one of the 13 studies met criteria for low risk of bias. Among children and adolescents, longitudinal evidence shows either null or small effects [27–29], although one meta-analysis reported moderate-to-large effects for inhibitory control [30]. Publication bias is also evident in some cases [31]. In a recent comprehensive review, Schellenberg & Lima [13] concluded that existing evidence does not support far-transfer effects of music training on auditory processing, language or general cognitive abilities.

Furthermore, positive findings in some meta-analyses [30,32,33] could stem from methodological limitations in the original studies, such as lack of random assignment, differential attrition across groups or the use of intensive short-term interventions that are not representative of real-world music training. For example, Román-Caballero *et al.* [33] found that in studies without randomized designs, musically trained children outperformed controls at baseline, suggesting that self-selection was involved. Additionally, the finding of training effects was not moderated by assignment method, training duration or type of control groups (passive versus active), which complicates causal interpretation.

Here, we addressed the question of far transfer from a different angle. If musical expertise enhances general cognitive abilities, individuals with greater expertise should exhibit corresponding cognitive advantages—a dose–response association. This rationale underlies many correlational studies that link *duration* of music training with cognitive or neural outcomes [16,34–42], a finding that is often interpreted as stronger evidence for causality than simple group comparisons. After all, if cognitive outcomes do not vary systematically with the amount of musical expertise, or follow nonlinear patterns, then plasticity-based interpretations become less convincing.

Recent data collected online by Vincenzi *et al.* [43] illustrate this approach. They compared the cognitive and personality profiles of nonmusicians, amateur musicians and professionals. All musicians had at least 6 years of lessons, but only professionals had music-related jobs or were university music students. Professionals outperformed the other groups in musical ability, but they were indistinguishable from nonmusicians in nonverbal reasoning and even performed worse than amateurs. For personality, both musician groups scored higher than nonmusicians in open-mindedness[1] and agreeableness. Additionally, professionals were more extraverted than both amateurs and nonmusicians, and more conscientious than nonmusicians. Kuckelkorn *et al.* [46] found similarly that open-mindedness increased with musicianship. In fact, the largest group difference in personality was in open-mindedness, with professionals scoring highest, followed by amateurs, then nonmusicians. Differences in other traits were smaller and more complex: amateurs were more agreeable than both nonmusicians and professionals, more extraverted than nonmusicians, and more conscientious than professionals.

Building on these findings, the present study examined whether musicianship status (amateur versus professional) predicts differences in musical abilities, cognitive abilities, and personality traits. We reanalysed data from the *Music Ensemble* project [47], a large-scale initiative involving 33 sites and over 1200 participants who were tested individually in controlled laboratory settings. Participants were young adults aged 18 to 30, selected to include musicians with ≥10 years of music training, and nonmusicians with ≤2 years of extra-school music training. The primary focus of the original project was on short-term memory (STM), with large group differences evident for tonal STM (i.e. memory for melodies), but much smaller differences for visuospatial and verbal STM—results partially consistent with prior meta-analyses [48]. Musicians also outperformed nonmusicians in musical abilities and showed small differences in other cognitive abilities, socio-economic status (SES) and personality, except for open-mindedness, which differed substantially across groups.

We subdivided the group of musicians identified by Grassi *et al.* [47] into *amateurs* or *professionals*, based on their self-reported musicianship status. Although both groups were highly trained, professionals reported longer training duration, more intensive daily practice, and broader overall engagement with music. Our goal was to examine cognitive abilities linked previously to music training, including STM [48–51], verbal and nonverbal intelligence [17,20,52–54], and executive functions [52,55], as well as the Big Five personality traits. Although the cross-sectional design precluded causal inferences, it allowed us to test for predicted dose–response associations. If greater musical expertise enhances cognitive abilities, one would expect professionals to outperform amateurs. If no such gradient is observed—if cognitive performance plateaus or even declines among the most experienced individuals—claims of far transfer become harder to sustain. Rather, selection effects would offer a more parsimonious account of group differences [13].

Based on previous findings [43], we expected musical abilities to follow a monotonic pattern, with professionals outperforming amateurs, and amateurs outperforming nonmusicians. By contrast, for nonmusical cognitive outcomes, we anticipated nonlinear or null associations. Specifically, even though musicians might outperform nonmusicians, we did not expect professionals to exceed amateurs. Regarding personality, previous research reported that individuals with music training tend to score higher than nonmusicians on open-mindedness [38,56,57]. Although some studies suggest that professionals may score even higher than amateurs [46], others do not find this pattern [43], leaving open the question of whether increased expertise is associated with greater differences in open-mindedness.

2. Method

2.1. Participants

Thirty-three laboratories across 15 countries initially recruited 1357 participants [47]. For the present analysis, we first divided participants into musicians and nonmusicians, and then further categorized musicians as amateurs or professionals. Musicians were defined as individuals with at least 6 years of formal training, as per the norm in the literature [58], and nonmusicians as those with no more than

[1]In the current study, we used the second edition of the Big Five Inventory (BFI-2 [44]), in which the names of two of five personality traits were changed from the first edition [45]. *Openness-to-experience* and *neuroticism* were renamed *open-mindedness* and *negative emotionality*, respectively. To avoid confusion, the newer terms were used throughout the manuscript.

2 years of music training and no active playing in the previous 5 years. Group assignment was based on two measures: (1) item 36 from the Goldsmiths Musical Sophistication Index (Gold-MSI) [59], which assesses years of formal instrumental training, and (2) self-reported musicianship status (nonmusician, music-loving nonmusician, amateur musician, serious-amateur musician, semi-professional musician, professional musician). We excluded 108 participants due to inconsistencies between reported training and self-identification (e.g. 'musicians' reporting fewer than 6 years of training, or 'nonmusicians' identifying as amateur musicians).

The final sample included 1249 participants: 608 nonmusicians (358 women, 249 men, 1 non-binary) and 641 musicians (379 women, 260 men, 2 non-binary). All nonmusicians reported ≤2 years of training and identified as nonmusicians or music-loving nonmusicians. All musicians reported ≥6 years of training. Amateurs (n = 289) identified as amateur or serious-amateur musicians, whereas professionals (n = 352) identified as professional or semi-professional musicians. Note that the term *amateur* denotes a comparatively lower level of musical expertise rather than a 'hobbyist' status, as all musicians were initially recruited based on substantial musical experience. Nevertheless, we retain this label to reflect participants' self-categorization. Table 1 provides descriptive statistics for demographic and musical-background variables for the three groups.

2.2. Measures

2.2.1. Musical abilities

Objective Tests. Music perception was assessed using the Mini Profile of Music Perception Skills - Mini-PROMS [60], administered with LimeSurvey. This 15 min test included 36 trials and four subtests: Melody (10 trials), Accent (10 trials), Tuning (8 trials), and Tempo (8 trials). Each trial followed a same-different format: participants heard two standard stimuli followed by a comparison stimulus. Their task was to judge whether the comparison was identical to the standards using a five-point scale: *definitively different*, *probably different*, *I don't know*, *probably the same*, *definitively the same*. Scoring awarded two points for confident correct responses (*definitely different* on 'different' trials or *definitely the same* on 'same' trials), one point for less confident correct responses (*probably different* on 'different' trials or *probably the same* on 'same' trials), and zero otherwise. Total scores were divided by two, yielding a maximum possible score of 36.

The Melody subtest required participants to compare melodies comprised of harpsichord tones. On different trials, the comparison had the same contour as the standards but some (i.e. one or more) tones were displaced in pitch. The Tuning subtest involved listening to 1.5 s C-major chords comprising four piano tones (C_4, E_4, G_4, C_5). On different trials, the E_4 tone in the comparison chord was mistuned by 10 to 50 cents. The Accent subtest required participants to compare rhythmic sequences of rim-shots that varied in intensity. On different trials, one or more rim-shots in the comparison was altered in intensity. Finally, the Tempo subtest required participants to determine whether the standards and the comparison had the same tempo. On different trials, the tempo of the comparison differed from the standards by 1–7 beats per minute.

Self-Reports. Self-reported musical abilities and behaviours were assessed using the Gold-MSI [59], implemented in LimeSurvey. This scale was designed to measure musical abilities and behaviours broadly, particularly among nonmusicians. The Gold-MSI included 38 items rated on seven-point scales, which provided five subscale scores. The Active Engagement subscale (e.g. *I spend a lot of my free time doing music-related activities*) assessed participants' music-listening habits and personal interest in music. The Singing Abilities (e.g. *I am able to hit the right notes when I sing along with a recording*) and Perceptual Abilities (e.g. *I can tell when people sing or play out of tune*) subscales provided self-reports of singing and music-perception skills, respectively. The Emotions subscale (e.g. *I sometimes choose music that can trigger shivers down my spine)* focused on emotional responses to music. Finally, the Music Training subscale measured formal musical education and practice, music theory, number of instruments played, musical identity, and whether participants had received compliments on a musical performance. Because this subscale informed group classification and analyses of construct validity (see table 1 and Results), it was excluded from the main analyses. Two additional open-ended items asked about hours of current daily music practice (musicians only), and years of formal music lessons. Years of lessons were square-root transformed for the analyses because of positive skew.

Table 1. Means (and SDs) for nonmusicians, amateurs and professionals for demographic and musical-background variables.

	Nonmusicians $n = 608$	Amateurs $n = 289$	Professionals $n = 352$
Demographics			
Age	22.07 (3.07)	21.31 (2.69)	22.93 (3.44)
Gender (male:female)	249:358	104:185	156:194
Years of education	15.73 (2.11)	15.53 (1.96)	16.32 (2.45)
SES	44.54 (16.23)	52.46 (13.54)	49.20 (14.62)
Musical background			
Years of music lessons	0.37 (0.65)	11.70 (2.84)	13.08 (3.86)
Hours of current daily practice	—	1.26 (0.88)	2.55 (2.56)
Gold-MSI Music Training subscale (1–7)			
Years of lessons	1.64 (1.05)	6.86 (0.35)	6.91 (0.28)
Years of practice	1.39 (0.87)	6.36 (1.17)	6.58 (0.91)
Peak daily hours of practice	1.69 (1.18)	4.56 (1.40)	5.81 (1.23)
Years of theory instruction	1.28 (0.76)	5.34 (1.79)	6.19 (1.15)
Number of instruments	1.30 (0.60)	3.71 (1.40)	4.06 (1.51)
Musician identity	1.63 (1.22)	5.83 (1.26)	6.65 (0.94)
Received compliments	2.86 (1.88)	6.42 (0.89)	6.64 (0.74)

Note. Responses to individual items from the Gold-MSI Music Training subscale were made on 7-point ordinal scales (e.g. Years of Lessons: 1 = 0 years, 2 = 0.5 years, 3 = 1 year, 4 = 2 years, 5 = 3–5 years, 6 = 6–9 years and 7 = 10 or more years). These scores do not correspond to exact numerical values, such as years of lessons, hours of practice or number of instruments played.

2.2.2. Cognitive abilities

Vocabulary. Verbal (crystallized) intelligence was assessed using the Vocabulary subtest from the Wechsler Adult Intelligence Scale, 4th edition (WAIS-IV) [61]. Participants defined up to 30 words read aloud by the experimenter, with items increasing in difficulty. Precise definitions were scored two points, partially correct definitions one point, and incorrect or missing definitions zero points. In accordance with standardized administration procedures, the test was discontinued after three consecutive responses with a score of zero. Because there was no Portuguese version of the WAIS-IV, some participants completed the vocabulary subtest from the WAIS-III. For comparability, all raw scores were transformed to proportions of the maximum possible score.

Nonverbal Reasoning. Nonverbal (fluid) intelligence was assessed with Raven's Advanced Progressive Matrices [62], implemented digitally on LimeSurvey. Participants completed the last 10 items from set I and all 36 items from set II within a 10 min time limit. Each item comprised a 3 × 3 matrix of abstract patterns with the bottom-right cell missing. The task was to identify the correct completion from eight response options. Scores were the total number of correct responses.

Updating. The updating component of executive functions was assessed using a 2-back task, implemented with jsPsych [63]. Each of five blocks included 22 letters presented visually, one at a time, in the centre of the screen. Each letter appeared for 500 ms, followed by a 1500 ms inter-stimulus interval (ISI). Participants pressed the spacebar when the current letter matched the one presented two trials earlier. Each block had six such instances. A practice trial preceded the testing session, and scores were the number of correct responses minus false alarms. The maximum possible score was 30.

STM. STM was assessed in three modalities—verbal, visuospatial, and tonal—using three separate tasks, all implemented with jsPsych. Verbal STM was assessed with a forward digit-span task. Single digits (1–9) were presented visually, one at a time, in the centre of the screen for 500 ms each, with a 500 ms ISI. Participants were asked to recall the digits in the same order using the keyboard. The task began with a two-digit sequence, but sequences increased by one digit after two trials, provided at least one of the two responses was correct. The task was discontinued if both trials of a certain length were incorrect. Sequences were pseudo-randomized to avoid obvious patterns (e.g. 1, 2, 3, 4) and repeated digits. For sequences with more than 9 digits, repetitions were nonconsecutive. Sequences had a maximum of 18 digits.

Visuospatial STM was assessed with a forward matrix-span task. Each trial displayed a 4 × 4 matrix in which a 500 ms dot appeared sequentially in different cells (500 ms ISI). Participants were asked to click on the cells in the same order as the dots were presented. The rules for increases in sequence length, scoring and discontinuing mirrored those of the verbal STM task. Dot locations were pseudo-randomized to avoid simple spatial patterns (e.g. the four corners of the grid). No dot location was repeated unless the sequence exceeded 16 dots, when repetitions were nonconsecutive. The longest sequence had 32 dots.

Tonal STM was assessed with a recognition task. On each trial, participants heard a monophonic standard melody followed by a comparison melody and judged whether they were the same or different.[2] On different trials, two adjacent (different) tones in the comparison melody were reversed, changing the melody's contour. Melodies comprised 500 ms consecutive piano tones separated by a 2 s interval between standard and comparison. The task began with two-tone melodies. One additional tone was added after every four trials. To account for the relative ease of recognition compared with recall tasks, the test was discontinued after three incorrect responses. Each four-trial block included at least one *same* and one *different* trial. Tones were drawn from the C-major diatonic scale (C_4–C_5) and melodies were generated pseudo-randomly. The maximum duration was 40 tones. Standard melodies with three or more tones included at least one contour change. For standards with fewer than eight tones, no tones were repeated. In longer melodies, repeated tones were never consecutive.

Each of the three STM tasks was preceded by practice trials and administered twice with different sequences, although sequences and presentation orders were fixed across participants. For each task, scores were the number of sequences recalled correctly, summed across both administrations.

2.2.3. Personality and socio-economic status

Personality was measured using the second edition of the Big Five Inventory [44], a 60-item self-report instrument measuring extraversion, agreeableness, conscientiousness, negative emotionality, and open-mindedness. SES was estimated using the Hollingshead four-factor index [AB Hollingshead 1975, unpublished data], based on parental education, occupation and marital status.

2.3. Procedure

Participants were tested individually in quiet laboratory rooms, using high-quality headphones. Each laboratory followed standardized protocols for recruitment and testing. After providing informed consent, participants completed all tasks on a computer unless stated otherwise. Testing began with the three STM tasks, counterbalancing order in each laboratory, followed by Raven's matrices and the Vocabulary subtest, the latter administered orally and scored manually by an experimenter. Participants then completed the 2-back task, the Mini-PROMS, and the questionnaires (BFI-2, Gold-MSI, SES).

2.4. Data analysis

We combined standard frequentist null-hypothesis significance testing (NHST) with Bayesian analyses in JASP (version 0.19.3, default priors, [64]). Bayes factors (BF_{10}, reported with 3-digit accuracy) quantify the relative likelihood of the data under the alternative hypothesis compared with the null. Following Jarosz's framework [65], BF_{10} values greater than 3.00, 10.0, 33.0 or 100 indicate substantial, strong, very strong or decisive evidence for the alternative hypothesis, respectively. Conversely, values below 0.333, 0.100, 0.033 or 0.010 provide substantial, strong, very strong or decisive evidence for the null hypothesis. BF_{10} values between 0.333 and 3.00 indicated anecdotal or inconclusive evidence. We interpreted group differences as reliable only when both the NHST threshold ($p < 0.05$, uncorrected) and the Bayesian criterion ($BF_{10} \geq 3.00$) were met. When a main effect of group emerged in comparisons among nonmusicians, amateurs, and professionals, we used Tukey's HSD tests along with Bayesian pairwise comparisons.

[2]Although the task involved musical stimuli and could be classified as a measure of musical ability, we included it among the cognitive variables because it was originally designed to target STM rather than perceptual abilities per se.

The dataset is publicly available on the Open Science Framework [66], which hosts all materials from the Music Ensemble Project [47,67]. A detailed description of the dataset is provided in Talamini *et al.* [67]. The laboratories included in the present analyses are listed in electronic supplementary material, table S1.

3. Results

The first set of analyses examined potential demographic differences among the three groups (see table 1 for descriptive statistics). There was decisive evidence that the male/female ratio did not differ across groups, $\chi^2(2, n = 1246) = 4.84$, $p = 0.089$, $BF_{10} = 0.083$. Gender was not considered further. One-way ANOVAs revealed decisive group differences in age, $F(2, 1246) = 21.82$, $p < 0.001$, $\eta^2 = 0.034$, $BF_{10} > 100$; years of education, $F(2, 1246) = 12.43$, $p < 0.001$, $\eta^2 = 0.020$, $BF_{10} > 100$; and SES, $F(2, 1246) = 29.07$, $p < 0.001$, $\eta^2 = 0.045$, $BF_{10} > 100$. Pairwise comparisons found that professionals were older than both amateurs and nonmusicians, *p*s < 0.001, BF_{10}s > 100, and that amateurs were younger than nonmusicians, $p = 0.002$, $BF_{10} = 44.0$. Professionals also had more years of education than both other groups, *p*s < 0.001, BF_{10}s > 100, but amateurs and nonmusicians did not differ, $p = 0.406$, $BF_{10} = 0.196$. Professionals and amateurs came from higher-SES families compared with nonmusicians, *p*s < 0.001, BF_{10}s > 100, but amateurs had higher SES than professionals, $p = 0.019$, $BF_{10} = 5.38$. Thus, age, education and SES were held constant in all subsequent analyses.

3.1. Univariate differences among amateurs, professionals and nonmusicians

Although initial group assignment was based on music training and musicianship status, additional self-report items allowed us to test the validity of the groupings, particularly the distinction between amateurs and professionals. We examined individual items from the Music Training subscale of the Gold-MSI, as well as responses to the open-ended questions. Responses to the open-ended years-of-training question correlated strongly with Gold-MSI item 36, $r = 0.953$, $p < 0.001$, $BF_{10} > 100$. Descriptive statistics appear in table 1.

One-way ANCOVAs controlling for age, education, and SES documented that the three groups differed decisively on all music-training variables, *p*s < 0.001, BF_{10}s > 100, with effect sizes (η^2) ranging from 0.554 (number of instruments played) to 0.918 (Gold-MSI years of lessons, which was one of the variables used to form the groups). Follow-up pairwise comparisons confirmed that large effect sizes stemmed primarily from amateur and professional musicians scoring higher than nonmusicians across all measures, *p*s < 0.001, BF_{10}s > 100. More crucial were comparisons between amateurs and professionals. For the two open-ended items, there was decisive evidence that professionals had more years of lessons and more hours of current daily practice, *p*s < 0.001, $BF_{10} > 100$. For items from the Music Training subscale (measured on 7-point scales), the data provided decisive evidence that professionals had more years of music training, more hours of daily practice at the peak of their interest, more music-theory instruction, and that they were more likely to identify as a musician, *p*s < 0.001, BF_{10}s > 100. There was also substantial evidence that professionals could play more musical instruments, $p < 0.001$, $BF_{10} = 7.45$, but only anecdotal evidence for a group difference in years of regular practice, $p = 0.009$, $BF_{10} = 2.87$. Finally, although Bayesian statistics indicated strong evidence that professionals had received more compliments on their performances compared to amateurs, $BF_{10} = 25.0$, the difference was marginal according to NHST, $p = 0.057$.

3.1.1. Musical abilities

The next set of analyses examined performance on measures of musical ability not directly tied to training, including the objective test of music perception (Mini-PROMS) and the four Gold-MSI subscales other than Music Training. Descriptive statistics are provided in table 2. Group differences are illustrated in figure 1 (left panel).

There was decisive evidence for group differences on the Mini-PROMS, as indicated by a one-way ANCOVA (table 3). All pairwise comparisons were significant, *p*s < 0.001, BF_{10}s > 100: both musician groups outperformed nonmusicians, and professionals outperformed amateurs. The same pattern was evident for the Gold-MSI subscales of Active Engagement, Perceptual Abilities, and Singing Abilities, with all pairwise differences significant, *p*s < 0.001, BF_{10}s > 100. For the Emotions subscale, the results

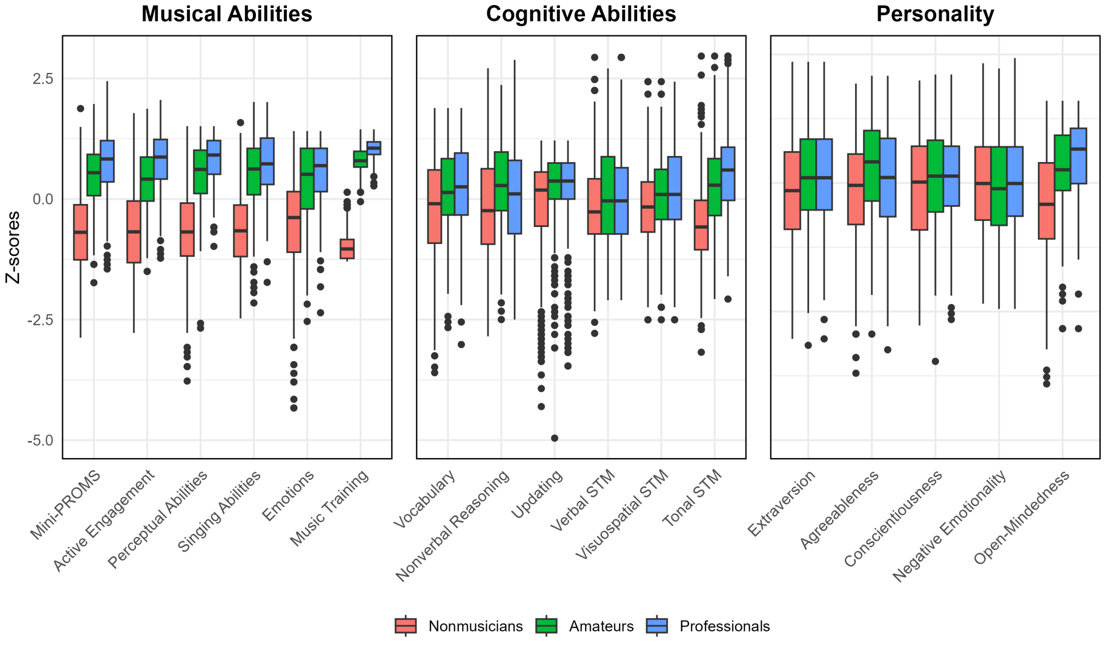

Figure 1. Box plots of musical abilities, cognitive abilities, and personality for nonmusicians, amateurs, and professionals. *Note*. Scores are standardized (*z*-scores) for comparability. Each box represents the interquartile range (IQR; Q1–Q3), with the median shown as a horizontal line. Whiskers extend to values within 1.5 × IQR, and points beyond indicate outliers. One extreme outlier ($z = 9.71$) was removed from the visuospatial STM data to improve visualization.

Table 2. Means (and SDs) for nonmusicians, amateurs, and professionals for musical abilities, cognitive abilities, and personality.

Variable	Nonmusicians *n* = 608	Amateurs *n* = 289	Professionals *n* = 352
Musical abilities			
Mini-PROMS	19.55 (4.31)	25.67 (3.49)	27.23 (3.46)
Active engagement	32.36 (9.59)	43.92 (7.26)	48.07 (6.87)
Perceptual abilities	40.59 (8.26)	53.20 (6.31)	56.00 (5.02)
Music training	11.78 (4.72)	39.07 (4.03)	42.85 (3.02)
Singing abilities	23.87 (7.37)	34.75 (7.19)	37.31 (6.16)
Emotions	31.33 (5.60)	36.21 (4.18)	37.30 (3.82)
Cognitive abilities			
Vocabulary	0.69 (.161)	0.74 (.132)	0.75 (.133)
Nonverbal reasoning	20.56 (5.80)	22.91 (5.44)	21.57 (5.68)
Updating	15.24 (11.27)	19.07 (9.28)	18.40 (10.24)
Verbal STM	9.87 (2.09)	10.36 (2.29)	10.23 (2.22)
Visuospatial STM	8.50 (1.75)	9.03 (1.84)	9.20 (2.17)
Tonal STM	21.50 (5.20)	26.53 (5.60)	28.65 (5.90)
Personality			
Extraversion	39.09 (7.80)	41.22 (8.30)	41.26 (7.78)
Agreeableness	45.21 (6.39)	48.25 (6.04)	46.62 (6.90)
Conscientiousness	41.09 (8.70)	42.75 (8.80)	42.44 (8.17)
Negative emotionality	36.25 (9.53)	35.47 (10.27)	36.37 (10.00)
Open-mindedness	44.97 (7.69)	50.04 (6.19)	51.88 (5.40)

were similar but the difference between professionals and amateurs was smaller, $p = 0.024$, $BF_{10} = 26.8$. Thus, across objective and self-reported measures of musical abilities, musicians scored higher than nonmusicians and professionals scored higher than amateurs.

3.1.2. Cognitive abilities

As shown in table 3 and figure 1 (middle panel), ANCOVAs provided decisive evidence of group differences in vocabulary, updating, and nonverbal reasoning. For vocabulary and updating, the pattern was similar. Both amateur and professional musicians outperformed nonmusicians, *p*s < 0.001, BF_{10}s > 100, but there was substantial evidence that professionals did *not* differ from amateurs (vocabulary, $p = 0.948$, $BF_{10} = 0.105$; updating, $p = 0.722$, $BF_{10} = 0.117$). For nonverbal reasoning, however, there was decisive evidence that amateurs outperformed nonmusicians, $p < 0.001$, $BF_{10} > 100$, and that professionals performed significantly *worse* than amateurs, $p = 0.036$, $BF_{10} = 8.07$, but similarly to nonmusicians, $p = 0.121$, $BF_{10} = 2.07$, although Bayesian evidence for no difference between professionals and nonmusicians was weak.

To examine further the apparent curvilinear association between musicianship and nonverbal reasoning, we conducted a multiple-regression analysis, predicting nonverbal reasoning from years of music training (open-ended question, centred) and its quadratic (squared) term. This approach allowed us to test formally for an inverted U-shaped association. There was decisive evidence for a positive linear effect, $p < 0.001$, $BF_{10} > 100$, and very strong evidence for a negative quadratic effect, $p = 0.005$, $BF_{10} = 53.2$. These results confirm that nonverbal reasoning was highest at intermediate levels of training but lower among individuals with minimal or maximal years of training.

Results for STM varied across tasks. For verbal STM, group differences were very small, with Bayesian analyses providing substantial evidence for the null hypothesis (table 3). Because this result appeared to differ from the original study [47], which had no covariates, we repeated the analysis excluding age, education, and SES as covariates. There was now substantial evidence for an overall group difference in verbal STM, $F(2, 1241) = 6.22$, $p = 0.002$, $\eta^2 = 0.010$, $BF_{10} = 4.28$. Nevertheless, amateurs and professionals did not differ, $p = 0.717$, $BF_{10} = 0.117$. Although amateurs outperformed nonmusicians, $p = 0.004$, $BF_{10} = 12.9$, the difference between professionals and nonmusicians was significant with NHST, $p = 0.034$, but weak according to Bayesian analysis, $BF_{10} = 1.75$.

For visuospatial STM, there was decisive evidence for a group effect (table 3). Both musician groups outperformed nonmusicians, *p*s = 0.001, BF_{10}s > 100, but amateurs and professionals did not differ, $p = 0.529$, $BF_{10} = 0.158$. Finally, for tonal STM, which had musical stimuli, there was decisive evidence for group differences and for all pairwise comparisons, *p*s < 0.001, BF_{10}s > 100. The pattern mirrored that of the musical tasks, with professionals outperforming amateurs, who in turn outperformed nonmusicians.

In short, for cognitive tasks other than tonal STM, group effects were either absent (verbal STM) or musicians outperformed nonmusicians. Professionals did not outperform amateurs in any instance, however, and for nonverbal reasoning they performed worse than amateurs.

3.1.3. Personality

As shown in table 3 and figure 1 (right panel), there was very strong to decisive evidence for group differences in extraversion, agreeableness, and open-mindedness. Open-mindedness accounted for substantially more variance than the other traits, as reflected in η^2 values. For negative emotionality, there was decisive evidence for no group differences. For conscientiousness, although NHST suggested a small effect, Bayesian analyses provided only anecdotal evidence.

Pairwise comparisons revealed that both amateurs, $p = 0.008$, $BF_{10} = 74.2$, and professionals, $p < 0.001$, $BF_{10} > 100$, scored higher than nonmusicians on extraversion, with no difference between the two musician groups, $p = 0.890$, $BF_{10} = 0.089$. For agreeableness, amateurs were more agreeable than both nonmusicians, $p < 0.001$, $BF_{10} > 100$, and professionals, $p = 0.005$, $BF_{10} = 11.0$. Professionals fell in between, but they still scored higher than nonmusicians, $p = 0.020$, $BF_{10} = 11.3$. Finally, open-mindedness showed decisive group differences for all comparisons, BF_{10}s > 100, with both musician groups scoring higher than nonmusicians, *p*s < 0.001, and professionals scoring higher than amateurs, $p = 0.006$.

In short, both musician groups scored higher than nonmusicians in extraversion, agreeableness, and open-mindedness, with the strongest group differences observed for open-mindedness. Professionals

Table 3. Results from three-group comparisons (ANCOVAs).

Variable	F(2, 1243)	d.f.	p	η^2	BF_{10}
Musical abilities					
Mini-PROMS	471.69	2, 1243	< 0.001	0.428	> 100
Active engagement	422.17	2, 1243	< 0.001	0.404	> 100
Perceptual abilities	600.43	2, 1243	< 0.001	0.490	> 100
Singing abilities	460.53	2, 1243	< 0.001	0.424	> 100
Emotions	190.11	2, 1243	< 0.001	0.233	> 100
Cognitive abilities					
Vocabulary	19.16	2, 1233	< 0.001	0.029	> 100
Nonverbal reasoning	10.48	2, 1243	< 0.001	0.016	> 100
Updating	12.88	2, 1240	< 0.001	0.020	> 100
Verbal STM	3.30	2, 1238	0.037	0.005	0.277
Visuospatial STM	14.57	2, 1239	< 0.001	0.023	> 100
Tonal STM	188.83	2, 1238	< 0.001	0.232	> 100
Personality					
Extraversion	8.61	2, 1243	< 0.001	0.014	47.7
Agreeableness	18.13	2, 1243	< 0.001	0.028	> 100
Conscientiousness	3.86	2, 1243	0.021	0.006	0.458
Negative emotionality	0.96	2, 1243	0.382	0.002	0.026
Open-mindedness	123.21	2, 1243	< 0.001	0.165	> 100

Note. Age, education and SES were held constant.

and amateurs did not differ in extraversion, although professionals were more open-minded and less agreeable than amateurs.

3.2. Multivariate differences between amateurs and professionals

To isolate factors that distinguished amateurs from professional musicians, we conducted three logistic regressions, each with a different set of predictors: musical abilities, cognitive abilities, or personality traits. In each model, age, education and SES were included as covariates, and all nondemographic predictors were standardized to facilitate comparison of odds ratios (OR). Amateurs were the reference group (coded 0). These analyses estimated the unique contribution of each variable in predicting the likelihood of being a professional, while simultaneously controlling for other variables from the same domain. Correlations among predictors are provided in electronic supplementary material, tables S2–S5, separately for each model.

The covariates alone increased predictive accuracy from chance (50%) to 59.3%, $\Delta\chi^2 = 47.14$, $p < 0.001$, McFadden $R^2 = 0.053$, $BF_{10} > 100$. Age contributed decisively, $p < 0.001$, $BF_{10} > 100$, consistent with the earlier finding that professionals were older than amateurs. SES contributed significantly with NHST, $p = 0.032$, but Bayesian evidence was inconclusive, $BF_{10} = 2.09$. There was substantial Bayesian evidence that education did not make an independent contribution, $p = 0.427$, $BF_{10} = 0.304$.

3.2.1. Musical abilities

To evaluate the extent to which musical abilities predicted which musicians were professionals, we tested a model that included the Mini-PROMS and four Gold-MSI subscales, excluding Music Training. This model increased classification accuracy significantly to 66.9%, $\Delta\chi^2 = 73.510$, $p < 0.001$, McFadden $R^2 = 0.088$, $BF_{10} > 100$. Summary statistics are provided in table 4, with ORs illustrated in figure 2 (top panel). Active Engagement and Mini-PROMS were significant independent predictors, with decisive and strong evidence, respectively. A 1-SD increase in Active Engagement more than doubled the odds of being a professional (OR = 2.20); a similar increase in Mini-PROMS scores raised the odds by a factor of 1.57.

3.2.2. Cognitive abilities

The next model predicted which musicians were professionals as a function of six cognitive variables: vocabulary, nonverbal reasoning, updating, and the three STM measures (verbal, visuospatial, and tonal). The model increased predictive accuracy to 63.2%, $\Delta\chi^2 = 32.65$, $p < 0.001$, McFadden $R^2 = 0.040$, $BF_{10} > 100$. Summary statistics are provided in table 4. ORs are illustrated in figure 2 (middle panel). Tonal STM and nonverbal reasoning were the strongest independent contributors, with decisive and substantial evidence, respectively. A 1-*SD* increase in tonal STM was associated with a 1.69-fold increase in the odds of being a professional. By contrast, higher levels of nonverbal reasoning were linked to reduced odds of professional status, with a 1.27-fold decrease per SD increase (i.e. OR = 0.785). Verbal STM showed a small negative contribution (OR = 0.810), but Bayesian evidence for this effect was weak. None of the remaining predictors reached the threshold for substantial evidence.

3.2.3. Personality

The model with the five personality traits improved classification accuracy to 63.0%, $\Delta\chi^2 = 28.50$, $p < 0.001$, McFadden $R^2 = 0.034$, $BF_{10}>100$. Summary statistics are provided in table 4, and ORs are illustrated in figure 2 (bottom panel). Open-mindedness and agreeableness made decisive independent contributions. A 1-*SD* increase in open-mindedness raised the odds of being a professional by a factor of 1.68. A 1-*SD* increase in agreeableness reduced the odds by a factor of 1.42. There was no evidence that any of the other three traits had independent predictive value.

3.2.4. Combined model

To identify the most robust predictors of professional status across domains, we tested a final logistic-regression model that included the two significant predictors from each domain: Active Engagement and Mini-PROMS (musical abilities), tonal STM and nonverbal reasoning (cognitive abilities), and open-mindedness and agreeableness (personality). As in previous models, age, education and SES were included as covariates. This model improved predictive accuracy to 71.2%, $\Delta\chi^2 = 97.25$, $p < 0.001$, McFadden $R^2 = 0.117$, $BF_{10} > 100$. Summary statistics are provided in table 5 and ORs are illustrated in figure 3. The data provided decisive evidence that both Active Engagement and agreeableness made independent contributions. Whereas a 1-*SD* increase in Active Engagement continued to more than double the odds of being a professional (OR = 2.22), higher agreeableness was associated with reduced odds (OR = 0.706), which corresponded to a 1.41-fold decrease.

There was also very strong evidence for independent contributions of Mini-PROMS and age: the odds of being a professional increased by a factor of 1.67 for each 1-*SD* increase in Mini-PROMS and by 1.16 for each additional year of age. Moreover, the data provided strong evidence that nonverbal reasoning and tonal STM also made independent contributions: higher tonal STM increased the odds of being a professional by a factor of 1.35, whereas higher nonverbal reasoning decreased the odds by a factor of 1.34. Finally, there was substantial evidence that higher SES slightly decreased the likelihood of being a professional by a factor of 1.02. Notably, open-mindedness did not contribute independently to the model.

3.2.5. Mediation

The null effect of open-mindedness was unexpected considering its robust predictive value in the earlier analyses. To explore the possibility of an indirect effect, we conducted a mediation analysis. Among the predictor variables, there was decisive evidence that open-mindedness and Active Engagement were correlated, $r = 0.457$, $p < 0.001$, $BF_{10} > 100$, and that Active Engagement was associated with professional status, $r = 0.275$, $p < 0.001$, $BF_{10} > 100$. These patterns raised the possibility that individuals who are high in open-mindedness may also be more likely to engage with music, which in turn relates to professional status.

The mediation model included direct paths from all predictors to professional status (see table 5) as well as an indirect path from open-mindedness via Active Engagement. As shown in figure 4, the

Table 4. Summary statistics from logistic-regression models predicting which musicians were professionals.

Model	Estimate	SE	OR	z	Wald	*p*	BF_{10}
Musical abilities							
Mini-PROMS	0.454	0.144	1.57	3.16	9.98	0.002	35.9
Active engagement	0.788	0.162	2.20	4.87	23.74	< 0.001	> 100
Perceptual abilities	0.360	0.204	1.43	1.77	3.12	0.077	1.24
Singing abilities	0.138	0.145	1.15	0.95	0.90	0.342	0.426
Emotions	−0.141	0.150	0.868	−0−	0.89	0.346	0.421
Cognitive abilities							
Vocabulary	0.046	0.104	1.05	0.45	0.20	0.654	0.385
Nonverbal reasoning	−0.243	0.099	0.785	−2.45	6.02	0.014	5.52
Updating	−0.017	0.102	0.983	−0.17	0.03	0.867	0.357
Verbal STM	−0.211	0.097	0.810	−2.17	4.71	0.030	2.96
Visuospatial STM	0.150	0.089	1.16	1.69	2.86	0.091	1.36
Tonal STM	0.522	0.107	1.69	4.88	23.85	< 0.001	> 100
Personality							
Extraversion	−0.065	0.091	0.937	−0.72	0.51	0.474	0.424
Agreeableness	−0.348	0.094	0.706	−3.70	13.70	< 0.001	> 100
Conscientiousness	0.024	0.089	1.03	0.27	0.08	0.784	0.346
Negative emotionality	−0.047	0.089	0.954	−0.53	0.28	0.599	0.379
Open-mindedness	0.518	0.122	1.68	4.25	18.09	< 0.001	> 100

Note. Age, education and SES were held constant. Predictor variables were standardized. SE = standard error; OR = odds ratio.

direct effect of open-mindedness on professional status was not significant, $\beta = 0.04$, $p = 0.187$, as in the logistic-regression findings (table 5). Nevertheless, the indirect path through Active Engagement was significant, $\beta = 0.06$, $p < 0.001$, such that the total effect of open-mindedness was also significant, $\beta = 0.10$, $p < 0.001$. In short, Active Engagement mediated the association between open-mindedness and professional musicianship.

4. Discussion

The present study examined the association between music training and nonmusical variables [13,28]. We compared large samples of nonmusicians, amateur musicians, and professional musicians on measures of musicality, cognitive abilities, and personality. As expected, groups differed in self-reported musicianship and in multiple aspects of their musical background, including duration of music training, playing and practice; number of instruments played; and history of studying music theory and receiving compliments on performances. In all instances, professional musicians reported the most extensive experience, followed by amateurs, then nonmusicians. Thus, if musical expertise improves nonmusical cognitive abilities, such improvements should, in principle, be most apparent among professionals.

Preliminary analyses revealed additional group differences in age, education, and SES, consistent with previous results [38,43]. These findings confirm that sociodemographic factors are associated with taking music lessons and becoming a professional musician. To account for these confounding variables, we controlled for age, education, and SES in all analyses. Group differences also extended to objective tests of music perception and self-reported musical sophistication (Gold-MSI subscales). Professionals scored higher than amateurs, who scored higher than nonmusicians. When comparing amateurs and professionals while considering all musical-expertise variables simultaneously, two independent predictors of professional status emerged: music-perception abilities and active engagement with music (Gold-MSI subscale). Given the quasi-experimental design, causal inferences are

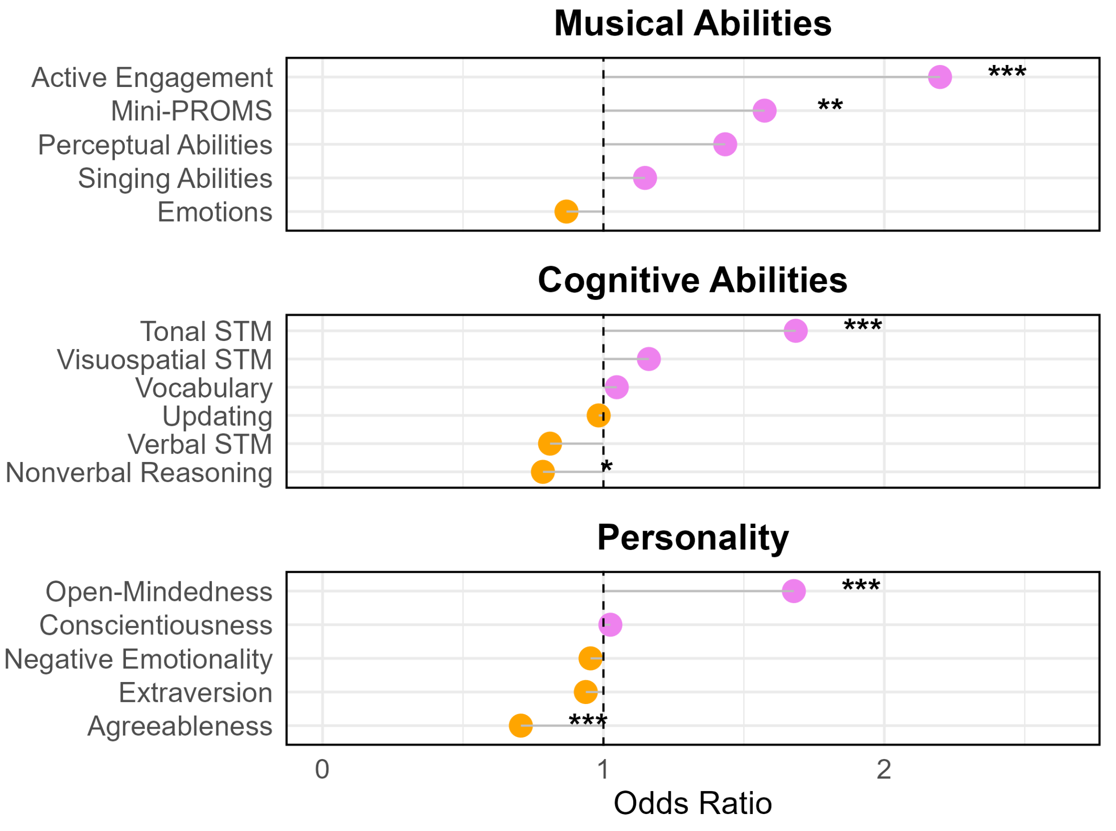

Figure 2. Odds ratios of being a professional musician predicted by musical abilities, cognitive abilities, and personality. *Note*. *$p < 0.05$, $BF_{10} > 3$; **$p < 0.05$, $BF_{10} > 33$; ***$p < 0.05$, $BF_{10} > 100$. Pink dots represent an increase in the likelihood of being a professional; orange dots represent a decrease in the likelihood.

precluded. Music training and experience could enhance perceptual abilities and foster regular contact with music, or individuals with a natural interest in music and good musical aptitude could be more inclined to pursue a professional music career. Both processes are likely to be complementary, reflecting gene-environment interactions.

Different patterns emerged for cognitive variables, except for tonal STM, when professionals again performed best. The tonal STM test indexed participants' ability to discriminate melodies and was similar to the music-perception tasks, although designed to emphasize memory demands. In any case, professionals outperformed amateurs and nonmusicians on all tasks involving musical stimuli.

For nonmusical cognitive variables, associations with musical expertise were more complex. For verbal STM, the three groups performed similarly, a finding that appears to contrast with findings from the original multi-lab study [47], potentially due to differences in sample composition, categorization of musicians into two groups, inclusion of covariates, or analytic approach (Bayesian statistics). Nevertheless, even in the original study, group membership was not an independent predictor of verbal STM. Rather, age, SES, nonverbal ability, and updating scores were. Both studies highlight the importance of controlling for extraneous differences when comparing musicians and nonmusicians. Our verbal STM task also used visually presented digits. Musician advantages can be more likely with auditory or audiovisual presentation formats [48–50].

The most common pattern for cognitive variables was an advantage for both musician groups, which emerged for vocabulary, updating, and visuospatial memory, as in previous research [68–70]. These advantages were small, however (see η^2 values in table 3), and in no instance did professionals outperform amateurs. Thus, if cognitive advantages stem from musical experience, as often assumed, they appear to be at least partially independent of increasing musical expertise. One possibility is that far-transfer effects plateau beyond a certain level of experience, a phenomenon sometimes observed in clinical [71] and ageing populations [72]. Nevertheless, plateau effects are not part of current proposals of far transfer from music training. Moreover, in the present data, this explanation would remain inconsistent with the monotonic increase that we observed in musical abilities, and with professionals performing lower than amateurs for nonverbal reasoning. Why would musical abilities, but not cognitive performance, be higher with additional experience? Selection effects offer

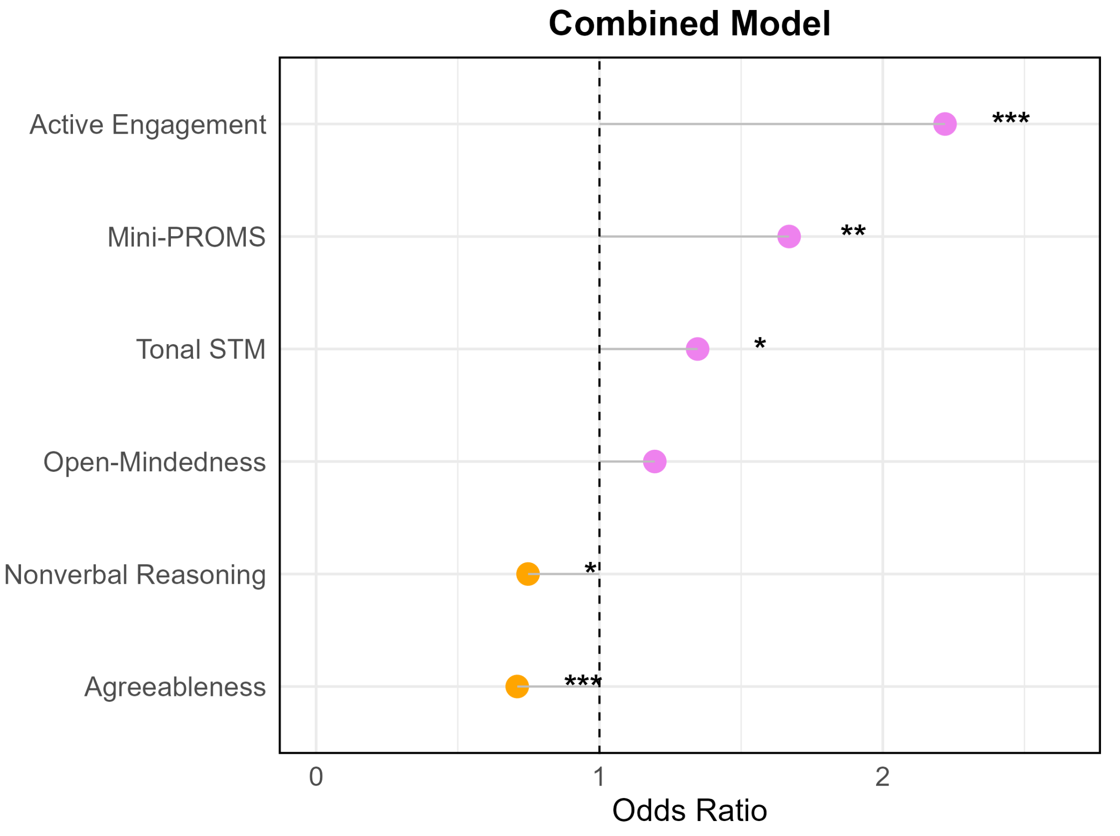

Figure 3. Odds ratios of being a professional musician resulting from the combined model. *Note.* *$p < 0.05$, $BF_{10} > 3$; **$p < 0.05$, $BF_{10} > 33$; ***$p < 0.05$, $BF_{10} > 100$. Pink dots represent an increase in the likelihood of being a professional, whereas orange dots represent a decrease in the likelihood.

Table 5. Summary statistics from combined logistic-regression model predicting which musicians were professionals.

Model	Estimate	SE	OR	z	Wald	*p*	BF_{10}
Age	0.149	0.049	1.16	3.04	9.25	0.002	33.7
Education	−0.027	0.066	0.974	−0.41	0.17	0.683	0.303
SES	−0.017	0.007	0.983	−2.55	6.52	0.011	6.90
Mini-PROMS	0.513	0.154	1.67	3.32	11.03	< 0.001	64.1
Active engagement	0.797	0.157	2.22	−2.55	25.91	< 0.001	> 100
Tonal STM	0.297	0.109	1.35	2.72	7.39	0.007	10.3
Nonverbal reasoning	−0.290	0.098	0.748	−2.97	8.81	0.003	21.6
Open-mindedness	0.178	0.133	1.120	1.34	1.80	0.179	0.668
Agreeableness	−0.343	0.095	0.710	−3.62	13.11	< 0.001	> 100

Note. Predictor variables except age and education were standardized. SE = standard error; OR = odds ratio.

a simple explanation. Individuals with higher preexisting musical and cognitive abilities—along with favourable personality and SES—may be more likely to engage and persist in music lessons in general [14,38,43]. Pursuing a professional career may depend critically on optimal musical aptitude rather than cognitive ability, explaining why professionals exhibit maximal expertise without corresponding cognitive advantages.

A particularly interesting finding emerged from evidence of a curvilinear association between musical expertise and nonverbal reasoning. Amateurs scored highest, with nonmusicians and professionals performing similarly. This pattern held when using years of training as a continuous predictor, and after adjusting for other cognitive and demographic variables. Vincenzi *et al.* [43] reported a similar pattern using a different test, the Matrix Reasoning Item Bank—MaRs-IB [73],

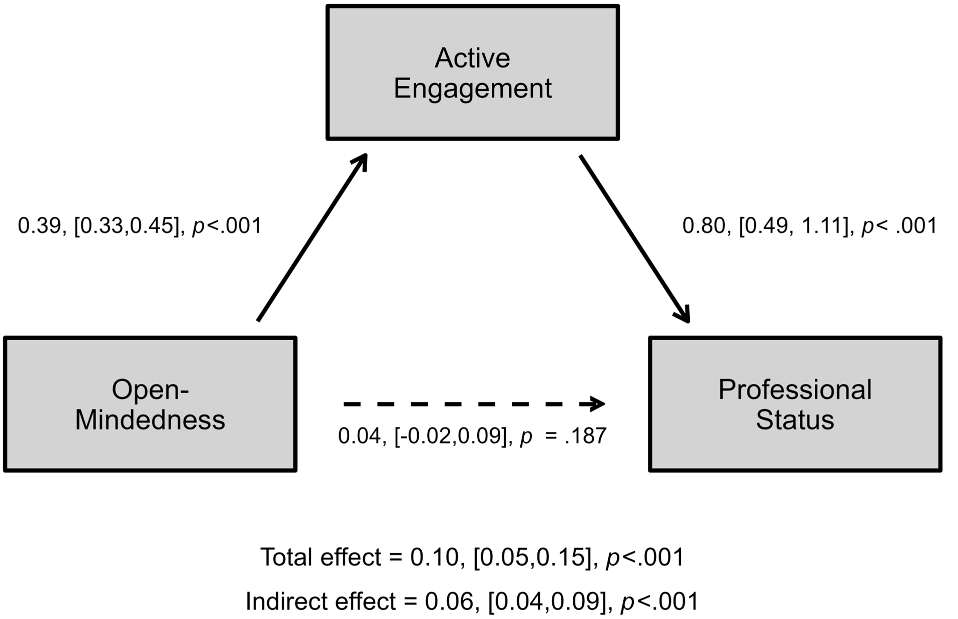

Figure 4. Model illustrating the mediation of active engagement on the association between open-mindedness and professional status. *Note*. The model held constant age, education, SES, mini-PROMS scores, tonal STM, nonverbal reasoning and agreeableness. Values in brackets indicate 95% confidence intervals (CIs). These CIs were estimated using a nonparametric percentile bootstrap with 20 000 resamples.

and different scoring method, which suggests that the finding is robust across independent samples and methods. Perhaps individuals who self-identify as amateurs engage simultaneously in musical activities and other career or educational pursuits, which place higher cognitive demands on them. Alternatively, amateurs may be more likely to work in fields where strong nonverbal reasoning or general intelligence is particularly beneficial, pointing to a selection effect rather than a direct influence of musical practice.

Are similar nonlinear associations evident outside the domain of music? In a large sample of Swedish men (n = 59.000), Keuschnigg *et al.* [74] observed a plateau in the association between income and cognitive ability. Cognitive scores increased with income up to approximately 60.000€ (around $70.000 USD), then levelled off and declined slightly at the highest income percentiles. The authors suggested that brighter individuals choose prestigious but less financially rewarding professions, and/or that extreme financial success reflects a combination of cognitive ability and chance. In line with this view, Denrell & Liu [75] concluded that exceptional career success tends to involve more randomness (e.g. early advantages, luck) than skill alone. Although higher cognitive abilities correlate generally with expertise in soccer [76], gaming [77], chess [78] and music [79], exceptional success may depend on additional factors, such as personality, opportunity, and chance, diminishing the relative role of cognitive skills. Notably, one study on soccer expertise assumed that personality and cognitive predispositions influence who becomes an expert [76], in contrast to much music-training research, which often considers training as the causal factor, despite the fact that most available evidence is similarly correlational.

Controversies about causality have been raised in other areas. For example, a recent study with over 170 000 individuals concluded that the widespread belief that education attenuates age-related cognitive decline is not supported empirically; rather, observed associations more likely reflect preexisting individual differences, such as the tendency for individuals with certain neurobiological traits to engage in education for longer periods of time [80]. For music, a large study involving over 10 500 twins found that the association between music practice and IQ vanished after accounting for genetic and shared environmental factors, indicating that the link between music and intelligence reflects shared genetic predispositions rather than effects of training [81].

In terms of personality, our groups differed markedly in open-mindedness, with professionals being particularly open-minded. Agreeableness showed a similar curvilinear pattern to nonverbal reasoning. Amateurs were more agreeable than both professionals and nonmusicians. Finally, extraversion differed across musicians and nonmusicians, but not between amateurs and professionals. The same results were evident when we considered all personality traits simultaneously and used logistic regression to predict professional status. Open-mindedness increased the odds of being a professional by nearly 70% per 1-*SD* increase. Similar patterns for open-mindedness and agreeableness were identified by Kuckelkorn *et al.* [46].

Although Vincenzi *et al.* [43] found that musicians scored higher than nonmusicians for both open-mindedness and agreeableness, their amateurs and professionals did not differ, and professionals were particularly extraverted. Differences between these findings and ours, and across studies more generally, may stem from different personality measures, classification criteria for amateurs and professionals, or the percentage of singers, who tend to be particularly extraverted [46]. Nevertheless, open-mindedness is associated consistently with music construed broadly. In addition to increasing the odds of becoming a professional musician, open-minded individuals are more likely to engage and persist in music lessons [38], to enrol their children in music lessons [82], to score higher on musical expertise [17,18,57,83], and to have extreme emotional responses to music (e.g. awe [84,85]). In short, open-mindedness is a good predictor of an interest in music and responses to music, as it is for the arts in general [86–88].

Six variables (excluding demographics) predicted professional status when controlling for other variables from the same domain. Five made independent contributions when all six were considered simultaneously, the exception being open-mindedness, which was surprising considering its strong predictive power in other analyses. Nevertheless, open-mindedness had a strong indirect association mediated by Active Engagement (Gold-MSI subscale), which assessed overall involvement with music (e.g. *Music is kind of an addiction for me—I couldn't live without it*). Although correlational, this finding suggests that open-mindedness may foster active engagement, which in turn increases the likelihood of becoming a professional musician. To our knowledge, this mediation effect is novel. Moreover, because of its exploratory nature, the finding needs to be replicated in future research.

In sum, we documented differences across musical, cognitive, and personality domains among nonmusicians, amateur musicians, and professional musicians. Professionals performed best on all music-related measures, including tonal STM, but this advantage did not extend to nonmusical cognitive tasks. Verbal STM showed no group differences. For vocabulary, updating, and visuospatial STM, both musician groups had small advantages that did not differ, and nonverbal reasoning revealed a curvilinear pattern, with amateurs performing best. Thus, except for tasks involving musical stimuli, professionals never outperformed amateurs in cognitive performance.

Our results challenge claims of far transfer from musical expertise to cognition. In our view, a parsimonious explanation is that the differences observed for musicians stem largely from preexisting factors, including open-mindedness and agreeableness, good natural musical ability, above-average cognitive ability [16,17,56,89], as well as more education and higher SES [38]. Crucially, professionals differed from amateurs, not because of their cognitive performance, but because of their musical ability and open-mindedness, which likely promoted consistent and active engagement with music, while reducing the relative influence of other factors (e.g. agreeableness, cognitive abilities, SES) in pursuing a professional career. Future longitudinal and genetic studies could help to disentangle these processes. Overall, our findings provide support for a nuanced perspective on the relation between musical expertise and cognitive abilities, and highlight the importance of distinguishing between different profiles of expertise when studying these associations.

Ethics. This work did not require ethical approval from a human subject or animal welfare committee.

Data accessibility. The dataset analysed in this article is freely available for public use at the OSF platform [66].

Supplementary material is available online [90].

Declaration of AI use. We have not used AI-assisted technologies in creating this article.

Authors' contributions. F.T.: conceptualization, data curation, formal analysis, project administration, validation, visualization, writing—original draft, writing—review and editing; G.S.: conceptualization, formal analysis, validation, writing—original draft, writing—review and editing; M.G.: data curation, project administration, writing—review and editing; C.F.L.: conceptualization, validation, writing—original draft, writing—review and editing.

All authors gave final approval for publication and agreed to be held accountable for the work performed therein.

Conflict of interest declaration. César Lima (author of the manuscript) is a member of the Royal Society Open Science editorial board at the time of submission; however, he was not involved in the editorial assessment of the manuscript in any way.

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