The Effect of Music Training and Musical Literacy on Empathy

Authors: Mount Hua, Jiang Xintong, Gao Yangzhenyu, Mu Yan, Du Yi, Mu Yan, Du Yi

Date: 2024-09-10T00:00:00+00:00

Abstract

Empathy constitutes a crucial factor in predicting and facilitating prosocial behavior, and music training is believed to promote the development of empathic ability. An individual's musical literacy represents a comprehensive manifestation of their musical experience; even without formal music training, individuals possess a certain level of musical literacy and can accumulate musical experience through such training. However, it remains unclear whether the influence of musical experience on empathy originates from the effects of music training or from differences in musical literacy, nor is it clear which specific components of empathy are affected and the pathways through which musical experience exerts its influence. This study examines both trait empathy and state empathy as two entry points, employs music training and musical literacy as two indicators to measure individual musical experience, and utilizes questionnaires and behavioral experiments to explore their influence pathways on empathic ability. The results demonstrate that in terms of trait empathy, musicians exhibit significantly higher cognitive empathy ability than non-musicians. However, after controlling for relevant variables including personality, subjective socioeconomic status, and mental health status, music training shows no significant effect on empathy. Conversely, musical literacy significantly positively predicts the fantasy dimension of cognitive empathy and can even serve as a mediating variable through which music training influences the fantasy dimension of cognitive empathy. Regarding state empathy, employing the pain empathy paradigm, the study reveals that compared to non-musicians, musicians demonstrate greater empathic resonance when witnessing others in painful situations. This state empathic ability is influenced by a chain mediation effect of musical literacy and the fantasy dimension of trait cognitive empathy. In summary, music training indirectly enhances cognitive empathy ability (fantasy) within trait empathy by improving musical literacy, thereby enabling musicians to exhibit stronger capacity in empathizing with others' painful states. These findings elucidate the

facilitating mechanism through which musical experience promotes empathic ability.

Full Text

The Impacts of Music Training and Music Sophistication on Empathy

HUA Shan[1,2]†, JIANG Xintong[1,2]†, GAO Yangzhenyu[4], MU Yan[1,2]‡, DU Yi[1,2,3]‡

[1] Institute of Psychology, Chinese Academy of Sciences, Beijing 100101
[2] Department of Psychology, University of Chinese Academy of Sciences, Beijing 100049
[3] Chinese Institute for Brain Research, Beijing 102206
[4] College of Life Sciences, University of Chinese Academy of Sciences, Beijing 100049

Abstract

Empathy is a crucial factor in predicting and promoting prosocial behavior, and music training is believed to facilitate its development. Musical sophistication represents a comprehensive manifestation of an individual's musical experience. Even without formal music training, individuals possess varying levels of musical sophistication that can be cultivated through musical engagement. However, it remains unclear whether the influence of musical experience on empathy stems from the effects of music training or from differences in musical sophistication. The specific components of empathy affected and the pathways through which musical experience operates are also unknown. This study investigated these questions by examining both trait empathy and state empathy, using music training and musical sophistication as indicators of musical experience. Through questionnaire surveys and behavioral experiments, we explored their influence pathways on empathic abilities. Results showed that for trait empathy, musicians exhibited significantly higher cognitive empathy than non-musicians. However, after controlling for personality, subjective socioeconomic status, and mental health variables, music training showed no significant direct effect on empathy. In contrast, musical sophistication significantly and positively predicted the fantasy dimension of cognitive empathy and even served as a mediator between music training and this dimension. For state empathy, using a pain empathy paradigm, we found that musicians experienced stronger empathic responses when witnessing others in pain compared to non-musicians. This state empathy was serially mediated by musical sophistication and the fantasy dimension of trait cognitive empathy. In summary, music training indirectly enhances cognitive empathy (fantasy) in trait empathy by improving musical sophistication, which in turn enables musicians to show greater empathic resonance with others' pain states. These findings reveal the mechanisms through which musical experience promotes empathic abilities.

Keywords: music training, musical sophistication, trait empathy, state empathy, pain empathy

---

Introduction

Empathy is the capacity or psychological process through which individuals accurately perceive and experience others' emotional states, generating a resonant response (Preston & de Waal, 2002). It plays a critical role in social interaction and cooperation (Han et al., 2009) and serves as a key motivational factor directly triggering prosocial behavior (Batson et al., 2007), capable of predicting individuals' prosocial tendencies (Eisenberg & Miller, 1987; Roberts & Strayer, 1996; Zhang et al., 2021). Empathy functions both as a stable personality trait or ability and as a psychological process (Huang & Su, 2010), with the empathic process emerging from the interaction between trait capacities and situational influences (Cuff et al., 2016). Trait empathy represents relatively stable abilities or personality traits, reflecting how well individuals can understand and feel others' mental states and thoughts. State empathy, conversely, is a psychological process occurring in real-world contexts, influenced not only by individual trait empathy but also subject to change with varying situations and emotional states.

Empathy comprises both cognitive and affective components. The cognitive component refers to the ability to identify and understand others' emotions or perspectives (including real-world perspective-taking and immersing oneself in a protagonist's role and circumstances in fictional scenarios), involving higher-order cognitive processes such as self-other distinction and reasoning. The affective component reflects the capacity to perceive and experience others' states, involving more automatic, primary cognitive processes (Walter, 2012). These two components are neurologically dissociable (Shamay-Tsoory et al., 2009; Fan et al., 2011; Yu & Chou, 2018). Notably, the ability to distinguish self from others is fundamental to empathy. During state empathy, individuals must process perspective information from both self and other viewpoints to achieve emotional sharing and cognitive regulation (Huang & Su, 2010; Cuff et al., 2016). Research by Zhong et al. (2015) found that higher self-other overlap leads to more pronounced helping behavior, demonstrating that the overlap in self-other information representation is particularly important for generating prosocial behavior.

Empathy essentially requires "feeling with" others, necessitating the utilization of overlapping emotional or sensory information from both self and other perspectives in state empathy. Pain empathy represents a crucial form of state empathy, manifesting as the degree to which individuals resonate with others' pain when witnessing painful situations (Meng et al., 2010). Pain empathy paradigms allow simultaneous collection of self-reported feelings and judgments about others' feelings on identical measurement scales (Han et al., 2009), thereby quantifying the degree of "feeling with" in state empathy.

Music and empathy are closely intertwined. As a unique and ancient social activity, music can reduce interpersonal distance and enhance group cohesion (Cross et al., 2012). The "Music and Social Bonding" hypothesis (Savage et al., 2021) posits that supporting social connection and facilitating social interaction are core functions in the evolution of human music, with a potential causal relationship between music and social bonding. Music's rhythmic structure and repetitive characteristics promote interpersonal synchronization and coordination (e.g., dance, choir), while its sociocultural meanings help construct and strengthen group identity. The rich social interactions and connections generated through musical participation and intervention foster prosocial behavior (Savage, 2019; Savage et al., 2021). Moreover, empathic ability plays an important role in music perception and interaction. Individuals with high empathy are better at recognizing emotions expressed in music (Steele, 2019), particularly sadness (Eeroia et al., 2016; Kawakami & Katahira, 2015; Wöllner, 2012), and more easily synchronize with others musically (Stupacher et al., 2022). During music appreciation, individuals undergo a process similar to empathy, imagining music as a virtual "personality" with its own emotions and intentions, and connecting it with their own thoughts and feelings to understand, experience, and interpret music (Jackendoff & Lerdahl, 2006; Perlovsky, 2012; Epperson, 1967). This musical empathizing—a more perceptual cognitive process of understanding others' emotions and self-reflection—represents an important cognitive style in music perception and experience (Greenberg & Rentfrow et al., 2015).

Consequently, music training is considered an effective means to enhance empathy (Wu & Lu, 2021). Studies show that after music training, children exhibit more cooperative behavior (Rabinowitch & Knafo-Noam, 2015; Rabinowitch & Meltzoff, 2017; Wan & Zhu, 2021), are more willing to help others (Wan & Zhu, 2021), and develop prosocial skills (Schellenberg et al., 2015). Longitudinal research indicates that compared to control groups, 6-7-year-old children who received three months of music training showed significantly improved empathy (Kalliopuska & Ruókonen, 1986), with effects persisting at nine-month follow-up (Kalliopuska & Ruókonen, 1993). Music training has also been found to significantly enhance affective empathy in 10-year-old schoolchildren (Rabinowitch et al., 2013), though this study did not measure cognitive empathy. Regarding mechanisms, some researchers propose that music training enhances perception of emotion carried in sound, making adult musicians more sensitive to pitch information in vocal processing than non-musicians, which aids emotional understanding (Kraus & Chandrasekaran, 2010). Research shows musicians' sensitivity to pitch information helps perceive infant emotions (Parsons et al., 2014), indirectly reflecting higher empathy levels. Long-term music training can alter brain structure, shaping musicians' ventromedial prefrontal cortex (vmPFC) and inferior frontal gyrus (IFG) (Olszewska et al., 2021)—brain regions overlapping with those involved in processing cognitive and affective components of empathy (Shamay-Tsoory et al., 2009). However, direct evidence confirming music training's promotion of adult empathy remains lacking, and it is unclear whether its effects occur in cognitive or affective components.

Therefore, investigating music training's impact on empathy requires examining its effects on different components. Davis (1983) proposed four dimensions—Perspective Taking, Fantasy, Empathic Concern, and Personal Distress—to comprehensively assess trait empathy. Fantasy, as the ability to immerse oneself in fictional situations, is closely related to artistic activities (including music) (Stotland, 1978). Perspective Taking, while not directly associated with music activities, represents the ability to place oneself in others' real-world situations. Fantasy and Perspective Taking represent cognitive empathy abilities, with research finding associations between these dimensions and preference for sad music (Kawakami & Katahira, 2015). The latter two dimensions focus on bottom-up emotional sharing, representing the capacity to generate empathic concern and process personal distress, respectively—components of affective empathy. Rabinowitch et al. (2013) suggested music training enhances this component, though supporting evidence remains limited. Additionally, current research on music training's promotion of empathy has been restricted to subjective self-report measures of trait empathy (Kalliopuska & Ruókonen, 1986, 1993), leaving unclear whether state empathy measured behaviorally is similarly affected.

Meanwhile, researchers typically use music training to assess musical experience (e.g., Kraus & Chandrasekaran, 2010). Music training involves acquiring professional musical skills through long-term, continuous, and specialized instruction. Besides longitudinal intervention studies, existing research also distinguishes trained individuals through cross-sectional comparisons of musician and non-musician groups. Musicians are defined as those who have received years of music education and maintained regular training frequency over substantial periods (Schellenberg & Lima, 2024). However, musical experience is not exclusive to professionally trained individuals; it can also be acquired through active or passive participation in musical activities based on innate predispositions. Therefore, using only music training to assess musical experience is narrow and cannot effectively differentiate the broader population of non-musicians who have never received training. Musical sophistication is a continuous measure that comprehensively assesses musical experience, considering not only training but also daily musical engagement, investment, and perceptual abilities (Müllensiefen et al., 2014). Musical sophistication can reflect individuals' musical experience across both musicians and non-musicians, making it applicable to diverse populations and compensating for the limitations of using only music training as a variable, thereby facilitating deeper investigation into whether music's impact on empathy is limited to the training pathway.

In summary, this study aimed to examine the effects of music training and musical sophistication on cognitive and affective components of trait empathy and on state empathy in painful situations, using questionnaire measures and behavioral research. The study comprised two parts: Study 1 used questionnaires to investigate relationships among music training, musical sophistication, and trait empathy in professional musicians and the general population, focusing on how music training and sophistication affect different empathy dimensions. Given that empathy is influenced by gender (Chen et al., 2014; Burton & Nkwo, 2022), mental states (e.g., anxiety, depression, alexithymia) (Davis, 1983; Yan et al., 2021), openness personality (Hekmat et al., 1975; Koivisto et al., 2023), and socioeconomic status (Wei et al., 2022), we controlled for these variables. While music training has been shown to promote prosocial behavior and trait empathy, this facilitation may stem from accumulated overall musical experience. Therefore, Study 1 analyzed the effects of music training and musical sophistication on trait empathy. We hypothesized that musicians would show higher trait empathy than non-musicians and that musical sophistication would positively correlate with trait empathy, though the specific relationships between training, sophistication, and empathy components required exploration. Since Study 1 relied on self-report measures lacking objective evidence and could not reflect state empathy in real-world contexts, Study 2 employed a pain empathy paradigm to examine whether music training and sophistication facilitate empathic resonance with others' pain. Empathy is an important motivator for prosocial behavior, and based on existing research, we reasonably hypothesized that both music training and sophistication would enhance state empathy—specifically, increase empathic resonance with others' pain. If supported, and considering that state empathy is necessarily influenced by trait empathy, we further hypothesized that music training and sophistication's effects on trait empathy would predict pain empathy levels.

Study 1: Questionnaire Study on Musical Experience and Trait Empathy

2.1.1 Participants

Using G*Power (Faul et al., 2009), the minimum required sample size for group comparisons was calculated as 200 (Cohen's d = 0.20, α = 0.05, power = 80%); for correlation analysis, the minimum was 191 (r = 0.20 for medium effect, α = 0.05, power = 80%). This study recruited 251 healthy students, including 130 musicians (80 females; age 21.00 $\pm$ 2.10 years), primarily from the China Conservatory of Music and Nanjing Normal University's School of Music, and 121 non-musicians (60 females; age 22.40 $\pm$ 2.78 years). Musician participants were professionals or majors in instrumental performance, with at least ten years of professional music training and a minimum of four training sessions per week over the past three years. Non-musician participants had less than two years of professional music training. All participants provided informed consent before completing questionnaires. This study was approved by the Ethics Committee of the Institute of Psychology, Chinese Academy of Sciences.

2.1.2 Measures

This study employed multiple questionnaire measures: the Interpersonal Reactivity Index (IRI), Goldsmiths Musical Sophistication Index (Gold-MSI), Ten-

Item Personality Inventory (TIPI), State-Trait Anxiety Inventory (STAI), 13-item Beck Depression Inventory (BDI-13), 20-item Toronto Alexithymia Scale (TAS-20), and Subjective Social Status Scale for college students (SSS).

The Interpersonal Reactivity Index (IRI) (Davis, 1983) measured trait empathy using a 5-point scale ("0" = "does not describe me well" to "4" = "describes me very well"), comprising four subscales: Perspective Taking (PT), Fantasy (FS), Empathic Concern (EC), and Personal Distress (PD). The PT and FS subscales assess individuals' ability to understand and immerse themselves in others' situations, with higher scores indicating stronger cognitive empathy; the EC and PD subscales focus on individuals' own emotional responses and tendencies, with higher scores indicating stronger affective empathy (Davis, 1983; Ren et al., 2019). The original IRI contains 28 items; the Chinese version (IRI-C) includes 22 items with good reliability and validity (Zhang et al., 2010). In this study, Cronbach's α coefficients for PT, FS, EC, and PD were 0.73, 0.73, 0.73, and 0.86, respectively.

The Goldsmiths Musical Sophistication Index (Gold-MSI) (Müllensiefen et al., 2014) assessed musical sophistication in the general population. The Chinese version (Lin, 2021) contains 38 items: the first 31 use a 7-point scale ("1" = "completely disagree" to "7" = "completely agree"), while items 32-38 are multiple-choice questions scored 0-6 for each of seven ordinal options. The questionnaire includes five subscales—Active Engagement (AE), Perceptual Abilities (PA), Musical Training (MT), Singing Abilities (SA), and Emotions (E)—and a composite dimension of General Musical Sophistication (GMS). This study used the GMS dimension to comprehensively quantify musical sophistication, with higher scores indicating greater sophistication. Cronbach's α for GMS in this study was 0.91.

The Ten-Item Personality Inventory (TIPI) (Gosling et al., 2003) measured Big Five personality traits. The adapted Chinese version (TIPI-C) (Li, 2013) consists of 10 pairs of adjectives covering Openness, Conscientiousness, Extraversion, Agreeableness, and Neuroticism, using a 7-point scale ("1" = "disagree strongly" to "7" = "agree strongly"). This study used the Openness dimension, with higher scores indicating greater personality openness. Cronbach's α for Openness was 0.75.

The State-Trait Anxiety Inventory (STAI) (Spielberger et al., 1983; Wang et al., 1999) measured anxiety levels, containing 40 items using a 4-point scale ("1" = "not at all" to "4" = "very much so"), with State Anxiety (STAI-S) and Trait Anxiety (STAI-T) subscales. Higher total scores indicate higher anxiety levels. Cronbach's α coefficients for STAI-S and STAI-T were 0.94 and 0.91, respectively.

The 13-item Beck Depression Inventory (BDI-13) (Collet & Cottraux, 1986) measured depression levels, comprising 13 multiple-choice items scored 0-3 for each of four ordinal options, with higher total scores indicating higher depression levels. Cronbach's α was 0.91.

The Toronto Alexithymia Scale (TAS-20) (Bagby et al., 1994; Wang et al., 1999) measured alexithymia levels, containing 20 items using a 5-point scale ("1" = "strongly disagree" to "5" = "strongly agree"), with higher total scores indicating higher alexithymia levels. Cronbach's α was 0.87.

The Subjective Social Status Scale for college students (SSS) (Cheng et al., 2015) measured subjective socioeconomic status, containing 7 items using a 10-point scale ("1" = lowest level to "7" = highest level), with higher total scores indicating higher subjective socioeconomic status. Cronbach's α was 0.81.

2.1.3 Common Method Bias Test

Harman's single-factor test was used for exploratory factor analysis of all questionnaire scores. Results showed 13 factors with eigenvalues greater than 1.00, with the first factor explaining 19.18% of variance, below the 40% critical threshold (Zhou & Long, 2004), indicating no significant common method bias.

2.1.4 Data Analysis

To compare differences between musicians and non-musicians on GMS and IRI subscales, normality tests were first conducted on all questionnaire scores. Independent samples t-tests were used for normally distributed measures, and Mann-Whitney U tests for non-normally distributed measures. Given gender's influence on empathy (Chen et al., 2014) and musical sophistication (Müllensiefen et al., 2014) and its potential effects on other control variables, partial correlation analysis was first used to calculate partial correlation coefficients between GMS, IRI, and control variables while controlling for gender. All analyses were conducted in jamovi 2.4 (The jamovi project, 2023), with significance set at $p < 0.05$.

To examine the mechanisms through which music training and musical sophistication affect trait empathy, structural equation modeling was used for path analysis after controlling for gender, anxiety (STAI-S, STAI-T), depression (BDI), alexithymia (TAS-20), openness personality (Openness), and subjective socioeconomic status (SSS). Music training was a dichotomous variable with "musician" and "non-musician" factors. Bootstrap mediation analysis was performed with 5,000 iterations using the generalized Newton method (GN) optimizer, implemented with the lavaan package in R (Rosseel, 2012).

2.2.1 Differences Between Musicians and Non-Musicians in Trait Empathy and Musical Sophistication

After normality testing, all questionnaire scores except GMS were non-normally distributed. Therefore, independent samples t-tests were used for GMS, and Mann-Whitney U tests for other scores.

Regarding musical sophistication, as shown in [Figure 1: see original paper]B, musicians' GMS scores were significantly higher than non-musicians' (t(184.72)

= 12.66, $p < 0.001$, Cohen's d = 1.61). For trait empathy, as shown in [Figure 1: see original paper]A, musicians scored significantly higher than non-musicians on both cognitive empathy dimensions (Perspective Taking: W = 6362.50, p = 0.008, rpb = 0.19; Fantasy: W = 5988.50, p = 0.001, rpb = 0.24), while differences in affective empathy (Empathic Concern: W = 6858.00, p = 0.079; Personal Distress: W = 7051.50, p = 0.156) were not significant.

Note: $p < 0.01$; *$p < 0.001$.

[**Figure 1: see original paper**] Differences in trait empathy and musical sophistication between musician and non-musician groups. A. Comparison of empathy dimensions between musician and non-musician groups. B. Comparison of general musical sophistication between musician and non-musician groups.

2.2.2 Descriptive Statistics and Partial Correlation Analysis Results

As shown in , after controlling for gender, musical sophistication (GMS) was significantly positively correlated with Perspective Taking (PT), Fantasy (FS), and Empathic Concern (EC), but significantly negatively correlated with Personal Distress (PD). Musical sophistication also showed strong correlations with other control variables.

**** Descriptive statistics and Spearman partial correlations controlling for gender among study variables and control variables (n = 251)

2.2.3 Path Analysis of Music Training and Musical Sophistication Effects on Trait Empathy

Structural equation modeling analysis (see [Figure 2: see original paper]) showed that music training's direct paths to trait empathy subdimensions were all non-significant (ps > 0.05). However, the indirect path from music training to the fantasy dimension of cognitive empathy through musical sophistication was significant ($\beta = 0.13$, 95% CI: [0.12, 0.35]). Specifically, music training significantly positively predicted musical sophistication ($\beta = 0.46$, $p < 0.001$), which in turn significantly positively predicted fantasy in cognitive empathy ($\beta = 0.28$, $p < 0.001$).

Note: ***$p < 0.001$. Bold solid lines indicate significant mediation paths; dashed lines indicate non-significant direct or mediation paths.

[**Figure 2: see original paper**] Path analysis diagram of music training and musical sophistication effects on trait empathy

2.3 Discussion

Study 1 examined relationships between music training, musical sophistication, and cognitive and affective components of trait empathy through questionnaire surveys. Results showed: (1) Compared to non-musicians, musicians scored significantly higher on Perspective Taking and Fantasy dimensions of cognitive empathy; (2) Musical sophistication was significantly positively correlated with Perspective Taking and Fantasy in cognitive empathy and Empathic Concern in affective empathy, but significantly negatively correlated with Personal Distress; (3) Musical sophistication showed significant correlations with other empathy-related variables. After controlling for gender, personality openness, and mental states, path analysis revealed that musical sophistication only significantly predicted the fantasy dimension of cognitive empathy. While music training could not directly predict trait empathy components, it could predict fantasy in cognitive empathy through the mediating effect of musical sophistication.

To investigate music training's impact on trait empathy, we compared musician and non-musician groups, finding that music training was associated with better trait empathy, consistent with previous research (Kalliopuska & Ruókonen, 1986, 1993). This group difference was primarily manifested in cognitive components. Cognitive empathy emphasizes understanding and immersing oneself in others' situations, including Perspective Taking and Fantasy dimensions, with Perspective Taking situated in real-world contexts and Fantasy in fictional contexts (e.g., books, films) (Davis, 1983). This contradicts Rabinowitch et al.'s (2013) findings, with differences in music training duration potentially explaining inconsistent results. Musicians in this study had over ten years of high-frequency music training, whereas Rabinowitch et al. (2013) used a shorter intervention period in their longitudinal design. Long-term professional music training may help musicians excel in complex cognitive tasks such as imitating others' actions and emotions (Cross et al., 2012) and inferring others' emotions (Kalliopuska & Tiitinen, 1991), thus demonstrating advantages in cognitive empathy.

This study further examined musical sophistication levels in musicians and non-musicians, finding that musical sophistication also significantly correlated with trait empathy, particularly in cognitive components. This further indicates that musical experience positively predicts empathy ability, mainly reflected in enhanced cognitive components. However, besides strong correlations with trait empathy, musical sophistication also correlated strongly with factors such as personality and subjective socioeconomic status that are strongly associated with trait empathy. Therefore, musical sophistication may have strong covariation with other psychological structures influencing trait empathy. Previous research has confirmed that openness personality predicts both empathy (Hekmat et al., 1975; Koivisto et al., 2023) and musical sophistication (Greenberg & Muellensiefen et al., 2015; Klarlund et al., 2023). This study also found strong correlations between openness personality and both trait empathy and musical sophistication. Furthermore, path analysis results showed that after excluding confounding variables and including music training, musical sophistication still significantly predicted fantasy in cognitive empathy and mediated music training's effect on trait empathy. Thus, a strong and stable intrinsic association exists between musical experience and cognitive empathy, not solely derived from music training benefits; rather, enhanced musical sophistication is the primary pathway through which music training promotes trait empathy.

Music appreciation relies on imagination (Stotland, 1978). Individuals with high musical sophistication have stronger perceptual abilities across musical dimensions and greater daily engagement in musical activities (Müllensiefen et al., 2014), making it easier for them to immerse themselves in fictional scenarios and resonate with characters (Epperson, 1967; Jackendoff & Lerdahl, 2006; Perlovsky, 2012).

In summary, musical experience acquired through either professional training or daily activities/innate predispositions positively influences cognitive components of trait empathy. Music training significantly enhances individuals' cognitive empathy, while musical sophistication significantly predicts cognitive empathy and plays an important mediating role in improving cognitive empathy through music training. Study 1 used questionnaires to measure trait empathy, which lacks situational context and fails to measure and discuss the crucial empathy characteristic of "self-other distinction." Therefore, Study 2 employed a pain empathy paradigm with relatively simple scenarios and low reporting burden to explore how musical experience affects state empathy in realistic contexts.

Study 2: Behavioral Experiment on Musical Experience and State Empathy

3.1.1 Participants

Using G*Power, the minimum required sample size for a mixed-effects model with seven predictors was approximately 104 (1 = 0, 2 = 0.04, $\alpha = 0.04$, power = 80%). This study recruited 120 healthy students, including 59 musicians (40 females; age 20.6 ± 2.74 years), primarily from the China Conservatory of Music, and 61 non-musicians (31 females; age 23.3 ± 2.87 years). Recruitment criteria for musicians and non-musicians were identical to Study 1. All participants had normal hearing (pure-tone thresholds $\leq$ 25 dB at 250-8000 Hz), normal or corrected-to-normal vision, normal intelligence ($ $85% correct on Raven's Progressive Matrices), were right-handed, and had no acute or chronic pain conditions or medication use.

3.1.2 Measures

This study continued using measures from Study 1, including the IRI, Gold-MSI, STAI, BDI, and TAS-20. Additionally, the Musical Ear Test (MET) (Wallentin et al., 2010) objectively measured musical abilities, including melody and rhythm discrimination. Participants listened to instructions and musical stimuli, then responded whether melodies/rhythms were identical. With 52 items each for melody and rhythm, this test authentically reflects musical ability levels and validates the musician/non-musician grouping. Results showed musicians performed significantly better than non-musicians on both melody (W = 310.50, $p < 0.001$, rpb = 0.83) and rhythm ($t(110.16) = 3.57$, $p < 0.001$, Cohen's d = 0.65) discrimination.

3.1.3 Experimental Task

To maximize the "feeling with" characteristic of state empathy while avoiding complex feelings (e.g., emotions) that increase reporting burden, this study measured performance on a pain empathy task, adapting and improving upon Han et al.'s (2009) paradigm. The experiment used 36 three-second pain stimulus videos divided into three types: needle_{{{with}}*{{expression}}}, needle*{{{without}}*{{expression}}}, and cotton*{{{swab}}*{{without}}}*{expression} (see [Figure 3: see original paper]). All videos featured six protagonists (3 male, 3 female), each undergoing three stimulus types, with left and right needle/cotton swab insertion directions, presented in random order.

Participants were informed they would watch pain-related videos and respond to on-screen questions via keypress. The experiment included two blocks of 18 trials each; participants answered two questions per trial. The procedure (see [Figure 3: see original paper]) was: participants first saw the first question ("How painful do you think the protagonist in the video feels?") for 4 seconds, then viewed the pain stimulus video. After watching, they rated pain intensity from the other's perspective (1-6, "1" = "not painful at all," "6" = "extremely painful") within 6 seconds, instructed to respond as quickly as possible while maintaining accuracy. After answering, a 1-2 second interval preceded the second question ("To what extent did you yourself feel pain?"), with identical stimulus presentation and rating procedures. In this phase, participants watched the same pain video and rated pain from the self-perspective. After responding, a 1-2 second interval preceded the next trial. Participants could rest 1-2 minutes between blocks.

3.1.4 Data Analysis

[**Figure 3: see original paper**] Pain empathy experimental flowchart

First, participants' ratings across two evaluation perspectives and three stimulus types were averaged, yielding six scores per participant. Based on the experimental design, this study used the ratio of self-pain ratings to other-pain ratings to quantify empathic resonance. This ratio reflects consistency between self-feelings and other-feelings at the individual level, as both were evaluated on identical psychological scales. Ratios closer to 1 indicate greater alignment between self- and other-pain ratings, demonstrating empathic resonance with others' pain. At the group level, this ratio eliminates individual differences in psychological scaling, considering only consistency between the two perspectives, which aligns with empathy's basic definition and effectively describes state empathy. Larger ratios indicate higher self-pain ratings relative to other-pain ratings, suggesting stronger subjective empathic pain responses. The formula was:

Degree of Pain Empathic Resonance = Self-Pain Rating / Other-Pain Rating

This formula was calculated for each participant under two painful conditions (needle_{{{with}}*{{expression}}} and needle*{{{without}}*{{expression}}});* *the cotton*{{{swab}}*{{without}}}*{expression} control condition was excluded from analysis. The resulting pain empathic resonance index served as the dependent variable in subsequent linear mixed-effects models and path analyses.

In the linear mixed-effects model, fixed-effect independent variables included music training, musical sophistication, stimulus type, and interactions between music training/sophistication and stimulus type. Since musical sophistication partially derives from professional music training experience, this analysis first regressed out music training's influence from musical sophistication, then included the residuals in the model. Additionally, gender, trait anxiety (STAI-T), depression (BDI), and alexithymia (TAS-20) were included as control variables. State anxiety (STAI-S) was measured 3-14 days before the formal experiment, making it less relevant to the experimental state and thus excluded from Study 2 analyses. Given individual differences in rating sensitivity, a random intercept model was used with participants as random variables. This analysis was implemented using the lme4 package in R (Bates et al., 2015).

To further explore pathways through which music training and sophistication affect pain empathy from the perspective of trait empathy's influence on state empathy, this study built upon Study 1's conclusions to construct a serial mediation model examining the path from music training through musical sophistication and trait empathy to pain empathy. Structural equation model construction followed Study 1's approach. Mediation effects were tested using bootstrap analysis with 5,000 iterations and the Gaussian-Newton algorithm optimizer, implemented with the lavaan package in R (Rosseel, 2012).

3.2.1 Effects of Music Training and Musical Sophistication on Pain Empathy

In the cotton_{{{swab}}*{{without}}}*{expression} condition, both groups' pain ratings were very low (self-perspective: M ± SD_{musicians} = 1.13 ± 0.21, M ± SD_{non}-musicians = 1.05 ± 0.10; other-perspective: M ± SD_{musicians} = 1.17 ± 0.22, M ± SD_{non}-musicians = 1.16 ± 0.27) with no significant difference (F(1, 118) = 1.48, p = 0.226). The main effect of rating perspective was significant (F(1, 118) = 13.27, p < 0.001, ^{2} = 0.10), with self-perspective ratings significantly lower than other-perspective ratings, and no interaction between rating perspective and music training (F(1,118) = 2.89, p = 0.092). A 2 (music training group) × 3 (stimulus type) repeated-measures ANOVA revealed no main effect of music training group (F(1,118) = 0.20, p = 0.657) and no interaction between music training group and stimulus type (F(2, 236) = 0.91, p = 0.404). The main effect of stimulus type was significant (F(2, 236) = 759.30, p < 0.001, ^{2}p = 0.87). Post-hoc comparisons showed needle_{{{with}}*{{expression}}} was significantly higher than needle*{{{without}}*{{expression}}} (t(118) = 18.83, pBonferroni < 0.001) and cotton*{{{swab}}*{{without}}}*{expression} (t(118) = 34.78, pBonferroni

< 0.001), and needle_{{{without}}*{{expression}}} was significantly higher than cotton*{{{swab}}*{{without}}}*{expression} (t(118) = 22.30, pBonferroni < 0.001), demonstrating effective pain manipulation.

A linear mixed-effects model was constructed with pain empathic resonance as the dependent variable. The model passed distortion tests, with random effects ICC = 0.35. As shown in , after controlling for other variables, main effects of music training and stimulus type were significant in fixed effects (music training: β = 0.16, SE = 0.07, t = 2.08, p = 0.040, 95% CI: [0.01, 0.30], see [Figure 4: see original paper]C; stimulus type: β = –0.30, SE = 0.05, t = –6.01, p < 0.001, 95% CI: [–0.40, –0.20], see [Figure 4: see original paper]D). Pain empathic resonance scores closer to 1 indicate greater consistency between self- and other-pain ratings, reflecting stronger empathic resonance. Therefore, one-sample t-tests were conducted separately for musicians and non-musicians. Musicians' empathic resonance scores did not significantly differ from 1 (self: M = 3.41, SE = 0.12; other: M = 3.92, SE = 0.12, see [Figure 4: see original paper]A; ratio: M = 1.02, SE = 0.04, t(117) = 0.41, p = 0.683, Cohen's d = 0.04, see [Figure 4: see original paper]C), while non-musicians' scores were significantly less than 1 (self: M = 3.63, SE = 0.12; other: M = 3.81, SE = 0.12, see [Figure 4: see original paper]A; ratio: M = 0.91, SE = 0.04, t(121) = –2.47, p = 0.015, Cohen's d = 0.22, see [Figure 4: see original paper]C). Under needle_{{{without}}*{{expression}}} stimulation, both self- and other-pain ratings were low (self: M = 3.05, SE = 0.11; other: M = 3.04, SE = 0.10, see [Figure 4: see original paper]B), with empathic resonance not significantly different from 1 (M = 1.08, SE = 0.05, t(119) = 1.76, p = 0.081, Cohen's d = 0.16, see [Figure 4: see original paper]D). Under needle*{{{with}}_{{expression}}} stimulation, others were perceived as experiencing more pain (self: M = 3.99, SE = 0.12; other: M = 4.69, SE = 0.08, see [Figure 4: see original paper]B), with empathic resonance significantly less than 1 (M = 0.84, SE = 0.02, t(119) = –9.40, p < 0.001, Cohen's d = 0.86, see [Figure 4: see original paper]D). Main effects of musical sophistication and all interaction effects were non-significant (ps > 0.10).

Note: *p < 0.05;* **p < 0.001. Error bars represent M ± 1 SE.

[Figure 4: see original paper] Effects of music training and stimulus type on pain ratings and pain empathic resonance. A. Mean pain ratings from different evaluation perspectives for musicians and non-musicians. B. Mean pain ratings across stimulus conditions and evaluation perspectives. C. Empathic resonance degree for musicians and non-musicians. D. Empathic resonance degree across stimulus conditions.

**** Fixed effects results from linear mixed-effects model of music training, musical sophistication, and stimulus type effects on pain empathic resonance

Fixed Effect	β	SE	t	p	95% CI of β
Music training (musician-non-musician)	0.16	0.07	2.08	0.040*	[0.01, 0.30]
Musical sophistication (residualized)	0.10	0.08	1.30	0.196	[–0.04, 0.25]
Stimulus type (needle_{{{without}}{{expression}}}-needle{{{with}}_{{expression}}})	–0.30	0.05	–6.01	<0.001***	[–0.40, –0.20]
Music training × stimulus type	–0.04	0.05	–0.83	0.409	[–0.14, 0.06]
Stimulus type × musical sophistication	–0.07	0.05	–1.38	0.169	[–0.17, 0.03]
Music training × musical sophistication	0.07	0.08	0.90	0.371	[–0.08, 0.22]
Gender (female-male)	0.07	0.07	0.96	0.339	[–0.07, 0.20]
TAS-20	–0.11	0.08	–1.41	0.162	[–0.26, 0.04]
STAI-T	–0.11	0.08	–1.38	0.169	[–0.26, 0.04]

Note: *p < 0.05;* **p < 0.001.

3.2.2 Serial Mediation of Music Training Effects on Pain Empathy Through Musical Sophistication and Fantasy

Study 2 first validated Study 1's path analysis results: music training affected Perspective Taking and Fantasy in trait cognitive empathy through musical sophistication, with both mediation effects significant (Perspective Taking: β = 0.16, 95% CI: [0.02, 0.31]; Fantasy: β = 0.25, 95% CI: [0.10, 0.41]). Meanwhile, correlation analysis between trait empathy and pain empathy showed that Fantasy in cognitive empathy and Empathic Concern in affective empathy were significantly correlated with pain empathic resonance (Fantasy: = 0.21, p = 0.001; Empathic Concern: = 0.21, p = 0.001). Consequently, the final path model was constructed as music training → musical sophistication → Fantasy → pain empathy. Results (see [Figure 5: see original paper]) showed that music training only indirectly affected pain empathy through the serial mediation of musical sophistication and Fantasy (β = 0.05, 95% CI: [0.001, 0.09]). Specifically, music training positively predicted musical sophistication (β = 0.80, p < 0.001), musical sophistication positively predicted Fantasy (β = 0.55, p < 0.001), and Fantasy positively predicted pain empathy (β = 0.11, p = 0.033). Although music training negatively predicted Fantasy (β = –0.24, p = 0.007), its indirect effect on pain empathy through Fantasy mediation was non-significant (β = –0.03, 95% CI: [–0.06, 0.01]). Music training's direct and other indirect paths to pain empathy were non-significant (ps > 0.100). Similarly, musical sophistication only indirectly affected pain empathy through Fantasy mediation (β = 0.06, 95% CI: [0.001, 0.12]), with its direct path to pain empathy non-significant (p = 0.255).

Note: *p < 0.05;* ***p < 0.01;*** p < 0.001. Bold solid lines indicate significant mediation paths; dashed lines indicate non-significant direct or mediation paths.

[**Figure 5: see original paper**] Path analysis diagram of music training, musical sophistication, trait empathy, and pain empathy

3.3 Discussion

Study 2 investigated music training and musical sophistication effects on state empathy using a pain empathy paradigm. Linear mixed-effects model results showed significant main effects of music training and stimulus type, specifically that musicians showed significantly greater pain empathy than non-musicians, and pain empathy was significantly greater in the with-expression condition than the without-expression condition.

First, significant main and interaction effects of rating perspective and stimulus type supported the experimental design's validity. For rating perspective, self-pain ratings were significantly lower than other-pain ratings, demonstrating that participants' feelings differed across perspectives and that they achieved self-other distinction during state empathy. For stimulus type, besides needle stimuli receiving higher ratings than cotton swab stimuli, painful expressions also produced significantly higher pain ratings than non-expression stimuli, similar to Han et al.'s (2009) behavioral results. Simple effects analysis of the rating perspective × stimulus type interaction showed that self-ratings were significantly lower than other-ratings only in the painful expression condition. These results demonstrate effective stimulus manipulation, with condition differences helping participants construct appropriate psychological scales.

The significant main effect of music training on pain empathy, with musicians showing closer alignment between self- and other-pain ratings, indicates that compared to non-musicians, musicians experienced smaller differences between their own feelings and evaluations of others' pain, feeling more similar to others and better able to "feel with" others' pain. Rabinowitch et al. (2013) used a facial expression matching task where children selected faces matching their feelings after watching animations; selections matching the target character's emotion were marked as "matches," with match rate quantifying state empathy. Their results showed children receiving music training intervention had higher match rate increases than controls (though differences were non-significant). Study 2's significant results using a pain empathy paradigm support that music training helps improve state empathy, suggesting music training helps individuals show stronger state empathy in specific contexts, which may be an important reason for its promotion of prosocial behavior. However, musical sophistication controlling for music training showed no significant main effect, further supporting the important role of acquired music training in improving empathy.

This study also explored relationships among musical experience, trait empathy, and state empathy, further explaining potential processes and mechanisms through which music training affects state empathy. Results showed music training's effect on "feeling with" degree was only serially mediated by musical sophistication and Fantasy in cognitive empathy, with both musical sophistication and Fantasy as necessary mediators. Individuals with music training have higher musical sophistication, greater imagination, and stronger self-feelings of protagonists' pain in fictional contexts. Meanwhile, musical sophistication enhancement cannot directly promote empathy for others' pain states but requires mediation through cognitive components of trait empathy (Fantasy).

In summary, acquired musical experience significantly affects state empathy, with musical sophistication and trait cognitive empathy (especially Fantasy) playing crucial mediating roles, both being indispensable. Professional musicians can better empathize with protagonists in pain stimuli than non-musicians, an effect serially mediated by musical sophistication and cognitive empathy (Fantasy) in trait empathy. Specifically, individuals with professional music training have higher musical sophistication, stronger imagination, and show smaller differences between self-feelings and evaluations of others' pain when watching others in pain, enabling stronger empathic resonance. However, after controlling for music training's influence, musical sophistication showed no direct association with state empathy, only mediating it through cognitive empathy (Fantasy) in trait empathy.

General Discussion

This study used questionnaire surveys and behavioral experiments to explore musical experience effects on trait and state empathy, quantifying musical experience through music training and musical sophistication indicators. Study 1 found through questionnaires that music training promotes cognitive empathy (Fantasy dimension) in trait empathy, while musical sophistication significantly predicts cognitive empathy and importantly mediates music training's effect on improving cognitive empathy. Study 2 found through a pain empathy paradigm that music training promotes pain state empathy through serial mediation of musical sophistication and Fantasy in trait cognitive empathy. Overall, musical experience promotes cognitive empathy in trait empathy; music training can enhance imagination (cognitive empathy) in trait empathy by improving musical sophistication, helping musicians achieve stronger ability to feel with others' pain states.

This study demonstrates musical experience's promoting effect on empathy, supporting the "Music and Social Bonding" hypothesis. This hypothesis emphasizes music's important role in interpersonal interaction, proposing music as a coevolved system for social bonding. This is because music initially served language-like functions, greatly facilitating group coordination and communication when language efficiency was low—a property retained throughout evolution (Savage et al., 2021). Previous research found music training promotes prosocial behavior. Schellenberg et al. (2015) found that after 10 months of music training, schoolchildren showed better prosocial skills. Rabinowitch and colleagues studied group music training effects in preschool (Rabinowitch & Meltzoff, 2017) and school-age children (Rabinowitch & Knafo-Noam, 2015), finding trained children performed better in cooperative games, indicating positive effects on children's social interaction and prosocial behavior development. These findings show music training changes prosocial behavior, but how it affects the psychological structures motivating behavioral change remains unconfirmed. The empathizing process in music appreciation (Epperson, 1967; Jackendoff & Lerdahl, 2006; Perlovsky, 2012; Greenberg & Rentfrow et al., 2015) and the "empathy-altruism behavior" hypothesis (Batson et al., 2007) emphasize empathy's importance in music and prosocial behavior. Study 1 confirmed from a trait empathy perspective that music training promotes empathy, supporting Kalliopuska and Ruókonen's (1986, 1993) conclusions while finding that music training primarily promotes cognitive components.

Moreover, individuals can acquire musical experience not only through music training but also through non-professional pathways such as innate or acquired musical activities. From the musical sophistication perspective, Study 1 results confirmed that even after strictly controlling irrelevant variables, musical sophistication still significantly predicted cognitive empathy in trait empathy. This demonstrates musical sophistication may have stable, direct effects on trait empathy, supporting the "Music and Social Bonding" hypothesis's proposition that music adapts for social bonding. The connection between music and empathy may originate not only from training but also from musically sophisticated individuals such as those with musical talent or strong music appreciation. Long-term professional training is ultimately rare, but musical experience's enhancement of empathy can extend to non-professional populations. However, Study 2 found from a state empathy perspective that music training significantly predicted pain empathy, while musical sophistication controlling for training showed no such effect. Path analysis showed music training promotes imagination through improved musical sophistication, which then affects pain empathy, replicating Study 1's results and identifying a potential pathway for music training's effect on state empathy.

This suggests acquired professional music training is necessary for empathy enhancement. Possibly because compared to other sophistication-enhancing methods, music training more directly trains coordination abilities (Savage et al., 2021), which helps imagination and immersion across different perspectives. Compared to the general population, musicians' musical sophistication obtained through long-term professional training is more effective in enhancing empathy, primarily manifested in promoting state empathy.

Across both studies, Fantasy in trait empathy played a crucial role. Study 1 found musical sophistication strongly correlated with Fantasy in cognitive empathy, with music training improving Fantasy through enhanced musical sophistication. Study 2 found pain empathy degree strongly correlated with Fantasy ability in trait cognitive empathy, which was a necessary mediator in the pathway from music training and sophistication to pain empathy. First, Fantasy plays a key role in music experience; Stotland (1978) proposed that music creates a fictional context where emotional perception and response generation depend on imagination. Other music aesthetics theories also emphasize Fantasy's important role in musical empathy (Jackendoff & Lerdahl, 2006; Perlovsky, 2012; Epperson, 1967). Music experience's effects on the cerebellum may also explain this phenomenon. Olszewska et al. (2021) found long-term music training strengthened cerebellar white matter fiber connections and increased white matter volume in musicians. Research also shows Fantasy level positively correlates with cerebellar Crus2 and pars triangularis of inferior frontal gyrus volume, and negatively correlates with mean diffusivity in these regions, indicating cerebellar white matter volume and fiber connections relate to Fantasy level (Picerni et al., 2021).

This study has two main innovations. First, it comprehensively investigated musical experience effects on empathy using both music training and musical sophistication indicators, supporting the "Music and Social Bonding" hypothesis. Second, it quantified "feeling with" degree through self-other perspective distinction in behavioral experiments, deeply exploring music training and sophistication effects on state empathy.

However, limitations exist. First, regarding music training, this study did not further examine how training onset age, duration, and proficiency affect trait and pain empathy, though previous research shows these factors influence empathy development (Watanabe et al., 2007; Bailey & Penhune, 2013). Second, the pain empathy task did not separate cognitive and affective components of state empathy. The task was relatively simple, requiring minimal reasoning, and research shows individuals with high pain empathy tend to overestimate others' pain (Green et al., 2009), making it difficult to use accuracy rates like those in the Multifaceted Empathy Test (Dziobek et al., 2008) to represent cognitive empathy. Future research could use other paradigms to further explore how musical experience affects state empathy's psychological processing, such as identifying which components show differences. Finally, this study could not distinguish innate versus acquired components of musical sophistication effects on trait and state empathy. Future research could examine whether empathy relates to innate musical sophistication, or whether acquired sophistication has specific effects—for example, whether active versus passive music participation differentially affects empathy—to deepen understanding of the music-empathy relationship.

This study's findings indicate musical experience positively predicts cognitive empathy in trait empathy. Specifically, music training promotes cognitive empathy in trait empathy, while musical sophistication directly affects Fantasy in cognitive empathy. Long-term music training enables professional musicians to better feel with others' pain states, as music training experience can improve musical sophistication, promote Fantasy in trait empathy, and thereby enhance empathy for others' pain states. Notably, musical sophistication controlling for music training shows no direct association with state empathy, requiring mediation through Fantasy in trait empathy. This suggests both musical sophistication and music training positively affect empathy through different pathways, but trait empathy—especially cognitive empathy's Fantasy dimension—is a necessary mediator for musical experience's promotion of state empathy. Musical sophistication plays a stable mediating role in music training's enhancement of trait empathy. These findings theoretically support the "Music and Social Bonding" hypothesis, revealing that musical sophistication and training may relate to empathy abilities in different ways, providing insights for understanding music's important role in prosocial behavior development and for individual empathy development.

References

Bagby, R. M., Parker, J. D., & Taylor, G. J. (1994). The twenty-item Toronto Alexithymia Scale—I. Item selection and cross-validation of the factor structure. *Journal of Psychosomatic Research, 38*(1), 23–32.

Bailey, J., & Penhune, V. (2013). The relationship between the age of onset of musical training and rhythm synchronization performance: Validation of sensitive period effects. *Frontiers in Neuroscience, 7*, Article 227.

Bates, D., Mächler, M., Bolker, B., & Walker, S. (2015). Fitting linear mixed-effects models Using lme4. *Journal of Statistical Software, 67*(1), 1–48.

Batson, C. D., Eklund, J. H., Chermok, V. L., Hoyt, J. L., & Ortiz, B. G. (2007). An additional antecedent of empathic concern: Valuing the welfare of the person in need. *Journal of Personality and Social Psychology, 93*(1), 65–74.

Burton, L., & Nkwo, C. (2022). Gender Differences in the Relationship between State and Trait Anxiety and Empathy. *Current Psychology, 41*(12), 8368–8373.

Chen, W. Y., Lu, J. M., Liu, L. Q., & Lin, W. Y. (2014). Gender Differences of Empathy. *Advances in Psychological Science, 22*(9), 1423–1434. [Chen, W. Y., Lu, J. M., Liu, L. Q., & Lin, W. Y. (2014). Gender differences of empathy. *Advances in Psychological Science*, 22(9), 1423–1434.]

Cheng, G., Chen, Y. H., Guan, Y. S., & Zhang, D. J. (2015). On Composition of College Students' Subjective Social Status Indexes and Their Characteristics. *Journal of Southwest University (Natural Science Edition), 37*(6), 156–162. [Cheng, G., Chen, Y. H., Guan, Y. S., & Zhang, D. J. (2015). On composition of college students' subjective social status indexes and their characteristics. *Journal of Southwest University (Natural Science Edition)*, 37(6), 156–162.]

Collet, L., & Cottraux, J. (1986). The shortened Beck Depression Inventory (13 items). Study of the concurrent validity with the Hamilton scale and Widlöcher's retardation scale. *L'Encéphale, 12*(2), 77–79.

Cross, I., Laurence, F., & Rabinowitch, T.-C. (2012). Empathy and Creativity in Group Musical Practices: Towards a Concept of Empathic Creativity. In G. E. McPherson & G. F. Welch (Eds.), *The Oxford Handbook of Music Education* (Vol. 2, pp. 337–353). Oxford University Press.

Cuff, B. M. P., Brown, S. J., Taylor, L., & Howat, D. J. (2016). Empathy: A Review of the Concept. *Emotion Review, 8*(2), 144–153.

Davis, M. H. (1983). Measuring individual differences in empathy: Evidence for a multidimensional approach. *Journal of Personality & Social Psychology, 44*(1), 113–126.

Dziobek, I., Rogers, K., Fleck, S., Bahnemann, M., Heekeren, H. R., Wolf, O. T., & Convit, A. (2008). Dissociation of cognitive and emotional empathy in adults with Asperger syndrome using the Multifaceted Empathy Test (MET). *Journal of Autism and Developmental Disorders, 38*(3), 464–473.

Eeroia, T., Vuoskoski, J. K., & Kautiainen, H. (2016). Being Moved by Unfamiliar Sad Music Is Associated with High Empathy. *Frontiers in Psychology, 7*, Article 1176.

Eisenberg, N., & Miller, P. A. (1987). The relation of empathy to prosocial and related behaviors. *Psychological Bulletin, 101*(1), 91–119.

Epperson, G. (1967). *The Musical Symbol: A Study of the Philosophic Theory of Music.* Wiley-Blackwell.

Fan, Y., Duncan, N. W., de Greck, M., & Northoff, G. (2011). Is there a core neural network in empathy? An fMRI based quantitative meta-analysis. *Neuroscience & Biobehavioral Reviews, 35*(3), 903–911.

Faul, F., Erdfelder, E., Buchner, A., & Lang, A.-G. (2009). Statistical power analyses using G*Power 3.1: Tests for correlation and regression analyses.* Behavior Research Methods, 41*, 1149–1160.

Gosling, S. D., Rentfrow, P. J., & Swann, W. B. (2003). A very brief measure of the Big-Five personality domains. *Journal of Research in Personality, 37*(6), 504–528.

Green, A. D., Tripp, D. A., Sullivan, M. J. L., & Davidson, M. (2009). The Relationship between Empathy and Estimates of Observed Pain. *Pain Medicine, 10*, 381–392.

Greenberg, D. M., Muellensiefen, D., Lamb, M. E., & Rentfrow, P. J. (2015). Personality predicts musical sophistication. *Journal of Research in Personality, 58*, 154–158.

Greenberg, D. M., Rentfrow, P. J., & Baron-Cohen, S. (2015). Can Music Increase Empathy? Interpreting Musical Experience Through the Empathizing–Systemizing (E-S) Theory: Implications for Autism. *Empirical Musicology Review, 10*(1–2), 80–95.

Han, S., Fan, Y., Xu, X., Qin, J., Wu, B., Wang, X., Aglioti, S. M., & Mao, L. (2009). Empathic Neural Responses to Others' Pain are Modulated by Emotional Contexts. *Human Brain Mapping, 30*(10), 3227–3237.

Hekmat, H., Khajavi, F., & Mehryar, A. H. (1975). Some personality correlated of empathy. *Journal of Consulting and Clinical Psychology, 43*(1), 89.

Huang, H. Q., & Su, Y. J. (2010). Interaction Between the Cognitive and Emotional Components of Empathy. *Journal of Southwest University (Social Sciences Edition), 36*(6), 13–19. [Huang, H. Q., & Su, Y. J. (2010). Interaction between the cognitive and emotional components of empathy. *Journal of Southwest University (Social Sciences Edition)*, 36(6), 13–19.]

Jackendoff, R., & Lerdahl, F. (2006). The capacity for music: What is it, and what's special about it? *Cognition, 100*(1), 33–72.

Kalliopuska, M., & Ruókonen, I. (1986). Effects of Music Education on Development of Holistic Empathy. *Perceptual and Motor Skills, 62*(1), 187–191.

Kalliopuska, M., & Ruókonen, I. (1993). A study with a follow-up of the effects of music education on holistic development of empathy. *Perceptual and Motor Skills, 76*(1), 131–137.

Kalliopuska, M., & Tiitinen, U. (1991). Influence of Two Developmental Programmes on the Empathy and Prosociability of Preschool Children. *Perceptual and Motor Skills, 72*(1), 323–328.

Kawakami, A., & Katahira, K. (2015). Influence of trait empathy on the emotion evoked by sad music and on the preference for it. *Frontiers in Psychology, 6*, Article 1541.

Klarlund, M., Brattico, E., Pearce, M., Wu, Y., Vuust, P., Overgaard, M., & Du, Y. (2023). Worlds apart? Testing the cultural distance hypothesis in music perception of Chinese and Western listeners. *Cognition, 235*, Article 105405.

Koivisto, M., Virkkala, M., Puustinen, M., & Aarnio, J. (2023). Open and empathic personalities see two things at the same time: The relationship of big-five personality traits and cognitive empathy with mixed percepts during binocular rivalry. *Current Psychology, 42*(11), 9552–9562.

Kraus, N., & Chandrasekaran, B. (2010). Music training for the development of auditory skills. *Nature Reviews Neuroscience, 11*(8), Article e38.

Li, J. D. (2013). Psychometric Properties of Ten-Item Personality Inventory in China. *China Journal of Health Psychology, 21*(11), 1688–1692. [Li, J. D. (2013). Psychometric properties of Ten-Item Personality Inventory in China. *China Journal of Health Psychology*, 21(11), 1688–1692.]

Lin, H. R., Kopiez, R., Müllensiefen, D., & Wolf, A. (2021). The Chinese version of the Gold-MSI: Adaptation and validation of an inventory for the measurement of musical sophistication in a Taiwanese sample. *Musicae Scientiae, 25*(2), 226–251.

Meng, J., Chen, Y. G., & Huang, X. T. (2010). Influencing Factors and the Mechanism of Empathy for Pain. *Advances in Psychological Science, 18*(3), 432–440. [Meng, J., Chen, Y. G., & Huang, X. T. (2010). Influencing factors and the mechanism of empathy for pain. *Advances in Psychological Science*, 18(3), 432–440.]

Müllensiefen, D., Gingras, B., Musil, J., & Stewart, L. (2014). The musicality of non-musicians: An index for assessing musical sophistication in the general population. *PloS One, 9*(2), Article e89642.

Olszewska, A. M., Gaca, M., Herman, A. M., Jednoróg, K., & Marchewka, A. (2021). How Musical Training Shapes the Adult Brain: Predispositions and Neuroplasticity. *Frontiers in Neuroscience, 15*, Article 630829.

Parsons, C. E., Young, K. S., Jegindø, E.-M. E., Vuust, P., Stein, A., & Kringelbach, M. L. (2014). Music training and empathy positively impact adults' sensitivity to infant distress. *Frontiers in Psychology, 5*, Article 1440.

Perlovsky, L. (2012). Cognitive function, origin, and evolution of musical emotions. *Musicae Scientiae, 16*(2), 185–199.

Picerni, E., Laricchiuta, D., Piras, F., Vecchio, D., Petrosini, L., Cutuli, D., & Spalletta, G. (2021). Macro- and micro-structural cerebellar and cortical characteristics of cognitive empathy towards fictional characters in healthy individuals. *Scientific Reports, 11*(1), Article 14519.

Preston, S. D., & Waal, F. B. M. de. (2002). Empathy: Its ultimate and proximate bases. *Behavioral and Brain Sciences, 25*(1), 1–20.

Rabinowitch, T.-C., Cross, I., & Burnard, P. (2013). Long-term musical group interaction has a positive influence on empathy in children. *Psychology of Music, 41*(4), 484–498.

Rabinowitch, T.-C., & Knafo-Noam, A. (2015). Synchronous rhythmic interaction enhances children's perceived similarity and closeness towards each other. *PloS One, 10*(4), Article e0120878.

Rabinowitch, T.-C., & Meltzoff, A. N. (2017). Joint Rhythmic Movement Increases 4-Year-Old Children's Prosocial Sharing and Fairness Toward Peers. *Frontiers in Psychology, 8*, Article 1050.

Ren, Q. Y., Sun, Y. M., Lu, X. J., Huang, C., & Hu, L. (2019). Empathy: Methodologies and characteristics from a psychophysiological perspective. *Chinese Science Bulletin, 64*(22), 2292–2304. [Ren, Q. Y., Sun, Y. M., Lu, X. J., Huang, C., & Hu, L. (2019). Empathy: Methodologies and characteristics from a psychophysiological perspective. *Chinese Science Bulletin*, 64(22), 2292–2304.]

Roberts, W., & Strayer, J. (1996). Empathy, Emotional Expressiveness, and Prosocial Behavior. *Child Development, 67*(2), 449–470.

Rosseel Y. (2012). lavaan: An R Package for Structural Equation Modeling. *Journal of Statistical Software, 48*(2), 1–36.

Savage, P. E. (2019). Cultural evolution of music. *Palgrave Communications, 5*(1), Article 16.

Savage, P. E., Loui, P., Tarr, B., Schachner, A., Glowacki, L., Mithen, S., & Fitch, W. T. (2021). Music as a coevolved system for social bonding. *Behavioral and Brain Sciences, 44*, Article e59.

Schellenberg, E. G., Corrigall, K. A., Dys, S. P., & Malti, T. (2015). Group Music Training and Children's Prosocial Skills. *Plos One, 10*(10), Article e0141449.

Schellenberg, E. G., & Lima, C. F. (2024). Music Training and Nonmusical Abilities. *Annual Review of Psychology, 75*(1), 87–128.

Shamay-Tsoory, S. G., Aharon-Peretz, J., & Perry, D. (2009). Two systems for empathy: A double dissociation between emotional and cognitive empathy in inferior frontal gyrus versus ventromedial prefrontal lesions. *Brain, 132*(3), 617–627.

Spielberger, C., Gorsuch, R., Lushene, R., Vagg, P., & Jacobs, G. (1983). *Manual for the State-Trait Anxiety Inventory.* Consulting Psychologists Press.

Steele, J. R. (2019). The Relationship between Music Aptitude, Empathy, and Sensitivity to Emotional Prosody: An ERP Investigation (Unpublished master's thesis). Middle Tennessee State University.

Stotland, E. (1978). *Empathy, fantasy, and helping.* Sage Publications.

Stupacher, J., Mikkelsen, J., & Vuust, P. (2022). Higher empathy is associated with stronger social bonding when moving together with music. *Psychology of Music, 50*(5), 1511–1526.

The jamovi project (2023). jamovi. (Version 2.4) [Computer Software]. Retrieved from https://www.jamovi.org.

Wallentin, M., Højlund, A., Friis-Olivarius, M., Vuust, C., & Vuust, P. (2010). The Musical Ear Test, a new reliable test for measuring musical competence. *Learning and Individual Differences, 20*(3), 188–196.

Walter, H. (2012). Social cognitive neuroscience of empathy: Concepts, circuits, and genes. *Emotion Review, 4*(1), 9–17.

Wan, Y., & Zhu, L. (2021). Effects of Rhythmic Turn-Taking Coordination on Five-Year-Old Children's Prosocial Behaviors. *Developmental Psychology, 57*(11), 1787–1795.

Wang, X. D., Wang, X. L., & Ma, H. (1999). *Rating Scales for Mental Health.* Chinese Mental Health Journal Publisher. [Wang, X. D., Wang, X. L., & Ma, H. (1999). *Rating scales for mental health* (Revised edition). Beijing: Chinese Mental Health Journal Publisher.]

Watanabe, D., Savion-Lemieux, T., & Penhune, V. B. (2007). The effect of early musical training on adult motor performance: Evidence for a sensitive period in motor learning. *Experimental Brain Research, 176*(2), 332–340.

Wei, B., Zhang, X., Cui, D., & Li, Y. (2023). Linking objective and subjective social status to altruistic sharing in China: The role of empathy. *Current Psychology, 42*, 27401–27414.

Wöllner, C. (2012). Is Empathy Related to the Perception of Emotional Expression in Music? A Multimodal Time-Series Analysis. *Psychology of Aesthetics Creativity and the Arts, 6*(3), 214–223.

Wu, X., & Lu, X. (2021). Musical Training in the Development of Empathy and Prosocial Behaviors. *Frontiers in Psychology, 12*, Article 646425.

Yan, Z., Zeng, X., Su, J., & Zhang, X. (2021). The dark side of empathy: Meta-analysis evidence of the relationship between empathy and depression. *PsyCh Journal, 10*(5), 794–804.

Yu, C.-L., & Chou, T.-L. (2018). A Dual Route Model of Empathy: A Neurobiological Prospective. *Frontiers in Psychology, 9*, Article 2212.

Zhang, F. F., Dong, Y., Wang, K., Zhan, Z. Y., & Xie, L. F. (2010). Reliability and Validity of the Chinese Version of the Interpersonal Reactivity Index-C. *Chinese Journal of Clinical Psychology, 18*(2), 155–157. [Zhang, F. F., Dong, Y., Wang, K., Zhan, Z. Y., & Xie, L. F. (2010). Reliability and validity of the Chinese version of the Interpersonal Reactivity Index-C. *Chinese Journal of Clinical Psychology*, 18(2), 155–157.]

Zhang, W. X., Li, X., Chen, G. H., & Cao, Y. M. (2021). The relationship between positive parenting and adolescent prosocial behaviour: The mediating role of empathy and the moderating role of the oxytocin receptor gene. *Acta Psychologica Sinica, 53*(9), 976–991. [Zhang, W. X., Li, X., Chen, G. H., & Cao, Y. M. (2021). The relationship between positive parenting and adolescent prosocial behaviour: The mediating role of empathy and the moderating role of the oxytocin receptor gene. *Acta Psychologica Sinica*, 53(9), 976–991.]

Zhong, Y. P., Yang, Z. L., & Fan, W. (2015). The Effects of Self-other Overlap on Helping Behavior: Moderating of Perspective Taking. *Acta Psychologica Sinica, 47*(8), 1050–1057. [Zhong, Y. P., Yang, Z. L., & Fan, W. (2015). The effects of self-other overlap on helping behavior: Moderating of perspective taking. *Acta Psychologica Sinica*, 47(8), 1050–1057.]

Zhou, H., & Long, L. R. (2004). Statistical Remedies for Common Method Biases. *Advances in Psychological Science, 12*(6), 942–950. [Zhou, H., & Long, L. R. (2004). Statistical remedies for common method biases. *Advances in Psychological Science*, 12(6), 942–950.]

Note: Figure translations are in progress. See original paper for figures.