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Rethinking musicians as a model for plasticity and transfer

César F. Lima[1,*],
Francesca Talamini[2], and
E. Glenn Schellenberg[1,3]

Differences between musicians and nonmusicians are routinely attributed to training-induced plasticity and transfer, even though pre-existing factors provide equally plausible explanations. We propose repositioning correlational research: not to infer training effects, but to constrain causal accounts, reveal the neurocognitive organization of abilities, guide experimental studies, and integrate with genetically informed designs.

Causal interpretations of musician–nonmusician differences

Over the past 25 years, musicians have served as a prominent model for studying expertise in psychology and neuroscience. Key questions include whether music practice enhances perceptual and cognitive abilities, and how it shapes brain structure and function. Differences between musicians and nonmusicians, and associations with duration of music lessons, are often interpreted as evidence of training-induced neuroplasticity and far transfer—the idea that training effects extend beyond music to domains such as language and memory [1]. Nevertheless, observed advantages may reflect pre-existing genetic, cognitive, personality, and socioeconomic differences that influence who pursues training. Despite this ambiguity, correlational findings from musician studies continue to shape causal narratives, with claimed implications for education, aging, and brain health [2,3].

Progress requires aligning inferences with study designs. As randomized and longitudinal studies increasingly test plasticity and transfer directly, correlational research on musicians remains valuable only if reconceptualized: not as evidence of training effects, but as a means to constrain causal accounts, to examine the neurocognitive organization of abilities, to integrate with genetically informed designs, and to generate hypotheses for experimental follow-up.

Why musicians' advantages may not reflect training

Heritability estimates for musical abilities and behaviors average 42% and exceed 85% for exceptional skill (for a review, see [4]). Genetic influences extend beyond musical aptitude to listening behavior, practice duration, and age at onset of training—variables typically treated as entirely environmental. Familial and genetic factors also help to explain why earlier training onset is associated with superior musical skills. Moreover, shared genetic influences across traits (pleiotropy) account for correlations between musical expertise and general cognitive ability that are routinely attributed to training.

Socioeconomic background, personality, and cognitive ability also influence who engages in music training [5,6]. When these variables are controlled for, or when studies are adequately powered, the advantages for musicians often diminish or fail to replicate [5,7–9] (Box 1). Crucially, randomized and longitudinal designs provide weak causal evidence for far transfer [1], with meta-analyses reporting small, heterogeneous effects [6,10] that may partly reflect publication bias [10]. Causal evidence is further weakened by methodological limitations, including small samples, differential attrition, brief interventions, and the lack of active control groups [1].

Repositioning correlational research

Although researchers may acknowledge that correlation does not imply causation, the titles, abstracts, and conclusions of correlational studies often continue to frame plasticity and transfer as default explanations, relegating competing explanations to brief caveats, partly because the field lacks an alternative framework for correlational research. This practice misrepresents the evidence, slows conceptual progress, and misinforms applications in education and health. Equally problematic is the assumption that controlling for covariates is sufficient to infer causality. Partial associations remain vulnerable to unmeasured factors, particularly genetic influences, and to reverse causation.

Correlational research on music training could be abandoned altogether or, as we argue, redirected toward questions that it can answer. Because causal hypotheses predict specific patterns of associations, correlational studies can constrain causal accounts by testing whether such associations are evident in the real world. When they are not, the range of plausible explanations narrows. Informative findings include null differences when training effects are expected, associations that disappear after accounting for covariates (Box 1), and effects that weaken with increasing expertise. In a large-sample study, professional musicians outperformed amateurs and nonmusicians on tests of musical ability and memory, but they scored lower than amateurs on a nonverbal proxy for general intelligence (*g*) and showed no advantage on several other measures of general cognitive ability [11]. Such findings are consistent with plasticity in closely related abilities but challenge claims of far transfer. More generally, designs that examine different levels of musical expertise or nonlinear associations with training offer informative tests of causal predictions.

Correlational studies are also well suited for investigating the neurocognitive organization of perceptual, cognitive, motor, and emotional abilities. Rather than asking

Box 1. Large-scale preregistered studies

Two recent preregistered, multisite investigations reported that previously documented musician advantages are small, unreliable, or absent after rigorous control. Considered jointly, the studies underscore the need for large-scale collaborations that increase statistical power, reduce contextual bias, and improve generalizability.

Grassi *et al*. [5] compared 600 highly trained musicians and 600 nonmusicians across 33 research units in 15 countries. Measures included socioeconomic status, personality, musical abilities, and cognition (short-term memory, executive functions, nonverbal reasoning, and vocabulary). Musicians came from higher socioeconomic backgrounds. They also scored notably higher on measures of musical abilities and open-mindedness. General cognitive differences, however, were small to negligible despite a decade or more of training, and the musicians' advantage in verbal short-term memory disappeared after adjusting for covariates.

With over 260 participants tested in six laboratories, Whiteford *et al*. [9] examined early auditory neural responses to the syllable /da/, indexed by the frequency-following response. Contrary to prior findings, music training was unrelated to neural encoding of speech or to tracking changes in pitch, regardless of training duration or age of onset. Musicians showed better melody discrimination, but this advantage was not related to neural measures. These results challenge claims that music training drives subcortical plasticity.

whether training enhances these abilities, a more informative question is how abilities are organized and what mechanisms they share. Whether defined as training or as an ability, musical expertise overlaps with multiple neurocognitive domains, revealing shared computations and functional organization. Associations with prosody perception, second-language proficiency, or auditory short-term memory, for example, may reflect overlapping mechanisms for processing sound.

Collectively, the many documented associations between musical expertise and other abilities offer a road map for potentially shared mechanisms. In one study, the association between music training and emotion recognition in speech prosody was explained by general cognitive abilities, whereas the correlation between musical ability and emotion recognition was explained by pitch discrimination, a basic auditory capacity shared across domains [8]. These findings suggest cross-domain mechanisms without invoking training effects. The same logic extends to research on multisensory integration, sensorimotor skills, temporal prediction, auditory imagery, and motor control, with musicians providing a model for investigating the neurocognitive organization of skilled performance rather than training effects.

Another opportunity lies in exploring theoretically meaningful variation within and across groups of trained individuals. Different forms of expertise—such as playing the violin or piano, or singing compared with instrumental training—require markedly distinct perceptual, motor, and cognitive skills. Examining this heterogeneity can refine hypotheses about mechanisms linking musical expertise to other abilities, regardless of causal direction. This potential remains largely unrealized, however, because musicians are typically treated as homogeneous groups. Musicianship is often defined using arbitrary thresholds, usually in years of training, with training rarely characterized sufficiently to allow systematic comparisons or replication. Treating music training as a continuous rather than dichotomous measure and reporting instruments played, individual or group training, age of onset, and practice status would improve comparability across studies while capturing relevant variation.

The same reasoning extends to comparisons with experts in other domains, such as sports. Such comparisons can distinguish domain-specific from domain-general features of expertise. Without active comparison groups, which are recognized as essential in longitudinal studies [1], cross-sectional designs cannot determine whether differences are music-specific or reflective of expertise more generally.

Nonmusicians with high musical aptitude are particularly informative. If these individuals do not show the same advantages as musicians, training remains a plausible explanation. However, if high-aptitude nonmusicians perform similarly to musicians and musical aptitude correlates with outcomes independently of training, predispositions become a parsimonious explanation of apparent training effects. Indeed, high-aptitude nonmusicians exhibit many of the perceptual, cognitive, and socioemotional advantages typically attributed to training [7,8,12].

Genetically informed designs provide a complementary opportunity to strengthen causal inference. Large twin studies have identified genetic and environmental contributions to musical phenotypes [4]. Recent molecular approaches extend this work by linking genetic variants to musical traits and behaviors (Box 2). Together, twin and molecular approaches help to disentangle genetic predispositions, shared familial influences, and training effects, while providing insights into gene–environment interplay.

Finally, correlational studies can guide randomized trials. After accounting for confounding factors, associations that remain evident in adequately powered samples inform task selection, effect sizes for power calculations, and neurocognitive targets for experimental follow-up. Correlational studies can also identify potential mediators and moderators of observed associations, generating mechanistic hypotheses for experimental testing. These contributions are greatest when they shape study rationale and design, rather than serving as *post hoc* qualifications for claims about training effects.

Reproducibility and open science

Our proposed agenda also depends on improved research practices.

Box 2. Genome-wide association studies

In genome-wide association studies (GWASs), researchers identify genetic variants associated with a phenotype or trait, whether relatively simple, such as pitch acuity, or more complex, such as music practice. In one recent large-scale preprint involving older individuals (*N* > 23 000), 21 independent genetic loci were associated at a suggestive threshold with active musical engagement [13]. Single-nucleotide polymorphism (SNP)-based heritability was estimated at 10%, consistent with other complex polygenic traits. A polygenic score (PGS) derived from the GWAS predicted related musical-engagement phenotypes in two independent samples. Notably, active musical engagement shared genetic architecture with rhythmic ability and aspects of cognitive and physical health, indicating that the link between musical activities and healthy aging may be partly genetic in origin.

A second GWAS examined whether musicality and language share a common genetic architecture [14]. Separate PGSs for beat synchronization and word reading were calculated from prior GWAS estimates. The word-reading PGS predicted objective rhythm discrimination, whereas the beat-synchronization PGS predicted reading ability independently of the word-reading PGS. Lower beat-synchronization PGSs also predicted a history of speech or language disorders. These findings suggest that observed associations between musicality and language reflect shared genetic architecture rather than, or in addition to, training-induced transfer between domains.

Underpowered samples, common in studies of musicians, inflate effect sizes and undermine replicability. The widespread appeal of music and simple causal narratives encourage a selective emphasis on positive findings, which are easier to publish and disseminate widely. When combined with extensive outcome testing without prespecified hypotheses or correction for multiple comparisons, these factors exaggerate the breadth and consistency of musicians' advantages.

Potential solutions include preregistration, open data and materials, larger samples, and multisite collaborations, all of which strengthen generalizability and enable cross-cultural comparisons. Replication and improved reporting standards are equally important. Box 1 illustrates these suggestions in practice.

Concluding remarks

The question is not whether musicians are a useful model, but what they model. Correlational studies cannot establish training effects. Instead, they can constrain causal accounts, reveal the neurocognitive organization of abilities, and generate hypotheses for randomized trials, especially when adequately powered and combined with informative comparison groups, genetically informed samples, and precise definitions of musical expertise. Redefining studies of musicianship around the questions and inferences they permit will broaden, rather than limit, their contribution to understanding musical expertise.

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Declaration of interests

The authors declare no competing interests.

[1]Centre for Psychological Research and Social Intervention (CIS-Iscte), Iscte – University Institute of Lisbon, Lisbon, Portugal

[2]Institut für Psychologie, Universität Innsbruck, Innsbruck, Austria

[3]Department of Psychology, University of Toronto Mississauga, Mississauga, Ontario, Canada

*Correspondence:
cesar.lima@iscte-iul.pt (C.F. Lima).

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