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Translational music education

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Abstract: Learning music is one of the core tasks of music education, alongside psycho-affective responses, cognitive understanding, aesthetic immersion and creative activities. While all these performances are inextricably intertwined with central-nervous processes, music educational theories and models are markedly lacking neuroscientific substantiation. Regardless of these shortcomings, a wealth of studies on neuro-cognitive music processing may profoundly elucidate music educational topics, hence the idea to bridge the gap between music-neuro-lab outcomes and music educational practice. About 30 years ago, translational medicine was designed to improve the application of lab-derived results in clinical practise – referred to as 'bench-to-bedside'. Inspired by this concept, the term 'translational music education' was coined. Integrating music-related psychobiological findings gives rise to epistemological meta-syntheses and theoretical frameworks, alongside comparative research on system compatibility between music education models and relevant lab data on music processing. This approach enhances the scientific reliability of music educational theories and highlights the distinct benefits of music education, such as music's role as a powerful booster of neuroplasticity, which is the basis of all learning and developmental processes. Distinct interdisciplinary and international research collaboration is essential for advancing translational music education, which is expected to increase the recognition of music education within the broader scientific community while significantly improving teaching techniques.

Keywords: complexity sciences, diversity and inclusion, interdisciplinary education, neurosciences, philosophy of science

Introduction

From the perspective of the philosophy of science, the question 'How scientific is music education?' arises, accompanied by arguments that music education models have mainly been based on subjective theories and reflective practice. The rationale behind this harsh criticism goes hand in hand with the complementary dualism of music education routine and research. Regarding music education as a scientific discipline, several key questions emerge: What are its fields of research? What research methods are being applied? And how are the results

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evaluated in an epistemological way as well as according to theories of truth?

A great deal of comparative music education research, such as the discovery of changes in national curricula or scrutinising differences between music education methods, typically applies techniques similar to those used in historical or jurisprudential realms, while, for instance, German music education strongly inclines towards philosophical considerations, such as 'aesthetic experience' in classroom education. Given the multifaceted spectrum of music education topics, there is no doubt that issues concerning musical learning in its broadest sense, along with its key mechanisms, play a crucial role. However, what are the most effective methods for exploring their characteristics and determining factors?

Examining the interdisciplinary domain of aesthetics may help to shed light on this issue in music education. While the ground-breaking works of Gustav Theodor Fechner (Ortlieb et al., 2020) differentiated psychological from philosophical approaches, today's aesthetics broadly encompass three areas: philosophical and arts-related aesthetics, empirical aesthetics, as pursued by the Max Planck Institute for Empirical Aesthetics (MPIEA), and neuroaesthetics (Iigaya et al., 2020), which focus on the central nervous mechanisms underlying aesthetic experience and judgement. This methodological triad also applies to key issues in music education and may inspire a holistic understanding of music-related learning processes.

In the context of music education, inferential considerations suggest distinguishing between three methodologically distinct realms: (i) philosophical and phenomenological approaches, subjective theories included, (ii) empirical approaches, encompassing a broad scope of standardised quantitative and qualitative designs as well as reflective practice, and (iii) neuroscientific and neuro-cognitive approaches, which elucidate the central nervous mechanisms underlying music-associated learning processes.

A wealth of studies relating to the first two areas have been published in journals such as *Philosophy of Music Education Review* (Indiana University Press) and *Music Education Research* (Taylor & Francis), reflecting topics like 'philosophising in music education' (Jorgensen & Yob, 2023) or presenting robust empirical results based on meta-syntheses of qualitative studies, such as how teachers can support students' musical learning (Fredriksson et al., 2024). Despite encouraging older publications (e.g. Collins, 2013), studies exploring the central nervous and neuro-cognitive factors of learning music are still rare, though they are vital for achieving a comprehensive in-depth understanding of music education.

Exploring the realm of neuroscientific research on music cognition, music

experience and creative music activities, however, opens new horizons. A surprising wealth of studies touch upon music education topics, without, however, providing music education methods By way of illustration, functional magnetic resonance imaging (fMRI) explores how the right inferior frontal gyrus of the human brain processes micro-melodies and motifs (Cheung et al., 2018), we learn about neuro-cognitive control of tonal stability (Li et al., 2021), and we get insights into how distinct interplay between the anterior cingulate and medial prefrontal cortex modulates the sense of musical dissonance (Bravo et al., 2020). Moreover, we get familiar with brain activations related to music experience and musical errors (Sakai et al., 2022), and, regarding cross-cultural music education and pupils with a migration background, how acculturation impacts music memory (Demorest et al., 2010). We are faced with cerebral functions modulating the musical impact on emotions and sociability (Sachs et al., 2018) or with what is going on in our brain during musical improvisation (Beaty, 2015).

The lack of neurosciences in music education and scientific findings with notable music educational relevance gives rise to an intriguing idea: considering lab-derived research as potentially applicable to music educational practice may result in inferential metasyntheses – in other words, a theoretical framework of neuroscientific music education. This idea, however, aligns with the principles of translational medicine, hence the proposed term 'translational music education'. But what is 'translational medicine'?

Translational Medicine (TM) is linked to the expression 'bench to bedside', indicating the transition from lab-based research to clinical practice. Its origin is inextricably intertwined with the disillusioning discovery that only a small part of scientific outcomes find their beneficial application in clinical practice. The term was coined in the late 1990s, and Worboys et al. (2021) refer to the British Medical Journal, which characterised TM as a process: 'TM is then about the movement of ideas, materials and technologies from research laboratories, through evaluation and trials, to routine clinical application.' Accordingly, Translational Medicine can be seen as a principle encouraging the shift from research to practice, today also involving digitalisation and artificial intelligence (Baxi et al., 2022), for instance. And it was precisely this close dynamic connection between scientific findings and their clear-cut application in practical areas that inspired the concept of 'Translational Music Education'.

Key features of Translational Music Education

And yet, there is a crucial difference between translational medicine and translational music education. While most medical lab-based research inherently aims to improve clinical and public health practices, neuroscientific research on musical processes and music processing does not necessarily intend to impact on music education. This crucial difference requires a certain ex post facto construction – in other words, translational music education has to search for relevant scientific findings that may ultimately serve as key constituents of dynamically built theoretical frameworks. Nonetheless, this process will eventually result in explicitly neuroscientific music education research, and initiate translational collaboration, much like in medical fields.

Impact on Scientific Music Education Frameworks

Bringing the notion of 'music education frameworks' into play simultaneously raises the question of whether music education can be regarded as a system with its innate internal logic, or whether it is rather an umbrella term encompassing the totality of ideas and practices around learning and teaching music. This question is far from trivial and evokes the science-theoretical problem of what definitions are and what they stand for.

Broadly speaking, we can distinguish three different types of music education frameworks or systems: (i) heuristic concepts based on in-depth considerations alongside an inherent inner logic, created and suggested by individuals, (ii) the open totality of music education practices and positions, and (iii) tentative plans to unearth the 'true nature of music education', akin to discovering natural laws. By way of illustration, Victoria Boler (2020) proposed a philosophical framework of music education consisting of the triad utilitarian, aesthetic and praxial philosophy of music education.

Such music education systems and frameworks (usually) imply areas of music education such as the history of music education, cross-cultural music education, or music education techniques, each (scientific) sub-discipline requiring specific research methods. In this regard, the present article focuses on mechanisms underlying mental processes with key relevance to music education, such as learning, experiencing or understanding music – in other words, without certain brain functions there is no musical experience or musical learning, hence their crucial significance for music education frameworks.

Music Education and the Essence of Music

While it may seem trivial to emphasise that music plays a crucial role in music education, posing questions about the nature and essence of music is not trivial at all. Being a key authority in theoretical realms dealing with music, musicology is faced with a myriad of definitions, such as Saint Augustine's famous delineation 'ars bene modulandi' and 'ars bene movendi' [the art of fine modulation and motion], or cross-cultural semantics around music, including the phenomenon of languages without a specific word for what English-speaking people call music, with Inuit being a well-known example. Moreover, dealing with the phenomenon of music involves ontological issues (Nussbaum, 2007) such as the notion of 'musica universalis' between Pythagoreanism and Daoism, Kepler's 'harmonices mundi' or Leibniz's theory of pre-established harmony (Vamvacas, 2009).

Although this article's aim is not to explore the essence of music, we must remember that without music-processing brain functions, there would be no awareness of music, and without cognitive processors in the brain, there would be no philosophy or ontology of music. However, this paper does not advocate any kind of neuroscientific reductionism; rather, it acknowledges the ontological autonomy of different entities – comparable to Karl R. Popper's Three Worlds Theory (Popper, 1972), which differentiates between the physical world, which also contains biological objects such as the human brain, the world of mental states or processes, such as experiencing music, and the world of objective contents, such as cultural objects, music included. Similar to the metaphor that a poem's sense cannot be discovered through a chemical analysis of paper and ink, we highlight different ontological qualities of music, mind and brain, while still emphasising the inevitable necessity of brain functions for all music processing, music education topics included.

These considerations relate to key issues of music education. For instance, the first German music educational concept issued after World War II, Michael Alt's (1968) 'Didaktik der Musik. Orientierung am Kunstwerk' [The Didactics of Music. Orientation towards the Work of Art], was harshly criticised for two shortcomings: first, it widely ignored the individual learning music, and second, it narrowed the subject of music education down to what he called 'Kunstwerk' [the work of art], implying an aesthetic value hierarchy that sharply conflicted with the open-minded nature of music education. In contrast, Dankmar Venus (1969) argued that music education should focus on distinct interactions between music and the pupil, suggesting a model that aligns closely with today's neuroscientific positions on music education.

Identification of the Benefits of Music Education

For decades, international music education has faced scrutiny from authorities who question the importance of music within public education and come up with convincing reasons for replacing it, for example, with a second or third obligatory foreign language or intensified training in IT and AI. Consequently, music educators have sought compelling justifications, such as 'music education supports individual personal development', 'music education is essential for understanding sociocultural traditions and, consequently, for becoming a well-rounded member of society', 'music is an important emotional counterpart within a dominantly cognitive school environment' or 'music education nurtures creativity and an aesthetic sensibility'. However, such a line of reasoning stems from within music education circles and is consequently ranked or 'unmasked' as being self-serving. Moreover, many such explanations lack a scientific foundation, making them vulnerable to interdisciplinary criticism and analyses, whereas translational statements may cogently advocate music education. However, translational logic is not merely a form of justification; it also serves as a powerful tool for unearthing fresh evidence as to why music education is far from being marginal.

More than a decade ago, a much-noticed Harvard study (Wan & Schlaug, 2010) called music making 'a tool for promoting brain plasticity across the life span', and Merrett et al. (2013) pointed out that musicians' brains differ structurally and functionally from non-musicians' brains, including variations in volume, morphology, density, connectivity and function across a broad variety of central nervous regions. Complementary to these basic studies, more recent research focuses on specific topics such as music as a booster and facilitator of neuroprocessing mechanisms during foetal and neonatal development (Chorna et al., 2019) and the beneficial impact of music on brain connectivity in the treatment of neurological disorders (Speranza et al., 2022). Given that the entirety of mental development, including learning and personal growth, is vitally and substantially linked to neuroplasticity, such neuroscientific outcomes are of striking importance for educational systems. They greatly advocate music education activities such as learning an instrument, group improvisation or live vocal arrangement – and when combined with dance as another strong booster of brain plasticity (Teixeira-Machado et al., 2019), complex models such as Elemental Music & Dance Education gain immensely in importance.

There is no doubt that music enhances neuroplasticity as well as the complex dynamic connectivity of neural networks,

which mirror our mental capacity, flexibility, adaptability and creativity. While in arts education domains the term 'creativity' is often reduced to inventiveness within artistic processes, from an interdisciplinary perspective, creativity is one of the fundamental traits of human beings. It is inextricably linked to the evolution of the mind, including the evolution of the genetic networks that shape human creativity (Zwir et al., 2022), and is indispensable for scientific progress and epistemic worth (Sánchez-Dorado, 2023). Moreover, the phenomenon of creativity is interrelated with the dynamics of the Default Mode Network DMN, hence the importance of this huge central nervous functional complex for music education (Mastnak, 2018). In this context, we have to emphasise that there is a certain rivalry between the DMN and cognitive executive processors of the brain, which are needed to solve, for instance, mathematical tasks. In other words, permanent overstimulation of this regions inhibits DMN-activities and results in an adverse imbalance of the central nervous system – or in other words, the human brain.

Why are humans creative? Why do they have a sense of beauty? Why do they seek love and strive for identity? And why are there huge inter-personal differences such as between extraversion and introversion, rigidity and flexibility, agreeableness and hostility, interests and intelligence? There is one simple answer: Our genes are masterminds and game-changers. However, there is an obvious difference between the biochemical structure of a gene and the genetic effect on our body and mind. This transition is the focus of the relatively young discipline of epigenetics, and while music is (most probably) not able to alter DNA, it may significantly impact on epigenetic processes. We know today that listening to music regulates human microRNA expression (Nair et al., 2021), and a recent study (Gallazzi et al., 2024) pointed out – with significant relevance to psychopathological manifestations in today's children and adolescents – that music has profound effects on emotion, cognition, mood regulation, stress reduction and social inclusion, and that researchers have begun to explore links between these benefits and epigenetic modifications, suggesting that aesthetic experiences might induce dynamic and/or stable changes in gene expression profiles.

At this point, we conclude our elucidation of the translational identification of music education's features and benefits, and state that further interdisciplinary research is needed. Translational music education is a scientific discipline in statu nascendi and may importantly change modes of music education reasoning, alongside the development of novel music education models and theories.

Compatibility of Music Education Systems

The question of how to prove theories is a core issue in scientific realms. While in some disciplines, such as mathematics, absolute proofs are possible, philosophy of science points out that empirical or correspondence-theoretical hypotheses (Mastnak, 2021a) cannot achieve absolute verification – only the possibility of falsification. The seminal work of Karl Popper, in particular his treatise *Logic of Scientific Discovery* (Popper, 2002), suggested the so-called 'degree of corroboration' as a measure of robustness (Lienau & DeSalle, 2009). For instance, evidence-based medicine uses standardised research designs such as randomised controlled trials (RCTs) to assess effect sizes of treatment tools. However, complex issues, which we frequently deal with in music education, do not allow such applications: multifactorial conditions make reliable scientific discoveries and proofs difficult.

Although there is high-ranking empirical research in music education, and a few research centres – e.g. in China – use neuro-imaging to elucidate music-educational processes, the lion's share of music education models still lack robust substantiation – at least according to theoretical scientific criteria. The present article encourages translational approaches and systemic meta-syntheses (Mastnak, 2021b) to construct relevant theories, such as in the realm of neuro-cognitive music education (Artýktay, 2024). This is one promising path, while another is to scrutinise existing music education theories with regard to relevant, e.g. neuro-cognitive, findings – a process that may result in the substantiation of music education positions, the discovery of errors or the improvement of explanations.

There are good reasons to assume that if music education practice is successful, its key mechanisms and associated explanations align with relevant neuro-cognitive theories. A comparative look at psychology may illustrate this assumption. Although both psychoanalysis and cognitive-behavioural therapy proved to be effective interventions, their theories were conflicting and gave rise to heated debates. Eventual comparative research, however, discovered unexpected theoretical similarities between both areas, while neurosciences highlighted that the Default Mode Network can be seen as a sort of unconscious information processor – and this was a final harmonising link between the former 'enemies'.

Music education comprises a wealth of schools of thought such as Orff-education, Jaques-Dalcroze's Eurhythmics (Fédération Internationale des Enseignements de Rhythmique, 2019), Roscher's Polyaesthetic Education (Allesch & Schwarzbauer, 2009), Eherenforth and Richter's Didactic Interpretation (Richter, 1994) and Mastnak's (2020) Ontolo-

gical Music Education. We are faced with an enormous diversity of related scientific foundations, for example, Didactic Interpretation importantly involves philosophical hermeneutics, while Carl Orff expressed profound cultural-anthropological ideas, today complemented by multidisciplinary approaches (Kalcher, 2022).

The interdisciplinary issue of how and/or to what extent these theories are consistent with relevant neuroscientific and neuro-cognitive findings calls for action. In other words, to compare these music education theories and models with relevant neuropsychological, neuroendocrinological, quantum-neuroscientific etc. findings can markedly improve their scientific robustness. Such cross-theoretical analyses and evaluation modes are in line with paradigms of translational music education research as proposed in this article. Furthermore, they may, elevate the recognition of music education within the broader scientific community. However, interdisciplinary and international collaboration is needed, and we hope that Czech colleagues will actively contribute to this endeavour.

Discussion and Prospects

All known populations have given birth to their very individual musical cultures, which is a strong indicator that music is inherent to the nature of the human race. This argument implies associated genetic and hereditary dispositions, and interdisciplinary research is on the verge of discovering music-related human genomics as well as the bio-cultural origin of music (Beccacece et al., 2021). While human beings are equipped with such genetic dispositions, recent research has highlighted the crucial importance of gene-environment interplay for the development and performance of music skills (Wesseldijk et al., 2023).

In this context, gene-environment interplay involves functions of specific music-sensitive processors in the brain, which decisively modulate a child's distinct (musical) acculturation. Similar to the acquisition of language, complex stimuli are integrated and form—starting as early as the third intrauterine trimester and with considerable impact on prenatal music therapy (Ji et al., 2024)—the child's holistic music experience, identity and understanding. The existence of these powerful central nervous processors gives rise to the question of the extent to which music education can contribute to musical talent and skills. Additionally, it prompts inquiry into the issue of whether translational music education is rather a descriptive approach analysing music-educational processes from neuroscientific or microbiological perspectives (Johnson, 2024), or whether it aims to influence music education practice, such as by improving teaching models.

Considering such topics, we may expect a watershed in music education,

where subjective theories and individual experience-based teaching techniques will be either replaced or complemented by science-based methods. It is highly likely that the optimisation of teaching modes will emerge from complex approaches that respect the value of professional experience as well as ideas. Thus, translational music education is based on interactive processes, compatible with paradigms of complexity sciences (Sturmberg & Martin, 2022), and aimed at improving music education epistemology and truth theory. International efforts are needed, and we eagerly look forward to substantial Czech contributions.

References

Allesch, C., & Schwarzbauer, M. (2009). Polyaesthetic Education: A model for integrating cultural experiences. In: J. N. Erzen (Ed.) *Congress Book II. Selected Papers XVIIth International Congress of Aesthetics*, 19-27. Sanart.

Alt, M. (1968). *Didaktik der Musik. Orientierung am Kunstwerk*. Düsseldorf: Pädagogischer Verlag Schwann.

Artýktay, G.G. (2024). Cognitive neuroscience and music education: Relationships and interactions. *International Journal of Educational Spectrum*, 6(1), 91-119. doi: 10.47806/ijesacademic.1402953.

Baxi, V., Edwards, R., Montalto, M. & Saha, S. (2022). Digital pathology and artificial intelligence in translational medicine and clinical practice. *Modern Pathology*, 35(1), 23-32. doi: 10.1038/s41379-021-00919-2.

Beaty, R.E. (2015). The neuroscience of musical improvisation. *Neuroscience and Biobehavioral Reviews*, 51, 108-117. doi: 10.1016/j.neubiorev.2015.01.004.

Beccacece, L., Abondio, P., Cilli, E., Restani, D. & Luiselli, D. (2021). Human Genomics and the Biocultural Origin of Music. *International Journal of Molecular Sciences*, 22(10), 5397. doi: 10.3390/ijms22105397.

Boler, V. (2020). Three philosophies of music education. https://victoriaboler.com/blog/three-philosophies-of-music-education

Bravo, F., Cross, I., Hopkins, C., Gonzalez, N., Docampo, J., Bruno, C. & Stamatakis, E.A. (2020). Anterior cingulate and medial prefrontal cortex response to systematically controlled tonal dissonance during passive music listening. *Human Brain Mapping*, 41(1), 46-66. doi: 10.1002/hbm.24786.

Cheung, V.K.M., Meyer, L., Friederici, A.D. & Koelsch, S. (2018). The right inferior frontal gyrus processes nested non-local dependencies in music. *Scientific Reports*, 8, 3822. doi: 10.1038/s41598-018-22144-9.

Chorna, O., Filippa, M., De Almeida, J.S., Lordier, L., Monaci, M.G., ... & Guzzetta, A. (2019). Neuroprocessing Mechanisms of Music during Fetal and Neonatal Development: A Role in Neuroplasticity and Neurodevelopment. *Neural Plasticity*, 2019, 3972918. doi: 10.1155/2019/3972918.

Collins, A. (2013). Neuroscience meets music education: Exploring the implications of neural processing models on music education practice. *International Journal of Music Education*, 31(2), 217-231. doi: 10.1177/0255761413483081.

Demorest, S.M., Morrison, S.J., Stambaugh, L.A., Beken, M., Richards, T.L. & Johnson, C. (2010). An fMRI investigation of the cultural specificity of music memory. *Social Cognitive and Affective Neuroscience*, 5(2–3), 282-291. doi: 10.1093/scan/nsp048.

Fédération Internationale des Enseignements de Rhythmique (2019). *Le Rhythme 2019 – Scientific Perspectives / Artistic Research*, Genčve.

Fredriksson, K., Zandén, O. & Wallerstedt, C. (2024). Teaching and learning in music education – a meta-synthesis. *Music Education Research*, 26(2), 193–204. doi: 10.1080/14613808.2024.2319579.

Gallazzi, M., Pizzolante, M., Biganzoli, E.M. & Bollati, V. (2024). Wonder symphony: epigenetics and the enchantment of the arts. *Environmental Epigenetics*, 10(1), dvae001. doi: 10.1093/eep/dvae001.

Iigaya, K., O'Doherty, J.P. & Starr G.G. (2020). Progress and Promise in Neuroaesthetics. *Neuron*, 108(4), 594-596. doi: 10.1016/j.neuron.2020.10.022.

Ji, C., Zhao, J., Nie, Q. & Wang, S. (2024). The role and outcomes of music therapy during pregnancy: a systematic review of randomized controlled trials. *Journal of Psychosomatic Obstetrics and Gynaecology*, 45(1), 2291635. doi: 10.1080/0167482X.2023.2291635.

Johnson, M.W. (2024). Music, cells and the dimensionality of nature. *Progress in Biophysics and Molecular Biology*, 186, 57-64. doi: 10.1016/j.pbiomolbio.2023.11.006.

Jorgensen, E. R. & and Yob, I.M. (2023). Editorial Reflections on Philosophizing in Music Education. *Philosophy of Music Education Review*, 31(2), 109-120. doi: 10.2979/pme.2023.a909305.

Kalcher, A.M. (Ed.) (2022). Orff im Wandel der Zeit – Kunst trifft Pädagogik. Wiesbaden: Reichert Verlag.

Li, C.W., Guo, F.Y. & Tsai, C.G. (2021). Predictive processing, cognitive control, and tonality stability of music: An fMRI study of chromatic harmony. *Brain and Cognition*, 151, 105751. doi: 10.1016/j.bandc.2021.105751.

Lienau, E.K. & DeSalle, R. (2009). Evidence, content and corroboration and the Tree of Life. *Acta Biotheoretica*, 57(1-2), 187-199. doi: 10.1007/s10441-008-9066-5.

Mastnak, W. (2018). Creativity. Neuropsychological conditions, music educational

perspectives, and health related benefits. *Musik-, Tanz- und Kunsttherapie* (Pabst Science Publishers), 28(1), 54-62. doi: 10.13140/RG.2.2.30675.86560.

Mastnak, W. (2020). Ontologische Musikpädagogik. *Diskussion Musikpädagogik*, 88(4), 44-52.

Mastnak, W. (2021a). Coherence Size and Confidence Range: Two new Parameters? *ResearchGate*. doi: 10.13140/RG.2.2.32833.28007.

Mastnak, W. (2021b). Systemic Meta-Synthesis. *ResearchGate*. doi: 10.13140/RG.2.2.25103.30886.

Merrett, D.L., Peretz, I. & Wilson, S.J. (2013). Moderating variables of music training-induced neuroplasticity: a review and discussion. *Frontiers in Psychology*, 4, 606. doi: 10.3389/fpsyg.2013.00606.

Nair, P.S., Raijas, P., Ahvenainen, M., Philips, A.K., Ukkola-Vuoti, L. & Järvelä, I. (2021). Music-listening regulates human microRNA expression. *Epigenetics*, 16(5), 554-566. doi: 10.1080/15592294.2020.1809853.

Nussbaum, C.O. (2007). *The Musical Representation: Meaning, Ontology, and Emotion*. Cambridge, MA: MIT Press.

Ortlieb, S.A., Kügel, W.A. & Carbon, C.C. (2020). Fechner (1866): The Aesthetic Association Principle—A Commented Translation. *I-Perception*, 11(3). doi: 10.1177/2041669520920309

Popper, K.R. (1972). *Objective Knowledge: An Evolutionary Approach*. Oxford: Clarendon.

Popper, K.R. (2002). *The logic of scientific discovery* [1st publication, 1935, last modified, 1980]. London: Routledge Classics.

Richter, Ch. (1994). Zum Umgang mit Musikwerken. Geschichte und Weiterentwicklung der didaktischen Interpretation von Musik. In: H. Gembris, R.D. Kraemer & G. Maas (Eds.) *Musikpädagogische Forschungsberichte 1993*, 41-70. Augsburg: Wißner.

Sachs, M., Habibi, A. & Damasio, H. (2018). Reflections on music, affect, and sociality. *Progress in Brain Research*, 237, 153-172. doi: 10.1016/bs.pbr.2018.03.009.

Sakai, K.L., Oshiba, Y., Horisawa, R., Miyamae, T. & Hayano, R. (2022). Music-experience-related and musical-error-dependent activations in the brain. *Cerebral Cortex*, 32(19), 4229-4242. doi: 10.1093/cercor/bhab478.

Sánchez-Dorado, J. (2023). Creativity, pursuit and epistemic tradition. *Studies in History and Philosophy of Science*, 100, 81-89. doi: 10.1016/j.shpsa.2023.05.003.

Speranza, L., Pulcrano, S., Perrone-Capano, C., di Porzio, U. & Volpicelli, F. (2022). Music affects functional brain connectivity and is effective in the treatment of

neurological disorders. *Reviews in the Neurosciences*, 33(7), 789-801. doi: 10.1515/revneuro-2021-0135.

Sturmberg, J.P. & Martin, C.M. (2022). Complexity sciences: Applied philosophy to solve real-world wicked problems. *Journal of Evaluation in Clinical Practice*, 28(6), 1169-1172. doi: 10.1111/jep.13781.

Teixeira-Machado, L., Arida, R.M. & de Jesus Mari, J. (2019). Dance for neuroplasticity: A descriptive systematic review. *Neuroscience and Biobehavioral Reviews*, 96, 232-240. doi: 10.1016/j.neubiorev.2018.12.010.

Vamvacas, C.J. (2009). *The Founders of Western Thought – The Presocratics*. Berlin: Springer Science & Business Media.

Venus, D. (1969). *Unterweisung im Musikhören*. Wilhelmshaven: Heinrichshofen.

Wan, C.Y. & Schlaug, G. (2010). Music making as a tool for promoting brain plasticity across the life span. *The Neuroscientist*, 16(5), 566-577. doi: 10.1177/1073858410377805.

Wesseldijk, L.W., Ullén, F. & Mosing, M.A. (2023). Music and Genetics. *Neuroscience and Biobehavioral Reviews*, 152, 105302. doi: 10.1016/j.neubiorev.2023.105302.

Worboys, M., Timmermann, C. & Toon, E. (2021). Before translational medicine: laboratory-clinic relations. *History and Philosophy of the Life Sciences*, 43(2), 48. doi: 10.1007/s40656-021-00379-6.

Zwir, I., Del-Val, C., Hintsanen, M., Cloninger, K.M., Romero-Zaliz, R., ... & Cloninger, C.R. (2022). Evolution of genetic networks for human creativity. *Molecular Psychiatry*, 27(1), 354-376. doi: 10.1038/s41380-021-01097-y.

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