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Music, sound, and health: a meeting of the minds in neurosciences and music

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Humans have been fascinated by the effect of sound on health since antiquity. In the sixth century BC, Pythagoras discovered that objects vibrating in simple numerical ratios produced harmonious sounds together. Building from this, he went on to posit that listening to different musical modes had different effects on health. Interest in music's impact on health continued over the centuries, and, in 2018, the study of music, sound, and health continues to excite scientists, therapists, and the potential recipients of interventions. Current and previous research have shown that music perception and music making change activity in many brain regions typically involved in emotion, reward, cognition, sensations, and movement. Music is a multisensory and motor experience, with a unique ability to further strengthen an already strong bond between brain regions that perceive with those that plan and execute motor commands.

Part of the interest in this field from the scientific community, as well as from the general public, stems from the fact that music is a fundamentally human experience. Music is ubiquitous across human cultures and across the human life span. Music brings people together in a multitude of social situations; its many uses include enjoyment, social bonding, and mood regulation. In recent years, the neurosciences of music have systematically investigated how, why, and for whom music and sound may influence the brain and the body. While effects of music on physiology and cognition have been demonstrated in

basic research and in music therapy, interindividual and intraindividual differences on these effects pose challenges but also opportunities of individualized and precision medicine approaches for the field. Thus, there is a need for theoretical as well as empirical work that aims to understand music and sound, their relationship to health and well-being, and how this relationship can be leveraged to increase human connections, interactions, and possibly healing. Better understanding of these relationships may offer improved clinical applications with sensitivity and specificity, such as by informing the design of targeted interventions and the type of engagement with music (such as singing, moving, and synchronizing to a beat) that are best suited to impact specific diseases and disorders, such as Parkinson's disease and other gait disorders; outcome and recovery from stroke in both the motor and the language domains; dyslexia and specific language impairment, stuttering, cognitive impairment, and dementia; and various forms of autism. Such research might also help us understand the underlying neural correlates of disorders of this music, such as tone deafness and beat deafness, and their effects on other neurological and psychiatric disorders and dysfunctions. The study of sound and health is also timely, as it capitalizes on technological advances of cognitive neuroscience and theoretical advances on the operating characteristics of the brain.

The Mariani Foundation for Paediatric Neurology hosted the Neurosciences and Music VI, an

international conference, in Boston, Massachusetts, from June 15–18, 2017, in partnership with the Harvard Medical School and Beth Israel Deaconess Medical Center. The central theme of the conference was music, sound, and health. With over 500 participants in attendance, the program included a preconference music intervention workshop; a keynote lecture by Professor Josef Rauschecker; symposia; poster sessions (260 were accepted: a record!; see Supplementary File 1, online only); and lightning poster presentations, chosen by a peer-review process. The meeting was of interest to neuroscientists, psychologists, and clinicians (both professionals and students) in the medical field, with participants from related disciplines, including therapy, education, musicology, and music performance, which elicited the collaboration of several qualified promotion partners.

The highly successful series "The Neurosciences and Music" was introduced in New York in 2000 (the conference title was "The Biological Foundations of Music"), resulting in the special issue *Annals of the New York Academy of Sciences* 930: 1−462. Since then, meetings have convened in Venice (2002, in cooperation with International School of Neurological Sciences), Leipzig (2005, with Max Planck Institute for Human Cognitive and Brain Sciences Leipzig), Montreal (2008 with BRAMS, International Laboratory for Brain, Music, and Sound Research), Edinburgh (2011, with IMHSD, the Institute for Music in Human and Social Development), and Dijon (2014, with the University of Bourgogne, Municipality of Dijon, and the University of Lyon in cooperation with EBRAMUS, Initial Training Network). All meetings have been held under the aegis of the Mariani Foundation, and each featured a theme: spanning development (*Ann. N.Y. Acad. Sci.* 999: 1−548), perception and performance (*Ann. N.Y. Acad. Sci.* 1060: 1−490), disorders and plasticity (*Ann. N.Y. Acad. Sci.* 1169: 1−569), learning and memory (*Ann. N.Y. Acad. Sci.* 1252: 1−367, E1−E7), and cognitive stimulation and rehabilitation (*Ann. N.Y. Acad. Sci.* 1337: 1−271).

The present volume includes the latest research in neurosciences and music from contributors across 16 countries coming from multiple disciplines and diverse theoretical and methodological perspectives. One theme of this volume addresses the effects of musical training across the life span. This includes children (Habibi, Iversen, and Zuk and Gaab), adolescents (Putkinen), training of different genres in young adults (Loui), and older adults (Alain, Russo and Dubinsky, Johnson, Degé, Bugos). Behavioral and neurophysiological work from nonhuman animals are also represented (Rauschecker, Honing, Merchant). Genetic and developmental contributions to musical aptitude are considered, encompassing a wide range of abilities, including prodigies and people with exceptional skills (Moser, Järvelä, Hambrick, Winner). Clinical and translational work covered in this volume range from very early musical interventions to support infant development (Tervaniemi, Loewy, Virtala, Partanen) to a multitude of disorders, including Landau-Kleffner syndrome, a childhood epileptic disorder (Caclin and Tillmann); developmental stuttering (McAuley); dyslexia (Zuk and Gaab); developmental coordination disorder (Trainor and Chang); autism (Chenausky, Lense); and specific language impairment (Gordon, Schön), as well as recovery from stroke (Schlaug, Särkämö, Baylan, Fujioka, Rodríguez-Fornells), and effects of musical interventions on Alzheimer's disease (Hanser) and age-related hearing loss (Russo and Dubinsky).

This special issue also addresses fundamental questions in the field that pertain to short-term memory (Griffiths, Lefebvre and Jolicoeur, Albouy), emotion and the predictive processes of the brain (Vuust, Koelsch, Zatorre, Pearce, Noppeney), cultural evolution (Ravignani), and the roles of rhythm and entrainment (Hannon, Cirelli, Lense, Trainor and Chang, Gordon), as well as the similarities and differences between brain processes for music and language (Patel, Jäncke, Elmer) and for music and voice (Belin), and effects of linguistic experience (White-Schwoch and Kraus) and the nature of interactions between multiple sensory systems (van Vugt, Furuya, Bernardi) and between multiple individuals (Zamm and Palmer, Lindenberger and Müller, Novembre *et al.*).

We are elated to see that the field of music neuroscience is burgeoning, as indicated by the increasing attendance and high quality of submissions to the Neurosciences and Music conferences over the years, with continued quality from established researchers as well as highly impactful work from young

investigators. We hope that this volume represents a maturation of theoretical ideas and methodological advances, while offering an expanded and more in-depth discussion and consideration of concepts touched upon at the conference. The present special issue provides a snapshot and current state of music neuroscience, and may also provide a useful introduction to the modern study of the potential benefits of musical sound and engagement on health and well-being.

Competing interests

The authors declare no competing interests