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Guest Editors' Introduction**MUSIC AS EMBODIED EXPERIENCE**

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Perhaps more than ever, technology influences how people experience music. We live in an era of online music streaming services such as Spotify, app-based musical instrument lessons such as Yousician, and user-friendly digital audio workstations like Garageband. Respectively, these tools increase the consumption and awareness of new music, gamify instrumental tuition, and democratize the once “experts only” area of musical production. The technology in these applications has evolved to an extraordinary level whereby the software could be considered a coparticipant within the experience. Indeed, music technology can act as song recommender, teacher, and collaborator.

In addition to technological advancements, we also are witnessing in the current era a shift in perspectives toward music’s societal function: Music is no longer simply a purely artistic pursuit but also a reliable therapeutic and salutogenic tool (see MacDonald, Kreutz & Mitchell, 2012). Music’s healing power has been observed since antiquity (the story of David using his skillful harp-playing to cast out evil spirits residing inside King Saul comes to mind), yet the focus on music’s role as a tool for emotional mood regulation (Saarikallio & Erkkilä, 2007) and how music-based interventions in clinical settings can aid in the process of stroke rehabilitation (Särkämö et al., 2008), just two diverse examples, is indeed unprecedented in history.

Taken together, technological advancement and changing attitudes toward music’s societal function have led to new questions and topics for researchers interested in music perception and cognition. How is technology rewiring the musical brain? What role can music technology play in music therapy and music education?

In the mid- to late-20th century, these questions would have been answered using a cognitivist approach. Within that framework, mental processes would have been understood to be analogous to a digital computer with the mind operating as a central information processor of inputs and outputs. In a Cartesian sense, the mind would have been seen as separate from the physical



world. Experimental designs from this era would have comprised stripped down, targeted listening tests in highly controlled settings; theories regarding how, for example, humans process musical structure would have been developed through proposed rule-based mental representations simulating real-world phenomena. In many ways, this disembodied approach to music cognition mirrored the then-recently discovered way of engaging with music. After all, it was just earlier in that century that humans first experienced music through recordings, far removed from the original sound source.

Yet throughout most of human history, musical experiences of all types required embodied actions. To participate in a musical activity, either as musician or audience member, required being within earshot of its source of production; most often, music was presented as a multimodal activity involving all the senses. The notion of music being a multimodal activity, one that incorporates all senses, is key to understanding why many music researchers started to adopt an embodied approach to music cognition. Since the late 1990s, the concept of embodiment has emerged as a viable and popular paradigm within music perception and cognition research, both as a concept to be explored philosophically and a phenomenon to be studied empirically. A recent collection edited by Lesaffre, Maes, and Leman (2017) demonstrates the multifaceted directions that embodied music cognition and music interaction have taken.

Proponents of the embodied cognition paradigm argue that the interactions between the body and the environment are central to shaping mental processes (Shapiro, 2014). In this view, the manner in which an organism in any realm learns and develops lies primarily on its body's physical shape and sensing properties. When applied to music, embodied music cognition views the body as the center of musical experience, acting as mediator between musical thought and action (Cox, 2016; Fincher-Kiefer, 2019; Leman, 2007). As a result, this research approach has assisted researchers in understanding how, for example, musicians' gestures enable observers to perceive the emotional expression of performers (Dahl & Friberg, 2007; Vuoskoski, Thompson, Spence & Clarke, 2014) and how dancers parse musical structure (i.e., metrical hierarchies) by physically mimicking temporal and acoustic features of music (e.g., Toiviainen, Luck & Thompson, 2010).

The embodied approach often relies heavily on high resolution capturing of movements or the tracking of day-to-day musical activities that would not be possible without recent technological advancements. Alongside epistemological developments, new technologies have influenced research approaches significantly, allowing new questions and methodologies to flourish. Such technologies also open space for reconsidering what musical experiences represent in this new millennium. First, motion capture of varying types has become a common method to measure and model music-related movements. Ranging from small portable inertial measurement units to expansive multicamera infrared optical systems, these technologies capture information with high temporal and spatial accuracy, allowing researchers to test hypotheses regarding how musicality is embedded within actions associated with music production, performance, and perception. Indeed, motion capture allows researchers to study a wide spectrum of interests, from modeling performers' gestures to tracking the rehabilitation of motor impairments through music therapy. Second, mobile apps can be used for experience sampling, which enables researchers to track personal listening habits (Randall & Rickard, 2017). This opens up intriguing new possibilities for investigating the experience of music in ecological ways. From these data, researchers model how listening choices affect behavior and vice versa, which in turn sheds light on, for instance, music's role in mood regulation and well-being.

The aim of the current Special Issue of *Human Technology* is to highlight how the wide diversity of technologies have matured to the point where they affect the way music is created, performed, enjoyed, and researched. For the issue, we encouraged submissions that would demonstrate how technology enables researchers to computationally model the structure of embodied musical expression and experience throughout various music-related activities. We received 11 stimulating and highly relevant submissions, of which six have been accepted for publication in this issue; an additional two remain under consideration for publication at a later date. These papers cover a range of topics, investigating music as a creative endeavor through performance and dance, as well as a tool toward healing, well-being, and development in therapeutic and educational settings.

The papers accepted for this issue can be divided into two broad groups: those focused specifically on embodiment—that is, embodied expression and communication in the context of musical performance and dance and those adopting a more applied approach to musical embodiment, investigating educational and therapeutic perspectives. In the former group, technology is used primarily as a tool enabling the systematic measurement, analysis, and modeling of music-related body movement, as well as an interface for embodied musical expression. In the latter group, technology could be characterized as serving a mediating role, facilitating educational, research, and therapeutic goals and processes.

Embodiment, Expression and Communication

Employing optical, marker-based motion capture as a method of data collection and stimulus generation, **Birgitta Burger and Petri Toiviainen** investigated how dancers embody musical emotions in their movements. Burger and Toiviainen collected ratings of perceived emotion from observers who watched silent stick-figure animations of people dancing. They later related the observer ratings to objectively measured movement characteristics, revealing consistent patterns in how emotion is perceived through visual channels of musically embodied movements. Using a similar combination of optical motion capture and perceptual experiments, **Anna Siminoski, Erica Huynh, and Michael Schutz** explored the role of auditory and visual feedback in ensemble performance. By manipulating the type and amount of coperformer feedback available to clarinet–piano duos, the authors were able to generate stimuli (audio recordings and point-light animations) for subsequent experiments investigating the perceptual implications of limited coperformer feedback under different presentation modalities (audio-only, visual-only, and audiovisual). **Lindsay Warrenburg, Lindsey Reymore, and Daniel Shanahan** also employed variations in presentation modalities (visual-only and audiovisual) in exploring the perception of emotion and sociality in video-recorded dance performances expressing melancholy, grief, and fear. In addition to collecting observer evaluations of perceived social connection and emotion, the video-recorded performances also were coded independently and systematically regarding the amount of physical contact between and among the dancers, suggesting a link between physical contact and perceived social connection. Finally, in a paper oriented toward the generation of new musical interfaces, **Çağrı Erdem, Qichao Lan, and Alexander Refsum Jensenius** explored the shapes of muscle energy used when performing on an electric guitar and then related them to the shapes of the resultant sounds. Subsequently, machine learning was used to generate muscle–sound design mappings for considering a new “air” instrument based on electromyography (EMG) sensors. One of the papers still under

consideration for future publication is that of **Luis Aly, Hugo Silva, Gilberto Bernardes, and Rui Penha**. These authors focus on embodiment and a broad range of biosensors in their review of interactive musical interfaces, covering 70 interactive musical artworks spanning more than 50 years.

Educational and Therapeutic Applications

Embodied musical experience encompasses far more than just the production and consumption of music. Indeed, we editors felt it important to include in this thematic issue research that demonstrated novel applications of embodied technology in, for example, education and psychological therapy. The two accepted studies are examples of how music processing tools (e.g., Max, pure data) and general use interaction tools (e.g., Bela boards) have a near limitless applicability to projects highlighting gestural interaction with new technology and how these lend themselves seamlessly to creative educational and therapeutic endeavors. In the first paper in this area, **Kjetil Falkenberg, Hans Lindetorp, Adrian Benigno Latupeirissa, and Emma Frid** investigated the method of vocal sketching as a means to inspire young children collaborating with master of arts students in designing novel digital musical instruments. During a workshop between the graduate students and children, the children described their ideal musical interface and what it would sound like. The graduate students then developed novel instruments based on the children's ideas. While vocal sketching ended up playing a limited role in the completed products, the authors highlighted how the technique could be useful in a more inclusive design process of new musical interfaces by opening creative channels to young children or other nonexpert groups. Then, **Gabriela Patiño-Lakatos, Hugues Genevois, Benoît Navarret, Irema Barbosa-Magalhaes, Cristina Lindenmeyer, Maurice Corcos, and Aurélie Letranchant** presented the outcome of a clinical platform trial that combined sounds, music, and vibrotactile mediation. In their pilot study, eight adolescents diagnosed with anorexia nervosa were exposed to a variety of common sounds and musical excerpts mediated through five audiovibrotactile objects (e.g., ball, table, headrest pillow, blanket, and microphone). By allowing the adolescents full control over the sounds, music, and audiovibrotactile objects, the mediating objects offered the youths a multimodal sensory interaction with different parts of their bodies. The authors noted how the mediating objects triggered various associations, memories, and feelings in each adolescent that acted as springboards for communicating inner experiences during clinical therapy sessions. Finally, the other paper still under consideration for later publication is that of **Andrew Danso and Rebekah Rousi**, which focused on music learning by primary school students. They studied use of the iPad and the KAIKU Music Glove as part of the pupils' regular music class pedagogy and analyzed the data via the Technology Acceptance Model to investigate the role of each device in students' academic performance and music experience.

A thematic issue dedicated to technology's current and future impact on the embodied musical experience is both timely and necessary. Collectively, the contributions paint a picture of a multifaceted area that, albeit young, comes from a rich lineage. This Special Issue on Music, Mind & Technology (MMT) is named after an international graduate degree program that was offered by the University of Jyväskylä (Finland) from 2005 to 2018. MMT was an interdisciplinary program that attracted students from around the world interested in bridging

the fields of musicology, cognitive science, and music technology. The program was also associated with the Academy of Finland funded Centre of Excellence (CoE) in Interdisciplinary Music Research (2008–2013). In the intervening years, the work of the MMT and CoE has continued through the recently formed Finnish Centre in Interdisciplinary Music Research. Meanwhile the field at large is growing with new established centers. For example, in 2018, the RITMO Centre for Interdisciplinary Studies in Rhythm, Time and Motion, was established in 2018 at the University of Oslo, Norway. In the same year, the University of Oslo, in collaboration with the Norwegian University of Science and Technology, opened a new master's program in Music, Communication and Technology (MCT). This new international program has taken up the mantle in training tomorrow's researchers enthusiastic about discovering the relationships among music, cognition, and technology. The above-mentioned groups are just examples of some of the exciting active research groups at the forefront of contemporary and innovative research on the musical experience. Though technology may have changed the way people engage with music, it remains a human endeavor. Research groups such as these ensure that the interdisciplinary field of music, cognition and technology will be pushed for years to come.

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