Music, movement, development and social interaction

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1 Background

1.1 The origins of music, movement, and social interaction

Countless debates have been drawn around the issue of music, dance, and its possible evolutionary roles (for a recent discussion, see Savage et al., 2021; Mehr, Krasnow, Bryant, & Hagen, 2021)[1]. Some hypothesize, for instance, that moving to sound is disadvantageous for survival, as it can cause physical injuries, it demands high levels of caloric expenditure, and it can even capture the attention of hostile forces (Christensen, Cela-Conde, & Gomila, 2017). A more common view, however, is that dance has evolutionary benefits, and several hypothesis have been developed to investigate this idea (Christensen, Pollick, Lambrechts, & Gomila, 2016; Phillips-Silver, 2009; Savage et al., 2021).

One of the most prominent hypothesis states that dance evolved as a mechanism of social bonding between members of a group (e.g. Savage et al., 2021)[2]. This view is often based on the fact that interpersonal synchronization to music is widely observed in social activities such as choirs, armies, and religious ceremonies (e.g. Huron, 2001). Recent studies generally strentgthen the social hypothesis, suggesting that group-synchronization to music can be linked to behaviors that are beneficial to society, such as collaboration (e.g. Wiltermuth & Heath, 2009; Kirschner & Tomasello, 2010), trust (Launay, Dean, & Bailes, 2013), and empathy (Keller, Novembre, & Hove, 2014) amongst group members (although, see Kirschner & Tomasello, 2010).

Beyond its apparent social benefits, music-induced movement appears to be an innate human capacity, rather than an arbitrary cultural imperative. Significan evidence suggests, for instance, that individuals as young as 5 months old tend to move when there is music (Zentner & Eerola, 2010; Ilari, 2015). The same is true for older individuals (e.g. Kohn & Eitan, 2016; González Sánchez, Żelechowska, & Jensenius, 2020). Importantly, newborns are generally sensitive to isochronous auditory stimuli (Winkler, Háden, Ladinig, Sziller, & Honing, 2009), an ability that may be fundamental for the development of rhitmic responses to music. Finally, the idea of dance as an innate predisposition is strengthened by studies on different animal species, which show that some parrots and primates spontaneously synchronize their bodies to periodic auditory stimuli (for discussions, see Fitch, 2013; Patel, 2014; Wilson & Cook, 2016).

In light of these studies, it seems convinging that some aspects of music-induced movement are beneficial to group cohesion, and also that these benefits constitute the product of some innate human capacities. Still, our knowledge about developmental and social dynamics of dance is relativelly scarce. Previous investigations of music

[1] Here we use the term "dance" as a reference to any sort of music-induced movement.

[2] Other prominent hypotheses state that dancing to music provide mating and communication benefits, as well as a combination of them (Savage et al., 2021)

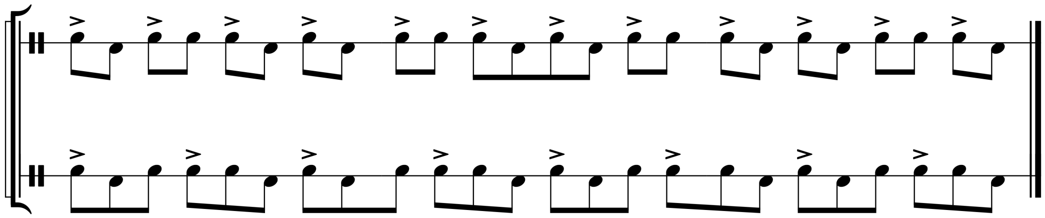

Figure 1: Example of metric ambiguity.

and movement did target different age-groups in different social setups, but only from a multitude of perspectives, methods and theoretical backgrounds (e.g., Launay et al., 2013; Wiltermuth & Heath, 2009; Zentner & Eerola, 2010; González Sánchez et al., 2020). In the next section, we explore a unified framework for investigating social and developmental variables related to music-induced movement.

1.2 A case for studying metrical hierarchies

The fact that individuals synchronize body-parts to periodic stimuli is nothing but a small portion of all the intricacies related to sound-movement interaction. Different from other animals (Fitch, 2013; Richter & Ostovar, 2016), human beings seem to be the only ones who are capable of moving in accordance with distinct **hyerarchical layers** of a pulse. Practically, this means that individuals can synchronize their bodies to different isochronous subdivisions of the same beat (Toiviainen, Luck, & Thompson, 2010; Phillips-Silver & Trainor, 2005; Burger, Saarikallio, Luck, Thompson, & Toiviainen, 2012). In Figure 1, for instance, individuals can either dance to a binary (Figure 1a), or to a ternary metric hierarchy (Figure 1b).

Hierarchical organizations of pitch and time are often thought to be a fundamental principle which determines how music is created, processed and perceived (e.g., Jackendoff & Lerdahl, 2006). For instance, the famous theory of tonal hierarchies (Krumhansl & Cuddy, 2010) explains why the same musical note can elicit different perceptual and phisiological responses (e.g., Koelsch, Rohrmeier, Torrecuso, & Jentschke, 2013). Not unlike tonal hierarchies, the concept of metrical hierarchies generally help us understand how different temporal patterns of acoustic stimuli elicit phisiological responses in the brain (Winkler et al., 2009), perceptual states (Desain & Honing, 2003) and, body-movement (Toiviainen et al., 2010; Burger, London, Thompson, & Toiviainen, 2018).

Temporal hyerarchies offer an outstanding oportunity for studying how music-induced movement can be influenced by social variables. That is because when a given stimulus has 2 or more possible metrical interpretations (i.e., metrical ambiguity), groups of people can make the implicit choice of agreeing or not about the subdivision to which they will synchronize. If dance is, in fact, an evolutionary tool which optimizes social interaction, it might be the case that individuals are sensitive to the way that their peers move to a particular stimulus.

From the perspective of human development, metric hierarchies can also inform us about how individuals develop social abilities. It could be the case, for instance, that group-synchronization disambiguates metrical hierarchies, but only for adults and seniors. This could indicate that individuals learn to use music in social settings. Conversely, we may find that this form of social exchange is present regardless of age, which would reinforce the idea of music as an innate tool for social-bonding. Next, we propose a set of 3 studies to test these hypotheses.

2 Action plan

2.1 Study design

Studies 1, 2 and 3 are designed to evaluate how social and developmental variables interact with metric complexity. All the procedures described below will be applied to a total of 1000 participants, randing from 5 to 90 years of age. Metrical hyerarchies will be explicitly manipulated to induce 2 different pulses (i.e., binary or ternary Figure 1).

STUDY 1. Participants, will be asked to dance freely to metrically ambiguous music (Phillips-Silver & Trainor, 2005, 2007), either in a group or in an alone condition. Auditory stimuli will be delivered through headphones (silent-disco paradigm), allowing us to bias the stimulus towards one of its two metrical hyerarchies (e.g., Figure 1), but only for a subset of the participants. We hypothesize that movements from the unbiased group will reflect the metric level suggested to the biased group. This would indicate that social interaction can determine how individuals perceive metrical hierarchies.

STUDY 2. Similar to study 1, participants will listen to metrically ambiguous strimuli through headphones (Figure 2). However, rather than dancing freely to music, participants will be blindfolded and asked to dance while holding hands in a circle (haptic coupling). A recent study by Chauvigné, Walton, Richardson, and Brown (2019) has shown that, in comparison with visual and auditory modalities, haptic coupling had the strongest effect in group-synchronization. Here we expand on this study by evaluating how tactile information can disambiguate metrical hierarchies.

STUDY 3. This study targets the development of novel and open-access tools which will fuel ecologically valid research on music-induced movement. The proponent of this project will continue the development of an application which collects movement data from built-in accelerometers in mobile phones. As both proof-of-concept and research extension, the alone condition of study 1 will be replicated remotely, and participants will be asked to download the application and hold their phones while moving to the musical stimuli. We hypothesize that accelerometer data will convey suficient information about participant's music-induced movements, and that therefore it can be used as a tool to enable large-scale, fast, low-cost, and ecologically valid research on music and dance.

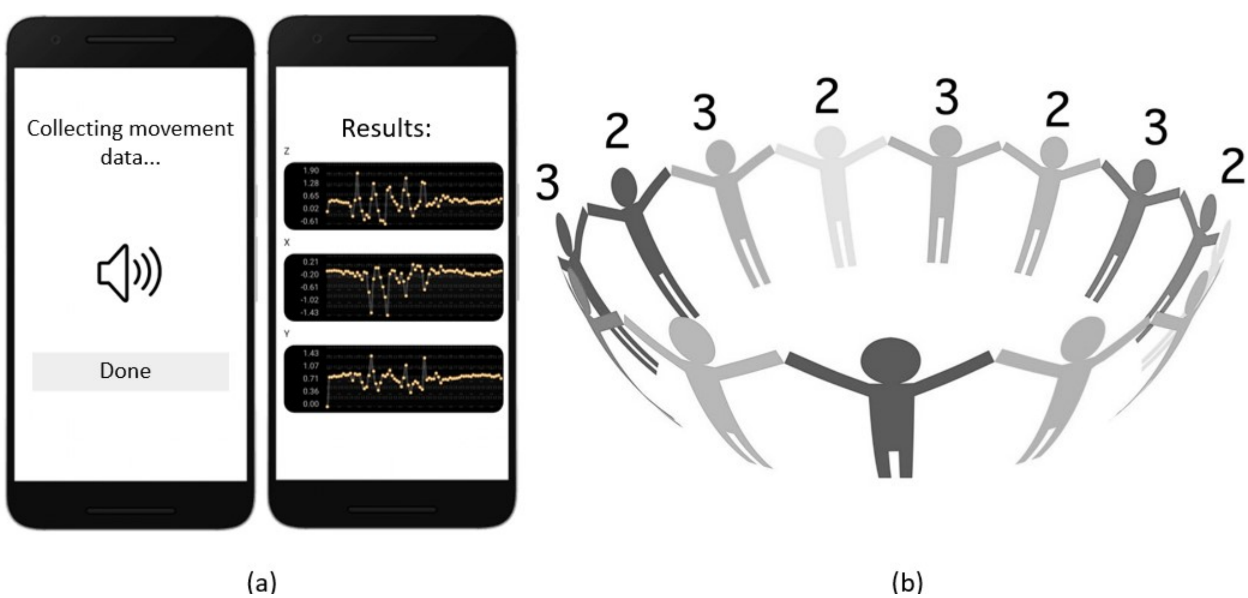

Figure 2: Illustratons of **(a)** accelerometer application for study 3, and **(b)** experimental design for study 2, where numbers indicate the metrical structure being administered individually to participants.

2.2 Methods

In studies 1 an 2, data will be collected with a 15-camera Qualisys optical motion capture system. Additionally, study 3 will use built-in accelerometers in participant's mobile phones. Movement data will be analysed with cutting-edge methods such as multiset cross-spectral techniques (Burger & Toiviainen, 2013) and recurrent neural networks. Acoustic variables such as beat clarity and spectral flux, which have been shown to influence how individuals synchronize to different metrical layers (e.g. Toiviainen et al., 2010; Burger et al., 2018) will be extrated using MIR toolbox (Lartillot & Toiviainen, 2007). Study 3 will extend the functionality of pre-existing technologies, such as JsPsych, (de Leeuw & Motz, 2016), a JavaScript library which allows researchers to collect data online and in the browser, and MoCap Toolbox (Burger & Toiviainen, 2013).

3 Significance of the work

This project is part of the Finnish Centre of Excellence in **Music, Mind, Body and Brain** (MMBB), led by Professor Petri Toiviainen from the Department of Music, Art and Culture Studies (University of Jyväskylä). The MMBB adopts a multidisciplinary empirical approach that combines cognitive musicology, psychology, education, therapy, computer science, and cognitive neuroscience to determine how experiences of music change 1) over the course of human life; 2) in different developmental disorders; and 3) in different social settings. From an applied perspective, the MMBB investigates how music-based interventions can be optimized to enhance learning, emotional, cognitive, motor and social wellbeing.

As part of that research initiative, the present proposal focuses on a specific gap of knowledge identifyed by the MMBB, which concerns the dynamics of social interaction and development related to music-induced movement. As stated in the main MMBB research proposal:

> Although evolutionary theories of music often emphasize its social origins and key role in group cohesion, bonding, and prosociality [...] the majority of music research focuses on individuals or dyads, covers only simple musical behaviours, and is limited to artificial experimental and laboratory settings. Therefore, our real-life understanding is very limited and rudimentary regarding the dynamics of and the variability in how music is used to coordinate movements and interact socially; how these functions evolve and are affected throughout different developmental stages.

Our proposed studies are significant because they address the issue of how multimodal and interpersonal interactions drive musical behavior in different social and developmental settings. Further, study 3 was specifically designed to overcome curent limitations of ecological validity, which are inherent to most of the previous investigations about music-induced movement. Overall, the outcomes of this project have the pottential to clarify deep issues regarding the origines of music behavior, its social functions, and how it developt throughout the course of human life.

4 Current stage

This project is on its early states of development, and we are currently working on the details of experiments 1 and 2, as well as on a prototype of the application proposed in study 3, which is available at Neto (2022). A comprehensive timetable for this study is displayed in the next section.

5 Timetable

The work that we propose here will be accomplished throughout the next 3 years of full-time work. The figure below represents an overview of our envisioned timetable.

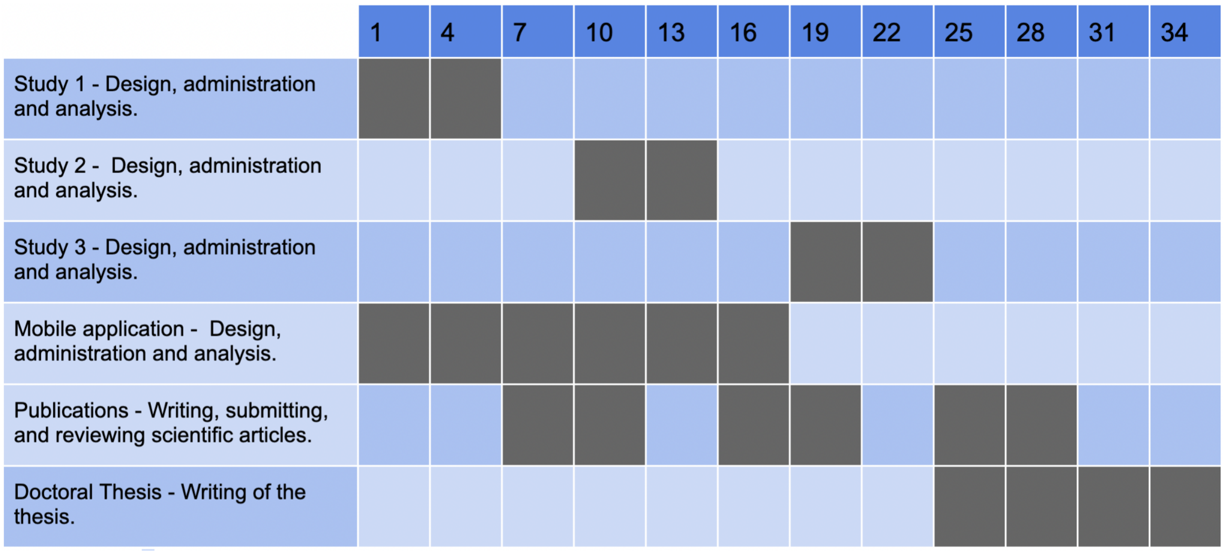

Figure 3: Timetable. Each column indicates 3 months of full-time work, and the dashed line represents the current stage of our project.

References

Burger, B., London, J., Thompson, M. R., & Toiviainen, P. (2018). Synchronization to metrical levels in music depends on low-frequency spectral components and tempo. *Psychological research*, *82*(6), 1195–1211.

Burger, B., Saarikallio, S., Luck, G., Thompson, M. R., & Toiviainen, P. (2012). Relationships between perceived emotions in music and music-induced movement. *Music Perception: An Interdisciplinary Journal*, *30*(5), 517–533.

Burger, B., & Toiviainen, P. (2013). MoCap Toolbox – A Matlab toolbox for computational analysis of movement data. In R. Bresin (Ed.), *Proceedings of the 10th sound and music computing conference* (pp. 172–178). Stockholm, Sweden: KTH Royal Institute of Technology.

Chauvigné, L. A., Walton, A., Richardson, M. J., & Brown, S. (2019). Multi-person and multisensory synchronization during group dancing. *Human movement science*, *63*, 199–208.

Christensen, J. F., Cela-Conde, C. J., & Gomila, A. (2017). Not all about sex: neural and biobehavioral functions of human dance. *Annals of the New York Academy of Sciences*, *1400*(1), 8–32.

Christensen, J. F., Pollick, F. E., Lambrechts, A., & Gomila, A. (2016). Affective responses to dance. *Acta psychologica*, *168*, 91–105.

de Leeuw, J. R., & Motz, B. A. (2016). Psychophysics in a web browser? comparing response times collected with javascript and psychophysics toolbox in a visual search task. *Behavior Research Methods*, *48*(1), 1–12.

Desain, P., & Honing, H. (2003). The formation of rhythmic categories and metric priming. *Perception*, *32*(3), 341–365.

Fitch, W. (2013). Rhythmic cognition in humans and animals: distinguishing meter and pulse perception. *Frontiers in systems neuroscience*, *7*, 68.

González Sánchez, V., Żelechowska, A., & Jensenius, A. R. (2020). Analysis of the movement-inducing effects of music through the fractality of head sway during standstill. *Journal of motor behavior*, *52*(6), 734–749.

Huron, D. (2001). Is music an evolutionary adaptation? *Annals of the New York Academy of sciences*, *930*(1), 43–61.

Ilari, B. (2015). Rhythmic engagement with music in early childhood: A replication and extension. *Journal of Research in Music Education*, *62*(4), 332–343.

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

Keller, P. E., Novembre, G., & Hove, M. J. (2014). Rhythm in joint action: psychological and neurophysiological mechanisms for real-time interpersonal coordination. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *369*(1658), 20130394.

Kirschner, S., & Tomasello, M. (2010). Joint music making promotes prosocial behavior in 4-year-old children. *Evolution and Human Behavior*, *31*(5), 354–364.

Koelsch, S., Rohrmeier, M., Torrecuso, R., & Jentschke, S. (2013). Processing of hierarchical syntactic structure in music. *Proceedings of the National Academy of Sciences*, *110*(38), 15443–15448.

Kohn, D., & Eitan, Z. (2016). Moving music: Correspondences of musical parameters and movement dimensions in children's motion and verbal responses. *Music Perception: An Interdisciplinary Journal*, *34*(1), 40–55.

Krumhansl, C. L., & Cuddy, L. L. (2010). A theory of tonal hierarchies in music. In *Music perception* (pp. 51–87). Springer.

Lartillot, O., & Toiviainen, P. (2007). A matlab toolbox for musical feature extraction from audio. In *International conference on digital audio effects* (Vol. 237, p. 244).

Launay, J., Dean, R. T., & Bailes, F. (2013). Synchronization can influence trust following virtual interaction. *Experimental psychology*.

Mehr, S. A., Krasnow, M. M., Bryant, G. A., & Hagen, E. H. (2021). Origins of music in credible signaling. *Behavioral and Brain Sciences*, *44*.

Neto, P. (2022). *Accelerometer test.* Retrieved 2022-02-01, from https://pasoneto.github.io/AccelerometerWeb/standaloneApp/accel_test.html

Patel, A. D. (2014). The evolutionary biology of musical rhythm: was darwin wrong? *PLoS biology*, *12*(3), e1001821.

Phillips-Silver, J. (2009). On the meaning of movement in music, development and the brain. *Contemporary Music Review*, *28*(3), 293–314.

Phillips-Silver, J., & Trainor, L. J. (2005). Feeling the beat: movement influences infant rhythm perception. *Science*, *308*(5727), 1430–1430.

Phillips-Silver, J., & Trainor, L. J. (2007). Hearing what the body feels: Auditory encoding of rhythmic movement. *Cognition*, *105*(3), 533–546.

Richter, J., & Ostovar, R. (2016). "it don't mean a thing if it ain't got that swing"–an alternative concept for understanding the evolution of dance and music in human beings. *Frontiers in human neuroscience*, *10*, 485.

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*.

Toiviainen, P., Luck, G., & Thompson, M. R. (2010). Embodied meter: hierarchical eigenmodes in music-induced movement. *Music Perception*, *28*(1), 59–70.

Wilson, M., & Cook, P. F. (2016). Rhythmic entrainment: why humans want to, fireflies can't help it, pet birds try, and sea lions have to be bribed. *Psychonomic bulletin & review*, *23*(6), 1647–1659.

Wiltermuth, S. S., & Heath, C. (2009). Synchrony and cooperation. *Psychological science*, *20*(1), 1–5.

Winkler, I., Háden, G. P., Ladinig, O., Sziller, I., & Honing, H. (2009). Newborn infants detect the beat in music. *Proceedings of the National Academy of Sciences*, *106*(7), 2468–2471.

Zentner, M., & Eerola, T. (2010). Rhythmic engagement with music in infancy. *Proceedings of the National Academy of Sciences*, *107*(13), 5768–5773.