Take the "N" Train: Dance, Entrainment and Prosocial Behavior

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Project title (topic): Take the "N" Train: Dance, Entrainment and Prosocial Behavior
Site of research: Department of Music, Art and Culture Studies, University of Jyväskylä

Abstract

The abstract is a summary of the research plan. It provides a brief overview of scientific and societal objectives, research methods and data as well as scientific and societal results and impact generated by the research.

Nearly all people across all known cultures engage in rhythmic entrainment with others through dance, and have done so since prehistoric times. Despite this, our understanding of the nature of entrainment and the functions of dance remain surprisingly limited. In particular, the role of different perceptual modalities in entrainment has not been thoroughly studied. Furthermore, some studies have suggested that dance promotes prosocial behavior and group bonding, but research on this has given inconsistent results. The current project aims to tackle these questions using an interdisciplinary approach that combines musicology, motion capture technology, music information retrieval, and dynamical systems theory with behavioral, neurochemical and subjective measures of individual experience. The project will be the first one to investigate complex, hierarchical full-body entrainment of multiple dancers and its prosocial effects, and to account for the role of visual, auditory, motoric and vestibular information in human experiences and outcomes of entrainment. By combining cutting-edge kinematic analysis techniques with grounding in perceptual data and both objective and subjective measures of prosocial outcomes, this project will seek to elucidate previously unknown aspects of dance, and provide new insights into human social functioning, the enigmatic evolutionary origins of dance and music, and the role of rhythmic entrainment in everyday human interactions.

1 Aim and objectives

1.1. Significance of the research project in relation to current knowledge

Describe how the project is linked to previous international or national research (state of the art).

Although dance is among the most universal of human behaviors, it is also among the most mysterious. Evidence suggests that humans have been dancing for more than 60,000 years, yet dance has no obvious evolutionary benefits and can even appear as a waste of energy better spent on hunting or reproduction (Christensen, Cela-Conde, & Gomila, 2017). Some have hypothesized that through *entrainment*—the act of moving in synchrony with others—dance serves human social needs by promoting group bonding or signaling group coalition (Richter & Ostovar, 2016). While most of our familiar experiences with entrainment involve music—tapping a toe in time with a song, or the feeling of being swept along by the music in dance, be it at a nightclub or a ballet class. However, entrainment also pervades our everyday lives in more subtle ways, from our tendency to 'fall into step' while walking beside a friend our ability to engage in a back and forth conversation (Cross, 2014). Some studies indeed suggest that there are links between rhythmic entrainment and outcomes such as increased group cohesion or prosocial behaviors (e.g., Rabinowitch & Meltzoff, 2017), these results are inconsistent A number of important factors have not been systematically accounted for in previous research, resulting in a lack of clarity about the underlying mechanisms by which dance may produce positive social effects. The current project therefore seeks to renew scientific knowledge of the role of dance in human social functioning by addressing the following unexplored factors:

The nature of complex, free, full-body entrainment: the majority of literature relating sensorimotor entrainment to positive social outcomes focuses on highly restricted movements such as finger tapping or drumming. Studies involving full-body movements of dyads or groups have employed restrictive choreographies, limited measurement of bodily movement to a single body part such as the head or hand, or did not directly measure movement at all (e.g., Woolhouse, Tidhar, & Cross, 2016). However, dance involves complex, whole-body, rhythmically hierarchical movement patterns (Toiviainen, Luck, & Thompson, 2010), and the degree to which entrainment in dance happens on multiple beat levels and between multiple parts of dancers' bodies, whether this varies depending on who is dancing together, and how or whether this affects the social outcomes of dance remains unknown.

The role of multiple modalities: entrainment can involve multiple modalities such as auditory, visual, proprioceptive (the feeling of one's own movements), vestibular (sense of head orientation, rotation, and translation), and biological (respiration and neurochemical). Although previous research has implicitly involved many of these modalities (e.g., Woolhouse et al., 2016; Phillips-Silver & Trainor, 2008), these different modalities have not been measured or controlled in a systematic way, leaving the relative importance of each modality and its relationship to others unknown.

The prosocial effects of entrainment: measures of pro-social outcomes have been inconsistent across previous studies, targeting varied potential mechanisms without regard to others. Some studies have suggested that rhythmic entrainment may positively affect a dancer's memory and attention towards a partner (Woolhouse et al., 2016), how much they like their partner (Stupacher et al., 2017), or their sense of their partners' trustworthiness (Knight, Spiro, & Cross, 2017). There is some evidence that rhythmic entrainment with others affects the release of neurochemicals related to social functioning such as endorphins (Tarr, Launay, Cohen, & Dunbar, 2015). However, research on this is limited and has not yet fully explored how dance might affect other important neurochemicals such as oxytocin, which research has implicated in social bonding (Donaldson & Young, 2008). While any or all of these factors may play important roles in mediating the effects of dancing on social functioning, but they have not been explored collectively or systematically.

The proposed project will address these factors using a naturalistic paradigm that measures participants' free dance movements using full-body optical motion capture, which has been established by previous work (e.g., Burger, Thompson, Luck, Saarikallio, & Toiviainen, 2013; Carlson, Burger, London, Thompson, & Toiviainen, 2016; Toiviainen et al., 2010). Systematic manipulation of coupling in visual, auditory and motor modalities and the collection of supporting perceptual data will be used to corroborate the role and relative importance of these modalities in establishing social entrainment from first- second- and third-person perspectives. Cutting-edge kinematic analysis methods will be employed and new analysis methods will be specially developed to deal with challenges that need to be met in the analysis of complex movement, including the nonstationary and multivariate nature of the data and the multiple timescales in which interactions take place. To measure social outcomes of entrainment, subjective, behavioral and biological measures will be employed.

A close examination of the psychological aspects of rhythmic entrainment may best be undertaken using an *embodied cognition* paradigm. While traditional models of cognition consider the mind and physical body to be separate, *embodied cognition* assumes that bodily actions and perceptions have a direct influence on and can be considered an integrated part of our thoughts and feelings. This view is supported by a variety of research. For example, body movement can affect how we perceive music, in that vestibular stimulation caused by head movement can influence the way we perceive hierarchical rhythmic structure (meter) in music (Phillips-Silver & Trainor, 2008). Moreover, depression, emotion, and personality traits can recognizably influence how we walk. Our own bodies also affect our social cognition; Chartrand and Bargh (1999) showed that humans tend to subconsciously mimic others during social interactions, and furthermore that we tend to like others better who mimic our own gestures and postures.

One consequence of the close relationship between action and perception is that, when examining social rhythmic entrainment, there is the need to disentangle *first-, second- and third-person perspectives* (Leman 2008). Two people who are rhythmically entrained through dance can be viewed from the perspective of one of the dancers, whose own (first-person) feeling of being entrained may be based on the combination of hearing the music, feeling her own movements and seeing how her partners' movements are in time with her own. She may also compare her self-perception with her partners' movements, evaluating her partner's entrainment with herself or the music from a second-person perspective. The pair can also be viewed from the outside, through observation and measurement of both dancers' movements, yielding a third-person perspective. The integration of action and perception in cognitive processes means that there is likely overlap in the perception of self and the perception of another during social interaction. Thus, a clearer understanding of social entrainment necessitates clarifying the relative importance of audio, visual and motoric modalities from the viewpoint of the different perspectives, which is a main aim of the current project.

Dynamical systems theory provides a mathematical framework for understanding various aspects of entrainment in multiple modalities. Most important to the proposed project, two different states resulting from entrainment can be distinguished. In *period-locking*, the dancers show a consistent relationship in their periods of movement (i.e. temporal lengths of their movement cycles), while the phases (i.e., positions within a movement cycle) thereof may not have a consistent relationship. In *phase-locking*, also the phases of movements show a stable relationship. These states can theoretically arise between matched or mismatched modalities (e.g., entrainment between a dancers' movements and her partner's movements compared to a dancers' movements and the heard music). The degrees of period- and phase-locking can be analyzed using spectrotemporal methods, such as cross-wavelet analysis, and compared between experimental conditions or correlated with other relevant measures such as perceptual data regarding entrainment from multiple perspectives, and outcomes of pro-social behavioral measures.

The potential social outcomes of entrainment through dance must also be considered in terms of embodied cognition using multiple perspectives and modalities. Subjective first-person feelings of social closeness or interpersonal liking can be gathered from participants. A well-established paradigm known as the *prisoner's dilemma game*, provides a useful behavioral measurement (Good & Russo, 2016). In the game, each member of a dyad has the option to either collaborate with or compete against the other, resulting in equal positive results if both collaborate (both gain points), equal negative results if both compete (both lose points), or a highly positive result for one and a highly negative result for the other if one chooses to compete, gaining many points, while the other chooses to collaborating, thus losing many points. As the "best" strategy for one play can only be determined in light of the other player's decisions, this paradigm provides a robust measure of cooperative behavior that does not depend on players being unfamiliar with the game, or failing to guess a "trick" (as when a researcher "accidentally" drops a box of pens to facilitate a helping scenario).

Finally the role of biological responses to entrainment provides another objective perspective. *Oxytocin* is a neuropeptide that can act as both a hormone and neurotransmitter that has been shown to be released in conjunction with important human interactions such as breast-feeding and sexual activity and is associated with social bonding and prosocial behavior, including mother-infant bonding, in which entrainment is highly implicated (Feldman et al., 2011). Oxytocin, which can be measured from blood plasma or saliva, may therefore be involved with positive social effects related dance. While there is evidence that listening to relaxing music can increase oxytocin (Nilsson, 2008), and that oxytocin levels improve synchronization during rhythmic tapping (Gebauer et al., 2016), no known research has explored the potential role of oxytocin release in dance, although dance has previously been shown to relate to endorphin release (Tarr, Launay, Benson, & Dunbar, 2017). The current project will therefore aim to test and develop new knowledge about whether oxytocin plays a role in the social outcomes of bodily entrainment.

The main objectives of the proposed project are as follows:

- Objective 1: To identify modes of corporeal entrainment between dancers in free naturalistic music-induced movement;
- Objective 2: To unravel the roles and relative importance of different perceptual modalities in corporeal entrainment;
- Objective 3: To elucidate effects of entrainment on prosocial behavior and manifestations thereof.

1.2. Research questions and/or hypotheses

We aim to answer the following four research questions (Q1-5) with the corresponding hypotheses (H1-5):

Q1: Which kinematic features predict high levels of perceived or felt bodily entrainment? Does the presence of multiple metrical levels in entrainment affect the accuracy of entrainment and the perceived or felt strength thereof?
H1: Perceived entrainment depends on the degree of period-locking; felt entrainment depends on the degree of phase-locking; the presence of multiple metrical levels enhances accuracy and strength of entrainment.

Q2: How do the kinematic characteristics of entrainment (accuracy, movement patterns) depend on the presence or absence of multimodal information (auditory, visual, motor)?
H2: The presence of multimodal information induces more accurate phase-locking and facilitates entrainment at several metrical levels.

Q3: How do perceived and felt entrainment depend on the presence or absence of multimodal information (auditory, visual, motor)?
H3: Perceived and felt entrainment is enhanced when multimodal information is present; presence of multimodal information makes perceived entrainment more dependent on phase-locking.

Q4: How does dance entrainment on multiple metrical levels involving interaction via multiple perceptual modalities affect prosocial behavior?
H4: Presence on multiple metrical levels and several perceptual modalities of interaction strengthens the prosocial effects of entrainment.

Q5: How are prosocial effects of dance entrainment manifested?
H5: Mediators such as interpersonal liking, oxytocin, sense of similarity to partners ultimately predict prosocial cooperative behaviors.

1.3. Expected research results and their anticipated scientific impact, potential for scientific breakthroughs and for promoting scientific renewal

The project will go beyond current state of the art by:

- providing accounts of the complex, multidimensional dynamics of embodied musical interaction, focusing on aspects that have received little attention so far: multimodal, multiperson, multivariate, and multiscale interactions;
- creating a formalized mathematical/computational framework for kinematic study of complex entrainment, based on advanced methods of signal processing, dynamical systems theory, statistics, and music psychology;
- resolving the effect of different perceptual modalities on full-body entrainment, from kinematic point of view and from both actor's and observer's perspectives;
- elucidating the effect of complex, multidimensional entrainment on prosocial outcomes in a naturalistic movement setting.

Additionally, the project will benefit the scientific community by publishing (as part of the MoCap Toolbox) open-access computer software, in which the developed analysis methods are implemented.

Beyond the musical domain, the results will elucidate aspects of human information processing, social behavior, and communication in general. These include gestural communication in everyday settings, and the role of auditory-visuo-motor coupling in interaction in general.

2 Implementation

2.1. Work plan and schedule

The main objectives of the proposed project are as follows:

- Objective 1: To identify modes of corporeal entrainment between dancers in free naturalistic music-induced movement;
- Objective 2: To unravel the roles and relative importance of different perceptual modalities in corporeal entrainment;
- Objective 3: To elucidate effects of entrainment on prosocial behavior and manifestations thereof.

Our preliminary results (Hartmann et al., under revision) show that perceived entrainment can be predicted by multivariate kinematic features, supporting the feasibility of the proposed project, in particular as regards Objectives 1 and 2.

The project will comprise two phases, Phase 1 (project years 1-2) focusing on dyadic and Phase 2 (project years 3-4) on group entrainment respectively. In each phase, three experiments will be conducted (Phase 1: Exp. 1a, 2a, 3a; Phase 2: Exp. 1b, 2b, 3b). Fig. 1 depicts the causal relations between data modalities that each experiment focuses on.

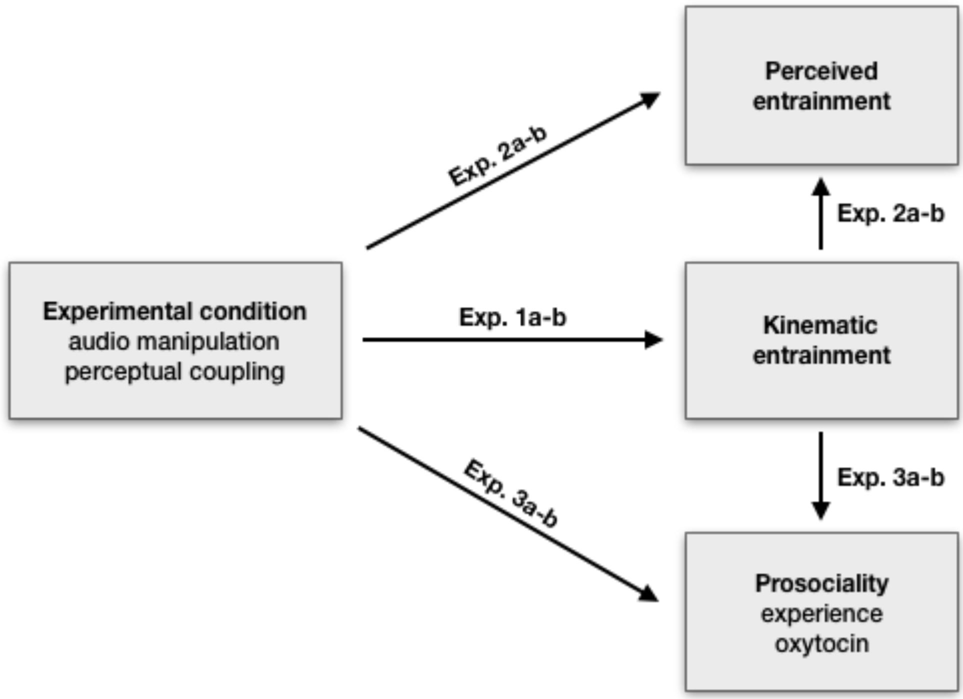
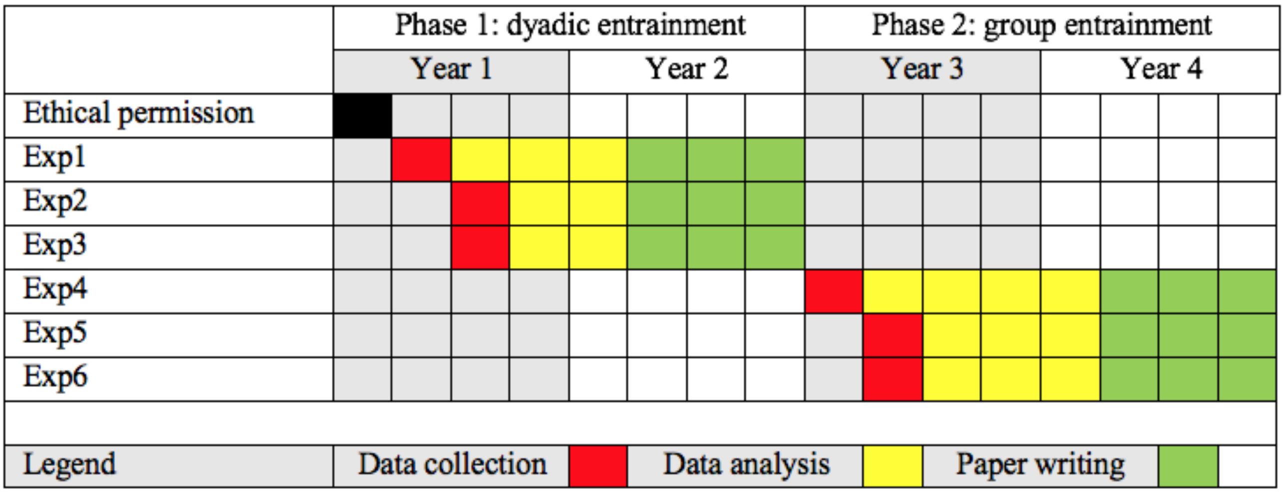


Fig. 1. Relations between data modalities addressed by each experiment.

While the three researchers of the project will work in close collaboration, each of them is assigned responsibility (including planning and organizing respective data collection and analysis, and reporting the results) of one of the three tasks as follows.

- *Prof. Petri Toiviainen* will be responsible for the overall management of the project, and the development methods to extract relevant features related to multivariate, multilevel, nonstationary entrainment;
- *PhD Birgitta Burger* will be responsible for investigating how perceived and physical entrainment depends on presence of multimodal information;
- *PhD Emily Carlson* will be responsible for organizing data collection and investigating how prosocial behavior depends on perceptual and kinematic entrainment.

The overall schedule of the project is displayed in the following Gantt chart.



The project will comprise two phases, with Phase 1 (yrs. 1-2) focusing on dyadic and Phase 2 (yrs. 3-4) on group entrainment. Each phase is divided into three Tasks:

Phase 1:

- Task 1: Kinematics of full-body dyadic entrainment (Q1, Exp.1)
- Task 2: Multimodal interactions in dyadic entrainment (Q2-3, Exp.1-2)
- Task 3: Prosocial effects of dyadic entrainment (Q4-5, Exp.3)

Phase 2:

- Task 4: Kinematics of full-body group entrainment (Q1, Exp.4)
- Task 5: Multimodal interactions in group entrainment (Q2-3, Exp.4-5)
- Task 6: Prosocial effects of group entrainment (Q4-5, Exp.6)

The following mobility is planned:

- *Birgitta Burger* will visit *Peter Keller* at Western Sydney U. for three months at the middle of the 2nd project year. The purpose of the mobility is to perform entrainment analysis on the data collected in Exp. 1 and prepare a joint publication.
- *Emily Carlson* will visit *Emma Cohen* at Univ. of Oxford for three months at the middle of the 2nd project year. The purpose of the mobility is to perform prosocial behavior analysis on the data collected in Exp. 3 and prepare a joint publication.

Human resources

- Birgitta Burger will be employed during 2020–23 for 37 months; Emily Carlson will be employed for 2022-24 for 32 months. Additionally EMily Carlson will work part-time for the project dusing 2021 as part of her post doc funded by the University of Jyväskylä.

Milestones

- Month 24: three journal papers corresponding to Tasks 1-3, with first authors Toiviainen, Burger, and Carlson, respectively.
- Month 48: three journal papers corresponding to Tasks 4-6, with first authors Toiviainen, Burger, and Carlson, respectively.

2.2. Research data and material, methods, and research environment

The following data will be collected:

- **Audio**: *musical features* computationally extracted from audio recordings of musical excerpts; they will be used to aid in selection of stimuli used in the experiments; in particular estimated tempo and pulse clarity will be used as criterion;
- **Kinematic**: *optical motion capture* data collected while the participants are dancing; these data are used to analyze kinematic features of movement; *video recordings* collected during perceptual tests will be used to estimate participants' amount of movement during perceptual tasks;
- **Perceptual**: ratings of *perceived and felt entrainment* (both 1^{st}- and 2^{nd}-person perspectives) collected from dancers after motion capture session; ratings of *perceived entrainment* between animated dancers (3rd-person perspective) will be collected; these will be subsequently modelled by kinematic features extracted from movement;
- **Psychosocial**: indirect *behavioral measures of prosocial behavior* will be obtained using a version of the prisoner's dilemma game (see Ch. 1.1); subjective ratings of *interpersonal liking* and *social closeness* will be obtained from participants following dance sessions;
- **Neurochemical:** difference between plasma and saliva *oxytocin levels* before and after a dance session will be used as a physiological measure of social bonding;
- **Demographics**: *age, gender, musical and dance training, personality* (Big Five), and *empathy* (EQ) data will be used to assess the significance of these variables for entrainment and social bonding;

In the project, researchers own the copyrights of the results of the research funded by the Academy of Finland, but University may assume the right to the invention.

Fig. 2 shows schematically the analysis pipeline for obtaining estimates of kinematic entrainment for full-body movement.

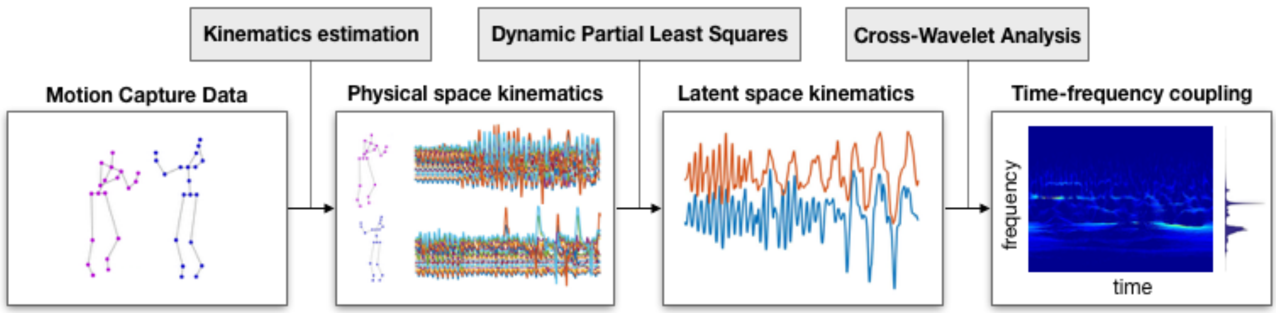


Fig. 2. Analysis pipeline for obtaining estimates of kinematic entrainment from full-body movement.

Experiments 1a-b. (Q1-3, 3^{rd}-person perspective.)

Participants. 40 dyads (Exp. 1a) and 20 quartets (Exp. 1b), whose members are not previously acquainted, recruited from the university community with variable amounts of musical and dance training. Participants will be rewarded by a movie ticket.

Stimuli. Excerpts of dance music representing different genres. The silent disco paradigm, in which each dancer is using wireless headphones, will be used, allowing for different stimuli being presented to each member. To induce entrainment at different levels of accuracy and with different styles, various *audio manipulations* are introduced to vary the dancers' mutual congruence and thus to vary the degree of auditory coupling. The manipulations, from weakest to strongest, include difference in beat clarity, phase shift, and tempo shift.

Procedure. Participants will move together to music under four different *perceptual coupling conditions*, in which the presence and absence of visual (V; participants either seeing each other or not) and motor (M; participants either holding hands or not) coupling is manipulated, constituting a two-factor design. Participant's movements are recorded using full-body optical motion capture. After each stimulus, participants will rate either perceived of felt entrainment. Subsequently, participants will fill demographic data questionnaires, a personality test, and an empathy test. Within each dancer group, data about familiarity with the other dancers will be collected and will be regarded as a random variable in subsequent analyses.
Data analysis. To quantify multivariate entrainment, participants' motion capture data will be analyzed using advanced multivariate associate measures. In particular, *Partial Least Squares* will be used to project the movements from physical space to latent spaces. To deal with the non-stationarity of human movement, these analyses will be performed *dynamically*, using a moving window. Subsequently, multilevel entrainment at different temporal levels is estimated from time-frequency coupling using *Cross-Wavelet Analysis*. In addition to whole-body analyses, *Vestibular activation* and entrainment thereof is estimated from the translational and rotational movement of heads. Two answer Q1, the thus obtained kinematic measures of entrainment are compared with entrainment ratings by correlation and regression analyses. To answer Q2, two-way ANOVAs will be used with V and M as factors and each entrainment measure in turn as the dependent variable.

Experiments 2a-b. (Q1-3, 3rd-person perspective.)
Participants. 40 participants recruited from the university community with variable amounts of musical training. To eliminate potential effects of familiarity, the perticipants will be different from trhose in Exp. 1. Participants will be rewarded by a movie ticket.
Stimuli. Animations created from the motion capture data collected in Experiment 1.
Procedure. Participants are asked to rate the perceived level of entrainment in the movement between the dancers presented in the stimuli.
Data analysis. Similar to Experiment 1.

Experiment 3a-b. (Q4, 1st- and 2nd-person perspectives)
Participants. 40 dyads (Exp. 3a) and 20 quartets (Exp. 3b) recruited, whose members are not previously acquainted, from the university community with variable amounts of musical and dance training. Participants will be screened for depression and anxiety using the Hospital Anxiety and Depression Scale (HADS) and Borderline Personality Disorder, as these conditions may result in abnormal responses to oxytocin (Olff et al., 2013). Participants will be rewarded by 50 euros.
Stimuli. Same as in Experiment 1. Each quartet will be subjected to one of the stimulus manipulations only.
Procedure. Participants will move together to music under *the V condition* while being motion captured. Subsequently, participants will be engaged with an *iterative prisoner's dilemma game* (see Ch 1.1).*)* Finally, participants will fill demographic data questionnaires, a personality test, and an empathy test. Blood and samples will be collected before and after the dance session, and oxytocin concentration will subsequently measured therefrom by PhenoSwitch Bioscience (Sherbrooke, Quebec, Canada; www.psbinc.ca) using the ELISA (Enzyme-Linked Immunosorbent Assay) protocol. Additionally, saliva samples will be collected to allow an alternative way for oxytocin level measurement, using Sallivete (Sarstedt, Rommelsdorft, Germany).

Data analysis. Overall level of entrainment will be estimated from the motion capture data using kinematic measures developed in Exp. 1. Levels of entrainment, change in oxytocin level, and measures of prosocial behavior are subjected to correlational analyses.

The Finnish Centre for Interdisciplinary Music Research (FCIMR) at the University of Jyväskylä is globally one of the leading research centres in the field of music perception and cognition, and music psychology. This is evident, for instance, from a recent bibliographical analysis on leading journals in the field (Anglada-Tort & Sanfilippo 2019), according to which Finland has produced, with a clear margin, most publications and citations per capita, most of these coming from FCIMR. The project will benefit from the wide within-house multidisciplinary expertise at the FCIMR (e.g. Suvi Saarikallio, music and emotion; Jaakko Erkkilä, music therapy; Martin Hartmann, music interaction analysis). Relevant for the proposed project, FCIMR has previous experience with oxytocin measurements, in particular within the Academy of Finland -funded project *Sweet sorrow* (2013–17), led by prof. Tuomas Eerola.

The Department of Music, Art and Culture studies, University of Jyväskylä, offers excellent infrastructure particularly for conducting research on music psychology and music cognition. Due to previous and ongoing projects funded by the EU and the Academy of Finland (e.g. *Finnish Centre of Excellence in Interdisciplinary Music Research*) the facilities are equipped with state-of-the-art infrastructure, and the topic of the project is aligned with the Department's research strategy. In particular, the Interdisciplinary Music Labs at the Department is a purposefully developed, exceptionally well-equipped research environment enabling top-quality, naturalistic movement research. It includes a professional optical motion capture system, a professional recording and sound processing studio, wireless headphones, and equipment for measuring physiological responses, including (stationary and portable) EEG, electromyogram (EMG), eye-tracking, heart rate variability, and skin conductance. High-level methodological expertise, administrative assistance, and departmental facilities including office spaces, laptops, software, and library services are available according to highest international standards.

2.3. Risk assessment and alternative implementation strategies

Four main risks are identified:

- *Difficulties in inducing prosocial effects in lab* (Exp. 3). Experiments are carried out in a motion capture lab with participants wearing motion capture suits. This environment might suppress any eventual prosocial behavior in some participants. However, in our previous similar studies we have interviewed our participants regarding the effect of the laboratory environment and they have for the most part reported no problems in this respect. The probability of this risk can thus be expected to be low. Should it materialize though, we will modify the experiment procedure to utilize low-end motion capture (i.e. accelerometers) in a more naturalistic environment, therefore recording only part of the movement but still obtaining data that can be used to estimate entrainment. Video data may also be further analysed in this case.
- *Difficulties in recruiting participants* (Exp 1, 3). It may prove challenging to reliably recruit participants who are not previously acquainted. If this proves to be unduly difficult, participants' level of familiarity with each other will be collected and treated as a random variable.
- *Complexity of movement* (Exp. 1, 3). Free full-body movement is high-dimensional and can be nonstationary, which makes its kinematic analysis challenging. However, the PI's group has extensive experience in analysing such movement with single dancers, and extending the

approach to multiple dancers is feasible. The probability of this risk is thus low. If it arises, we will focus our analysis on a subset of the body parts, which will still yield useful information on entrainment.

- *Oxytocin concentration measurement from blood samples* (Exp. 3). Although the measurement of oxytocin has been in use for several decades now as a biomarker related to human social functioning questions remain about its interpretability and its measurement is not yet fully standardized (McCullough, Churchland, & Mendez, 2013) Additionally, it may be difficult to recruit participants if they must agree to give a blood sample. If this is the case, only saliva samples will be used. A possible alternative, non-invasive measure of biological entrainment is heartrate, as used by Feldman et al. (2011) to show entrainment between infants and mothers, but this measure may be more susceptible to confound due to the physical exertion involved in dance, and therefor is considered less preferred and will only be used in the event that measurement of oxytocin is untenable.

3 Research team and collaborators

3.1. Project personnel and their relevant merits

- *Petri Toiviainen* obtained his PhD in musicology in 1996. He has carried out research on musical movement since 2004, using high-quality motion capture for data collection and developing advanced multivariate methods for their analysis. He has 152 refereed publications (6165 citations, h index 40, Google Scholar). He is co-author of two widely used open-access software toolboxes, MIR Toolbox and MoCap Toolbox. In addition to having his PhD in musicology, he has master's degree in Theoretical Physics. He has been the leader of Finnish Centre of Excellence in Interdisciplinary Music Research (2008-13) and several other research projects funded by the Academy of Finland, as well as co-leader of the EU-funded project Tuning the Brain for Music. For 2013–18, he held an Academy Professorship, which is the highest research post in Finland.
- *Birgitta Burger* has accomplished her PhD thesis in 2013 on relationships between music-induced movement and musical features, emotional characteristic and personality traits. She is an expert in optical motion capture and has gained proficiency in the extraction and analysis of movement and synchronization using various period- and phase-locking approaches. She co-develops the MoCap Toolbox together with Petri Toiviainen. She is co-author in 28 peer-reviewed scientific articles (744 citations, h-index 14, Google Scholar) and has presented her work at numerous international conferences, including winning the Young Researcher Award at ICMPC 12/ESCOM 8 in 2012.
- *Emily Carlson* completed her PhD degree in November 2018. Her thesis focused on individual differences and social context on music-induced movement (particularly relevant for Tasks 3 & 6). She also holds a degree in Music Therapy from Western Michigan University, and has worked as a professional, board-certified music therapist with multiple populations, and from 2019-2020 will be a Visiting Scholar at the Centre for Music and Science at Cambridge University.

The PI's research team has conducted research on dynamics of music cognition since 2004. In particular, the research on music-induced movement has mainly focused on the effects of musical content and listener characteristics thereon. The team has published 16 journal articles on this topic, and an open-access software for kinematic analysis of motion capture data (MoCap Toolbox). The proposed project builds on this expertise and extends the scope of research to dynamics of multivariate entrainment in dyad and group settings.

The project is designed to equally and effectively advance the research careers of the postdoc team members. Task leadership responsibilities are allocated to the postdoc according to their expertise (Burger, Tasks 2 & 5; Carlson, Tasks 3 & 6). This allows training management skills concerning task coordination and result delivery, offering preliminary experience of academic leadership. Communication and collaboration will be actively emphasized within the multidisciplinary group of researchers. Each module further contains close international collaboration with leading experts, strengthening each postdoc's collaboration networks and possibilities for future employment.

The postdoctoral researchers will devise a Personal Career Development Plan (PCDP), to help building their professional profiles, and they are offered training at our Department's research seminars and workshops, and courses offered by the University's Methodology Centre for Human Sciences. Ongoing research projects at our Department guarantee a lively researcher community with diverse expertise offering a natural and spontaneous learning environment.

Opportunities for teaching and supervision will be arranged for the employees of the project. Supervising master students is recommended for each postdoctoral researcher. The PI is also actively involved in supervision during the project, provided that the topics are related to the project theme.

3.2. Collaborators and their key merits in terms of the project

- *Prof. Peter Keller*, Western Sydney Univ., MARCS, is a world-leading expert on behavioral and brain bases of human interaction in musical contexts. Relevant to the proposed project, he has wide expertise on cognitive and motor processes associated with music-related interaction. His expertise will be crucial for the development of experiment procedures and analysis of movement data.
- *Prof. Emma Cohen*, Univ. of Oxford, School of Anthropology & Museum Ethnography, is an expert on evolution and psychology of bonding behavior in humans. Most relevant to the proposed project, her current research focuses on psychological and physiological links between collective movement and exercise, synchrony, social bonding, cooperation and wellbeing. She has experience in neurohumoral research.
- *Dr. Bronwyn Tarr*, Univ. of Oxford, School of Anthropology & Museum Ethnography, has background in evolutionary biology and social and evolutionary psychology, and is an expert on dance. Most relevant to the proposed project, she has been the first author on several papers dealing with neurohumoral responses in dance as they relate to social bonding (Exp. 3a-b).
- *Adjunct Prof. Jessica Phillips-Silver*, Georgetown Univ., Laboratory of Integrative Neuroscience and Cognition, is an expert on coordinated rhythmic movement, synchrony and entrainment. In particular, she has conducted ground-breaking studies on the effect of movement and the role of vestibular system on rhythm perception. Her expertise will be used in the development and assessment of entrainment measures, in particular regarding the vestibular modality.
- *Assoc. Prof. Jonna Vuoskoski*, Univ. of Oslo, Department of Musicology, RITMO Center of Excellence, is an expert on social cognition of music, and music and emotion. In particular, her expertise on music and individual differences will be useful for the project.

4 Responsible science

4.1. Research ethics

We will carefully follow the ethical principles and guidelines for responsible conduct in research outlined by the Finnish Advisory Board on Research Integrity (TENK) and the European Code of

Conduct for Research Integrity, published by ALLEA (All European Academies) in 2017. As Exp. 3 and 6 include collection of blood samples, appropriate ethical permission will be obtained from Ethics Committee of the Central Finland Health Care District (the Committee has recently granted permission for similar data collection for Tuomas Eerola's Academy-funded project "Sweet sorrow", project number 270220). All participants will be asked to sign an informed consent as a prerequisite for participation. They will be carefully informed about the procedures, the voluntary nature of participation, freedom to withdraw, and anonymity.

4.2. Promoting open science

We will mostly target open-access journals such as Frontiers in Psychology, Scientific Reports, and PlosOne. With non-open access journals, we will target those in RoMEO green categories, such as Music Perception, Psychology of Music, and Musicae Scientiae, and post-prints of respective publications will be distributed via the Jyväskylä University Digital Repository (https://jyx.jyu.fi/?locale-attribute=en).

Kinematic analysis methods developed in the project will be implemented and distributed as part of the Matlab MoCap Toolbox, which is freely available at the University of Jyväskylä website (https://www.jyu.fi/hytk/fi/laitokset/mutku/en/research/materials/mocaptoolbox).

4.3. Promotion of equality and non-discrimination

The project is carefully designed to promote equality. Task allocation, mobility visits, and paper authorships are equally divided to foster mutual advancement of the careers of each post-doctoral researcher. The composition of the team and collaborators also embraces gender equality. Divulgation of project results in popular media and social networks using accessible language will promote universal access to knowledge.

5 Societal effects and impact

5.1. Effects and impact beyond academia

Knowledge acquired in the project on the nature of entrainment and its prosocial transfer effects can have societal implications in particular in the areas of music and dance therapy. Greater understanding of the mechanisms involved in the apparent ability of synchronized movement to produce positive social outcomes could lead to improvements in the way music and dance are currently used to treat a variety of serious illnesses in which social functioning is implicated, including autism, depression and schizophrenia (Koch et al., 2014), and provide scientific justification that could increase funding for and access to such therapies for those in need. Additionally, the analysis methods developed for this project can be further utilized in future research specifically in therapeutic settings.

Participants of Exp. 3 and 6 will be given the opportunity to donate an additional blood sample to the Biobank of Central Finland (http://www.ksshp.fi/fi-FI/Potilaalle/Biopankki). The blood samples will be used for research and development of diagnostics and treatment.

5.2. Considering principles of sustainable development

Increased understanding of prosocial behavior will increase understanding of how prosocial choices related to the environment might be made. Applications of the research results to music and dance therapy will foster equal prospects for wellbeing for those living with disabilities and mental illnesses.

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