

# Musical Togetherness Symposium

(MTS-22)

13 – 15 July



University of Music and Performing Arts Vienna, Austria

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#MTS-22

Programme and Abstracts



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Musical Togetherness Symposium: Programme and Abstracts

Edited by Laura Bishop and Werner Goebel

Vienna, July 2022

<https://mdw.ac.at/togetherness/>

Department of Music Acoustics — Wiener Klangstil (IWK)

mdw – University of Music and Performing Arts Vienna

Anton-von-Webern-Platz 1, 1030 Vienna, Austria

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# Welcome to the Musical Togetherness Symposium

## Important information

### Symposium locations

All spoken presentations, Keynotes 2 and 3, the poster session, and the workshop will take place in Bankettsaal (AW SEG23, see map on back cover).

Keynote 1 (Wednesday at 18:00), the Piano Four Hands Concert (Wednesday at 19:30), and the Demo of the ACCompanion (Friday during lunch) will take place in Fanny Hensel Saal in the main building (AW CEG13).

For the IWK lab tour (Friday at 9:45), please meet outside Bankettsaal.

### Lunch and symposium dinner

Lunches are provided by the mdw mensa, located next to Bankettsaal. Please show your nametag at the check-out.

The symposium dinner will be held at Arco (Marokkanergasse 3, 1130 Vienna) on Thursday at 19:00. We will meet outside Bankettsaal at 18:45 and walk over together.

### Hybrid symposium format

Virtual participants will join the symposium via Zoom and can ask questions during the talks either by writing them into Slack or by raising their virtual hands.

During the poster session, virtual poster presenters will each have their own Zoom breakout room, while onsite poster presenters will show physical posters. Onsite participants are encouraged to check out the virtual posters and can use the spiel|mach|t|raum (upstairs from Bankettsaal) as a quiet space for Zoom.

### Internet access

Username: MusicalTogetherness

Password: Mts22

## Organizing Team

Laura Bishop  
Sara D'Amario  
Anna Niemand  
Werner Goebel

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# Wednesday, 13 July 2022

**Note:** (p) indicates an in-person presentation; (v) indicates a virtual presentation.

<b>TIME (CEST)</b>	<b>EVENTS</b>
11:30—12:00	<b>Welcome to MTS-22</b>
12:00—13:00	Lunch
13:00—14:40	<b>Session 1: Togetherness experiences</b> Chair: Clément Canonne  <i>Loehr, Christensen &amp; Nicol (p)</i> Experiences of “acting as one” during group music-making (p. 12)  <i>Lorenz (v)</i> “I play for togetherness”: Impacts of audio-visual asynchrony on feelings of social closeness in adult community band musicians (p. 13)  <i>Edwards-Fitzsimons (p)</i> Kekompakan, kesatuan, kebersamaan: ‘solidarity’, unity, and togetherness in Acehese sitting dances (p. 14)  <i>Ptasczynski, Blättermann, Greb, Grube &amp; Steffens (p)</i> The vibe of social and musical reward: Listening to groovy music acts as a surrogacy for social appreciation during the Covid-19 pandemic across Europe (p. 15)  <i>Smetana, Bishop &amp; Stepniczka (p)</i> Intersubjectivity and musical togetherness: What is the overlap? (p. 17)
14:40—15:00	Break
15:00—16:20	<b>Session 2: Rhythm and synchronization</b> Chair: Janeen Loehr  <i>Bégel, Demos &amp; Palmer (v)</i> Duet synchronization interventions affect social interactions (p. 18)  <i>Wolf, Novák, Sebanz &amp; Knoblich (p)</i> Joint rushing in rhythmic real-world interactions (p. 19)  <i>Zamm, Bauer, Wolf, Leeb, Debener &amp; Sebanz (v)</i> Circling around each other: Interpersonal synchrony of sonified oscillatory motion (p. 20)  <i>D’Amario, Schmidbauer, Roesch, Goebel &amp; Bishop (p)</i> Empathy affects body coordination in piano-singing duo performance (p. 21)
16:20—16:30	Break
16:30—17:40	<b>Poster session</b>

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TIME (CEST)	EVENTS
17:40—18:00	Break
18:00—19:00	<b>Keynote: Natalie Sebanz</b> Musical Togetherness: A joint action perspective (p. 8)
19:30—20:30	<b>Piano Four Hands Concert—Live Experiment</b> Featuring Lizaveta Bormotova & Xin Li

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## Thursday, 14 July 2022

TIME (CEST)	EVENTS
10:40—12:00	<b>Session 3: Musical interaction in large groups</b> Chair: Helena Daffern  <i>Swarbrick, Martin, Nielsen, Høffding &amp; Vuoskoski (v)</i> Collectively classical: Social connection at a classical concert (p. 22)  <i>Louven, Scholle, Gehrs &amp; Lenz (p)</i> Continuous real-time rating of musical performances using connected mobile devices with emoTouch Web (p. 23)  <i>O'Neill &amp; Egermann (v)</i> Intra-audience effects: The social experience of a live Western art music concert influences people's overall enjoyment of the event but not the emotional response to the music (p. 23)  <i>Goupil, Saint-Germier &amp; Canonne (p)</i> What does it mean to be "together" within a free improvisation orchestra? (p. 24)
12:00—13:00	Lunch
13:00—14:20	<b>Session 4: Artificial and virtual togetherness</b> Chair: Werner Goebel  <i>Van Kerrebroeck, Crombé, Wilain, Leman &amp; Maes (p)</i> Joint-action dynamics of polyrhythmic music interactions in augmented-reality (p. 26)  <i>Michalko, Campo, Stajic, Van Kerrebroeck, Pokric &amp; Leman (p)</i> Exploring the potential of augmented reality (AR) in instrumental music learning (p. 27)  <i>Dotov &amp; Trainor (v)</i> If Turing played piano with an artificial partner (p. 28)  <i>Cancino-Chacón, Peter &amp; Widmer (p)</i> Can we achieve togetherness with an artificial partner? Insights and challenges from developing an automatic accompaniment system (p. 30)

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<b>TIME (CEST)</b>	<b>EVENTS</b>
14:20—14:40	Break
14:40—15:40	<p><b>Session 5: Interaction dynamics I</b>  Chair: Pieter-Jan Maes</p> <p><i>Wolf, Goupil &amp; Canonne (v)</i>  Beyond togetherness: Interactional dissensus fosters musical creativity in collective free improvisation (p. 32)</p> <p><i>Hadar &amp; Rabinowitch (p)</i>  Applying a tight-loose paradigm to musical performance: Revealing the social structures underlying different musical genres (p. 33)</p> <p><i>De Souza (v)</i>  Musical ensembles as dynamic social networks (p. 34)</p>
15:40—15:50	Break
15:50—16:50	<p><b>Session 6: Interaction dynamics II</b>  Chair: Laura Bishop</p> <p><i>Demos &amp; Palmer (v)</i>  Birds flock; insects swarm; musicians affiliate (p. 36)</p> <p><i>Braun Janzen, Balardin, Sato &amp; Vanzella (p)</i>  Neural correlates of interpersonal coordination in ensemble music performance: an exploratory fNIRS study (p. 37)</p> <p><i>Novembre (p)</i>  On the role of inter-brain synchronisation in social interactive learning of music (p. 38)</p>
16:50—17:10	Break
17:10—18:10	<p><b>Keynote: Sten Ternström</b>  Choir singing, through the eyes and ears of an engineer (p. 9)</p>
19:00	Dinner at Arco

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Friday, 15 July 2022

<b>TIME (CEST)</b>	<b>EVENTS</b>
9:45—10:45	<b>IWK lab tour &amp; demos</b>
10:45—11:00	Break
11:00—12:00	<p><b>Workshop: Schmidbauer &amp; Roesch</b>  Computational wavelet analysis (p. 11)</p>

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<b>TIME (CEST)</b>	<b>EVENTS</b>
12:00—13:00	Lunch
	<b>Demo: Cancino-Chacón, Peter &amp; Widmer</b> Hands-on demo of the ACCompanion, an expressive automatic piano accompaniment system
13:00—14:00	<b>Keynote: Simon Høffding</b> The psychology, phenomenology, and physiology of shared musical absorption (p. 10)
14:00—14:20	Break
14:20—15:20	<b>Session 7: Attention in music ensembles</b> Chair: Sara D’Amario  <i>Tominaga, Knoblich &amp; Sebanz (p)</i> What makes musicians infer teaching intentions? (p. 39)  <i>Bishop (p)</i> Attention focus affects togetherness and body interactivity in piano duos (p. 39)  <i>Majeau-Bettez, Golvet &amp; Canonne (p)</i> Investigating musicians’ listening strategies in the performance of Eliane Radigue’s Occam Delta XV (p. 40)
15:20—15:40	Break
15:40—17:00	<b>Session 8: Physiology</b> Chair: Giacomo Novembre  <i>Niemand, D’Amario, Goebel &amp; Bishop (p)</i> Respiratory synchronization in Lied duos (p. 42)  <i>Cui, Vanhandel, Hu, Motamed Yeganeh, Werker, Boyd, Hermiston &amp; Ciocca (p)</i> Singing together on stage: Is there an influence of ensemble parameters on physiological stress? (p. 43)  <i>Scherbaum &amp; Müller (v)</i> Togetherness in traditional Georgian singing: From tuning adjustments to synchronisation of heartbeat variability (p. 44)  <i>Gibbs &amp; Egermann (p)</i> Synchrony, physiology, and flowing together in Javanese gamelan (p. 44)
17:00—17:20	Break
17:20—18:00	Roundtable and closing

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## Poster Session

### Online posters

Authors	Title
Booth	Leaders on (and off) stage: Orchestrating positive change (p. 46)
Oinas	The case of “sonic bridges”: Examining pitch-based bonding in ensemble performance (p. 51)
Renihan, Brook, Varela & Booth	Re-thinking musical togetherness in an online music theatre program for older adults (p. 52)
Revoredo Chocano	Structured musical improvisations in collectives during 2006–2018 (p. 53)
Sdraulig	One to one: Composing social dynamics (p. 53)
Wood, Chang, Bosnyak, Klein, Dotov & Trainor	Coordination dynamics in a professional string quartet learning to play unfamiliar pieces together (p. 58)

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## On site posters

Authors	Title
Abalde, Keller & Novembre	A framework for joint music making: Behavioural findings, neural processes and computational models (p. 46)
Christensen, Li, Zhou & Loehr	The roles of synchrony and perceptual distinguishability on joint agency and individual control in musical duetting (p. 47)
Daffern & Brereton	Using virtual reality technology to investigate togetherness in singing ensembles (p. 48)
Donnell	Valuing personality type differences and maximizing the artistic potential of early-career-stage singers (p. 49)
Herrero & Pérez-Nieto	Duo performance at sight, cognitive-social abilities and emotional context cues: A novel way to study synchronization with string and wind instruments (p. 50)
Smetana, Bishop & Stepniczka	The emergence of dialogue in dyadic improvisations: A mixed-methods design and analysis framework for an exploratory feasibility study (p. 55)
Staudt, Lussna, Rizzonelli, Stahl & Kim	Wireless detection of proximity and touch for closed-loop auditory interaction (p. 56)
Villanueva Hernandez	Interpersonal interconnectedness and artifactual interactions in music: The case of Fandango Jarcho in Mexico (p. 57)
Zhou, Christensen, Cummings & Loehr	Not just in sync: A mixed-methods investigation of the cues that influence joint agency in duet music performance (p. 59)

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## Keynote I

### Musical Togetherness: A joint action perspective

**Natalie Sebanz**

Department of Cognitive Science and Social Mind Center, Central European University,  
Austria and Hungary

Humans perform a wide range of joint actions. While some joint actions are primarily aimed at achieving particular instrumental goals that could not be achieved alone, others are performed for the sake of acting together and take on a playful and/or artistic character. In my talk, I will provide an overview of cognitive mechanisms supporting joint actions and discuss the role they might play in joint music making. I will focus on studies that have investigated how we plan joint actions, predict others' contributions, and modulate our own actions to facilitate coordination and teaching. Taking a "comparative" joint action perspective may help us understand what is special about musical togetherness as well as identifying open questions pertaining to joint actions across different domains.

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## Keynote II

Choir singing, through the eyes and ears of an engineer

**Sten Ternström**

Division of Speech, Music and Hearing

School of Electrical Engineering and Computer Science, KTH Royal Institute of Technology,  
Stockholm, Sweden

The voice is a rich and complicated instrument even on its own, and multiple voices together add even more degrees of freedom. Researchers in music have to simplify what they can; yet the standard paradigm of controlling for all variables but one quickly becomes too restrictive for the results to be interesting. In this mostly retrospective presentation, I will discuss an engineer's approach to picking apart the reality of ensemble singing into aspects that might be possible to measure, and then, hopefully, to reassemble. Some keywords are "analysis by synthesis", "ecological" and "statistical art".

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## Keynote III

### The psychology, phenomenology, and physiology of shared musical absorption

**Simon Høffding**

Department of Sports Science and Biomechanics, University of Southern Denmark  
RITMO Centre for Rhythm, Time and Motion, University of Oslo

Much recent research in music psychology has assumed a framework of simulation and mind reading. Minds are hidden behind the skull in brains to be deciphered by complicated cognitive processes such as simulation. In contrast, phenomenology and 4E cognition claims that we directly see others' minds in action, often making heavy cognitive processing superfluous.

Turning to communication between musicians, it is apt to investigate how these ideas play out in experts. In this talk, I share some of the main findings from my 10-year collaboration with the Danish String Quartet (DSQ)—one of the world's most famous string quartets. Three of its four members have known each other for nearly 30 years and together they have played for at least 10.000 hours, making them the ideal case study for understanding what I call shared musical absorption.

Analyses of “phenomenological interviews” with the DSQ reveal some of the principal mental structures supporting their communication and zone of shared musical absorption. Some of these consist in explicit simulation and mind reading, while others seem to point to an affective, auditive and bodily based form of sharing, which in phenomenology is referred to as “intercorporeity”. Experiences with a heightened sense of intercorporeity seem to coincide with experiences of intense musical absorption.

In order to probe this musical intercorporeity, a RITMO-based research team recently completed comparative analyses of cardiac synchronization in a novice quartet and the DSQ. Playing identical music, the DSQ has a significantly higher degree of cardiac synchronization than the novice quartet. In this talk, I investigate the implications of these analyses for our understanding of shared musical absorption and sketch ways forward for a democratic, open, embodied cognitive concert science.

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## Workshop

### Computational Wavelet Analysis

**Harald Schmidbauer<sup>1</sup> and Angi Roesch<sup>2</sup>**

<sup>1</sup> Shanxi University of Finance and Economics, Taiyuan, Shanxi Province, China

<sup>2</sup> FOM University of Applied Sciences, Munich, Germany

Wavelet transformation is a method to reveal the periodic contents of a signal. In other words, it makes explicit which period or frequency is important at each point in time. Wavelet transformation thus provides an analysis of a signal in both frequency and time domain—in contrast to Fourier transformation, which provides an analysis in the frequency domain only. A variant of wavelet analysis, cross-wavelet transformation, can determine which of two series is leading (that is, for example, whose amplitude is reaching its maximum earlier). The most straightforward application of wavelet analysis in the field of acoustics is the analysis of pitches. However, periodic phenomena also appear in musical performances, when musicians perform—and hence move—together. For example, cross-wavelet transformation can measure whether the singer or the pianist in a duo is leading. Wavelet analysis can thus analyse important aspects of togetherness in performing music.

The goal of our presentation is to introduce wavelet analysis informally and intuitively. Using our R package “WaveletComp”, we show typical examples of wavelet analysis which can be replicated easily.

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## Abstracts

### Session 1: Togetherness experiences

#### Experiences of “acting as one” during group music-making

Janeen D. Loehr<sup>1</sup>, Justin Christensen<sup>1,2</sup>, Jennifer Nicol<sup>1</sup>

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**Background:** The experience of musical togetherness sometimes takes the form of a powerful sense of “acting as one”. This sense of acting as one, referred to as united agency, is a type of joint agency (i.e., the sense that “we did it together”; Pacherie, 2012). First-hand accounts of united agency can be found in a variety of studies of music-making and music-listening (Loehr, 2022), and experiencing a sense of united agency has been implicated in musical coordination (Stephens, 2020) and subsequent social bonding (Gabrielsson, 2011). However, the musical contexts that facilitate united agency are just beginning to be investigated, as are its common features and its links to other aspects of agency such as a blurring between self and other (e.g., Saint-Germier et al., 2021).

**Aims:** The goal of the current study was to collect and analyze a set of detailed first-hand accounts of united agency during group music-making, in order to a) illuminate the breadth of contexts in which united agency occurs, b) identify common features of the experience of united agency, and c) elucidate links between united agency and other aspects of agency.

**Methods:** The current study employed the Critical Incident Technique (Woolsey, 1986), an established qualitative research method in which participants are asked to recall events that stand out in their lives in as much detail as possible. Descriptions were collected through an anonymous online survey of musicians who self-identified as having had powerful experiences of united agency, within a range of music-making situations (e.g., professional, recreational, and therapeutic). Descriptions were analyzed using thematic analysis (Braun & Clarke, 2006).

**Results:** Participants’ experiences of united agency occurred across group sizes ranging from duets through to ~200 performers; occurred more often in amateur than professional settings; were approximately equally divided between rehearsal and public performance contexts; and ranged in duration from a single note or chord through to an entire movement or performance. Notably, several accounts recounted the first activity from the first rehearsal of the participant’s first large group music-making experience, and numerous accounts recounted events that occurred many years previously. These features attest to the powerful and long-lasting impact of united agency experiences. Participants’ accounts also included common auditory and bodily sensations that accompany united agency and indicated that united agency can be accompanied by a loss of self-agency; a blurring of self and other; and/or a sense of external agency. Finally, participants’ accounts also delineate both short- and long-term impacts of united agency on emotion, social connection, and sense of meaning.

**Conclusions and Implications:** The current study advances our understanding of the phenomenology of united agency during group music-making. Our findings have implications for understanding the processes involved in group music-making, musical groups’ social dynamics, and the potential health benefits of group music-making in therapeutic and community-based contexts.

### References

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3, 77–101. doi: 10.1191/1478088706qp063oa

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Stephens, J. P. (2020). How the show goes on: Using the aesthetic experience of collective performance to adapt while coordinating. *Administrative Science Quarterly*, 66(1), 1–41.

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## “I play for togetherness”: Impacts of audio-visual asynchrony on feelings of social closeness in adult community band members

**Taina Lorenz**

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This study explores the effects of audio-visual asynchrony on feelings of social closeness in adult community wind band musicians. This research is situated between the fields of cognitive neuroscience and sociology and explores how changes to the cognitive load of a performing musician by means of conflicting sensory information affects interpersonal relationships, feelings of belonging and group solidarity, and feelings of social closeness.

Adult instrumental musicians (N=163) from four groups within the Cosmopolitan Music Society (Edmonton, Alberta, Canada), participated in this study which utilized a pre-test/post-test experimental design. Groups were organized by level of technical skill (Beginner, Novice, Intermediate, Advanced) with the following gender expressions (88 female, 60 male; 2 non-binary; 13 undisclosed). Cultural backgrounds were Canadian/European, Asian, South American, and Indigenous.

Participants first played a chorale in a synchronous manner with sensory information (visual, auditory, and motor) in agreement with established expectations (sheet music, conducting gesture, and common performance practice) intact, then again, with visual information (conducting gesture) altered to conflict with performance expectations. This resulted in the sounds produced by the participants becoming unpaired from the visual information seen in the sheet music, visual information coming from the conductor, and individual kinaesthetic feedback. Participants completed the same questionnaire after each condition which included 13 Likert-style questions and one open ended question.

Quantitative responses were combined into a composite measure called the Social Closeness Index (SCI), a measure used in previous research by Tarr, Launay & Dunbar (2016) and adapted to the band context. Qualitative coding methods to analyse open responses for overarching themes were also employed. Both quantitative and qualitative analyses indicated audio-visual asynchrony negatively impacted feelings of social closeness. Multiple linear regression analysis determined group membership was a significant factor in changes in feelings of social closeness, with novice, intermediate, and advanced groups experiencing large drops in SCI scores and the beginner

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group experiencing little effect. Participants in the intermediate group had an estimated drop in SCI scores of 1.00 points,  $b = -1.00$ ,  $SE = 0.18$ ,  $t(136) = -5.51$ ,  $p < 0.001$ , while participants in the novice and advanced groups saw an estimated drop in SCI scores of 1.17 and 1.15 points respectively,  $b = -1.17$ ,  $SE = 0.18$ ,  $t(136) = -6.70$ ,  $p < 0.001$ ;  $b = -1.15$ ,  $SE = 0.23$ ,  $t(136) = -5.09$ ,  $p < 0.001$ . These findings suggest an interpersonal/cognitive awareness threshold exists between beginner and non-beginner ensembles which influences feelings of social closeness.

Sensory congruence and adherence to established expectations of behaviour are significant factors in feelings of social closeness in adult band musicians. Implications include the value of quality conducting, the influence of cognitive experience in group dynamics, and the importance of interpersonal relationships to the success of ensemble music programs. Suggestions for further research include the effects of physical distance on social closeness, impacts of sensory asynchrony and social isolation due to COVID-19 restrictions and the reliance on technology for shared music-making, and a deeper exploration into sociological mechanisms and interpersonal relationships in large music ensembles.

## *Kekompakan, kesatuan, kebersamaan: ‘solidarity’, unity, and togetherness in Acehese sitting dances*

Niall Edwards-FitzSimons

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**Background:** From origins in coastal Aceh and the Gayo highlands, Acehese sitting dances have exploded in popularity, spreading to schools, universities, embassies, and festival stages across Indonesia and the world. They require intense rhythmic co-ordination between participants in a tightly packed kneeling line, who synchronize singing, body percussion, and dance movements to create a powerful impression of ‘moving with one body.’

**Aims:** This presentation will share findings from my doctoral research, which centers the embodied experiential and traditional knowledge of these “dancer-musicians”, using ethnography to explore issues which have mainly been examined using cognitive sciences methodologies. Scholars working in disciplines such as psychology, neuroscience, and behavioral biology have identified a pro-social effect of mutually synchronized, i.e., entrained, rhythmic movement, which may underpin the benefits to group cohesion many argue are conferred by shared musical activity. To complement such research, scholars like Martin Clayton have urged that the entrainment concept be investigated ethnographically with “contextualised studies of real-life music making”. This research aims to bring vital real-world context to music-cognition research into synchronized rhythmic movement.

**Methods:** While pursuing this research I conducted participant-observation with a dance group in Sydney, Australia, and interviews with over 90 dancers, teachers, and students across Aceh, in Jakarta, and in Sydney and Melbourne. This ‘multi-sited’ ethnographic project gathered testimony describing personal experiences of rehearsing, teaching, and performing, generating insights into the psychological moment of group mutual entrainment. This paper will present these emic understandings of synchronized rhythmic movement and describe links with empirical research.

**Results:** The term *kekompakan*, a borrowing from the English or Dutch ‘compact’ which is often translated as solidarity, cohesiveness, or harmony, reoccurred frequently during interviews. Achieving *kekompakan*—moving as one co-ordinated entity by keeping movements precisely in time and with the same affect and level of energy—was said to be key to a successful performance and to encourage deeper relationships between participants. It was described as a key value expressed in performance, and linked by many to either (or both) Acehese regional or

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Indonesian national unity. The terms *kebersamaan* (togetherness) and *kesatuan* (unity) also appeared frequently, and participants described experiencing these feelings of togetherness as a major motivator for participation.

**Conclusions:** These aspects of the testimony shared by interview participants demonstrate that cohesion, unity, and togetherness are important concepts in Acehese sitting dances, and that they are mediated by the mutual entrainment of rhythmically synchronized dance movements and body percussion.

**Implications:** The resonance between the concept of *kekompakan* and theory regarding the mutual entrainment of synchronized rhythmic movement suggests that this facet of the discourse around Acehese sitting dances could hold valuable insights for our understanding of those theories. The experiences, perspectives, and stories shared by participants can provide insights into the way that such practices become a focus for concepts of unity on interpersonal, regional, national, and international levels. This presentation is hoped to demonstrate the value of conducting such ethnographic research, drawing connections between contrasting approaches and bringing the insights of participants to bear on current questions in music scholarship.

## The vibe of social and musical reward: Listening to groovy music acts as a surrogacy for social appreciation during the Covid-19 pandemic across Europe

Lena Esther Ptasczynski<sup>1,2</sup>, Patrick Blättermann<sup>3</sup>, Fabian Greb<sup>4</sup>, Jochen Steffens<sup>3</sup>

<sup>1</sup> Department of Psychiatry and Neurosciences, Charité–Universitätsmedizin Berlin, corporate member of Freie Universität Berlin and Humboldt-Universität zu Berlin, Germany

<sup>2</sup> Berlin School of Mind and Brain, Humboldt-Universität zu Berlin, Germany

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**Background:** The mental health and psycho-social consequences of the Covid-19 pandemic raise the question of how home-based interventions, such as music therapy, can be used to overcome the feeling of loneliness or social isolation, a commonly encountered burden during the crisis (Fischer et al., 2020). While people intuitively used collective singing to create social cohesion across the globe, several large-scale studies highlight that music listening behaviour also changed to cope with elevated emotional distress, the lack of enjoyment as well as that of social interactions (Fink et al., 2021; Granot et al., 2021).

**Aims:** While those survey studies indeed confirm that music is actively used as a coping strategy, evidence for the direct link between social needs and music-based mitigation is still lacking. Moreover, previous studies fail to explain how abstract musical features might contribute to creating the feeling of togetherness, be it on a physiological or on a cognitive level. Here, we focused on musical groove or danceability of music given its well-studied stimulating effect on the dopaminergic system (Teki et al., 2012) and the implication of dopamine in the neuroscience of social reward. Considering the interaction between dopaminergic and oxytocinergic activation (Greenberg et al., 2021), we tested whether this feature can alleviate the need for (pleasurable) human interactions, one of the major wellbeing goals reported in several surveys throughout the pandemic.

**Methods:** Assuming that the general population has acquired an implicit knowledge of music-induced physiological effects, daily music listening behaviour was retrieved from Spotify, the most popular music streaming platform. The stringency index of lockdown measures restricting social interactions and subjective reports of social provision—a psychometric measure capturing

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experienced support from a social network on five subscales, namely social integration, reassurance of worth, attachment, sense of reliable alliance, and guidance – were accessed through the open-source Covid-19 hub (Guidotti & Ardia, 2020) and COVIDiSTRESS database (Yamada et al., 2021).

**Results:** A pre-post linear mixed model confirmed that the number of music streams—a proxy of listening duration—significantly increased after the onset of the pandemic across 14 European countries. A mediation between the stringency of lockdown measures, the lack of social provision, and listening to groovy music was found to be significant. The lack of attachment and sense of reliable alliance were the crucial mediators therein, while reassurance of worth best predicted listening behaviour.

**Conclusion:** The physiological overlap in musical and social reward processing gives a plausible explanation as to why music can act as a surrogacy for feeling socially appreciated. Our findings support the notion that pleasurable music can relieve dopamine-related craving, which has only recently been shown in the domain of alcohol use disorder (Mathis & Han, 2017). The observation by Ferrari et al. (2021) that increased sensitivity to musical reward correlated with increased music listening behaviour to alleviate psychological distress during the first lockdown supports this interpretation. The review of neurophysiological mechanisms in combination with feature analysis of complex music can, thus, lead to the development of (cost-)effective music-therapeutic interventions.

## References

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# Intersubjectivity and musical togetherness: What is the overlap?

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**Background:** References to the term “musical togetherness” have increased in recent years in the music psychology literature, as the quality of experiences of participants in collaborative musical activities has come under scrutiny. A standard definition has not been established, but the term is usually used to describe a facet of experience that is promoted by participants’ shared awareness of each other as intentional, attentive, responsive, capable, and creative collaborators on a shared musical task.

The term “intersubjectivity” has a longer history and can refer more generally to the “variety of possible relations between people’s perspectives” (Gillespie & Cornish, 2010) or more specifically as the sharing of experience between two or more people. In the domain of music therapy, intersubjectivity is rooted both in developmental as well in psychoanalytic theories. Discussed as a basis for dialogue, it is not necessarily characterized by converging or matching experiences. Indeed, during instances of intersubjectivity, two persons may interpret a shared experience in very different ways.

Given that these terms tend to feature in different bodies of literature, it is unclear to what extent and in what ways they overlap. It is likewise unclear whether systematic research on intersubjectivity might inform our developing understanding of musical togetherness and vice versa.

**Aims:** The aims of this Roundtable are 1) to establish a common understanding of musical togetherness and intersubjectivity and how they overlap and 2) to determine how a unified perspective on these terms might benefit research on musical interaction, specifically, with an improved understanding of how cognitive- behavioural and experiential aspects relate.

**Main contribution:** The inspiration to interrogate the overlap between these constructs comes from an interdisciplinary, mixed-methods study on dialogue and intersubjectivity in dyadic music therapy improvisations that we recently carried out. The study sought to establish a framework of intersubjective experiences that arise during music therapy improvisations and show how these experiences relate to measures of musical coordination and physiological arousal. We will start the Roundtable with a short presentation that explains our perspectives on musical togetherness and intersubjectivity. Following this, we will lead a discussion centered around the following questions:

1. What does “shared experience” mean in the contexts of musical togetherness and intersubjectivity?
2. How are contrasting or conflicting aspects of experience treated by these constructs?
3. How can interdisciplinary efforts be harnessed to further our understanding of musical togetherness, intersubjectivity, and, more generally, musical interaction (in all its forms)?

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## Session 2: Rhythm and synchronization

### Duet synchronization interventions affect social interactions

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**Background:** People report increased social connection and positive feelings about a person with whom they engage in synchronous behavior (Hove & Risen, 2009). In addition, the presence of a partner influences each individual’s synchronization with a metronome (Bégel et al., 2022). Ratings of social attribution of synchrony among performers does not always align with the amount of observed temporal synchronization (Demos et al., 2017), suggesting that different variables may influence the social interaction—musical synchrony relationship.

**Aims:** We addressed the causal relationship between observed temporal synchrony and perceived social interaction by manipulating the quality of the synchronization in intervention conditions. Based on auditory feedback manipulations to both partners, we tested their effect on both perceptions of social interaction with their partner and on subsequent synchronization. We also addressed whether turn-taking in a synchronization task was affected by simultaneous synchronizing with their partner.

**Methods:** We recruited 16 participants, half had musical training (8.5-12 years of music instruction) and half did not (0-2 years). Participants first performed a melody at a self-chosen pace (called the spontaneous rate). Then they synchronized with a metronome (Solo condition). Then participants were paired (musicians with musicians, nonmusicians with nonmusicians) to perform a Turn-taking task, in which participants produced a melody in synchrony with a metronome, taking turns with their partner. The metronome cue was set to the average of the two partners’ spontaneous tapping rates. In two Intervention conditions (manipulated within pairs), participants attempted to synchronize with their partner, either with normal feedback (A: Normal Feedback) or with (randomly placed) delayed feedback (30-70 ms) for 25% of tones to both partners (B: Delayed Feedback). The order of conditions was: Turn-taking Condition; Intervention-A; Turn-taking; Intervention-B; Turn-taking (interventions counterbalanced). After each intervention condition, participants completed a questionnaire about pleasantness, connectedness, relationship and feeling of synchronization with their partner.

**Results:** Preliminary results showed that partners’ asynchronies tended to be larger in Solo than in Joint tapping contexts. In addition, asynchrony variability (standard deviations of asynchronies between participants’ taps and the metronome cue) changed among the Turn-taking tapping conditions; variability was largest following the Delayed feedback Intervention. Finally, partners’ perception of how well they synchronized were significantly lower after the Delayed Feedback intervention than after the Normal feedback intervention. Ratings of Social Relationship with the partner were marginally lower after the Delayed feedback intervention than after the Normal feedback intervention.

**Conclusions:** Overall, these findings suggest that Turn-taking synchronization can be improved or disrupted by short interventions that allow partners to synchronize directly with a partner. Interventions to auditory feedback during simultaneous synchronization affected partners’ Turn-taking performance synchronizing with a metronome. The type of synchronization intervention also affected participants’ perceptions of their social interactions.

**Implications:** These findings suggest that a short-term bidirectional musical intervention in a social context can alter unidirectional synchronization skills. Both positive and negative effects of the musical interventions suggest a directionality of synchronization experience on perceived social interactions. These findings offer a step toward defining the causal relationship between synchrony and perceived social interaction in musical duets.

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## Joint rushing in rhythmic real-world interactions

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**Background:** Recent research has shown that people engaging in coordinated rhythmic interactions are biased to increase their tempo despite instructions to keep the initial tempo (Okano et al., 2017; Wolf et al., 2019). Wolf et al. (2022) have further shown that even musicians are not immune against this joint rushing phenomenon. However, all experiments so far are based on a synchronization-continuation task, with two important characteristics that differ from most cases of actual joint music-making and other rhythmic interactions. First, participants are initially asked to synchronize to a metronome beating at a target tempo. Second, participants are asked to tap isochronous rhythms. Joint music-making rarely starts with a metronome and the rhythms are usually more intricate than isochronous beats.

**Aims:** In this study we aim to compare the findings from previous lab studies with data from naturalistic rhythmic interactions as they can be found on online video sharing platforms such as YouTube.

**Methods:** We built a corpus of videos featuring music-related rhythmic actions either in a solo or a group context of up to 20 people. In a semi-automatic procedure, we gathered 45 such videos that fulfill a range of criteria such as that the rhythmic action is sustained for one minute or more or that there is no sign of an external timekeeper such as a metronome or the playback of pre-recorded music. The rhythmic actions in these videos include performances of percussion pieces, songs with body percussion elements, rhythmic movements games and pen tapping.

To extract the tempo profile of each video we asked three professional musicians to tap along with the beats in each audio track. To make the tempo change comparable across videos, we normalized the tempo profiles to express percentage of change from the initial tempo.

Data by Thomson et al. (2018) suggests that group size modulates the effect of joint rushing. The inclusion of videos with group sizes of up to 20 people allowed us to compare large groups (> 6 people) and small groups (<= 6 people).

**Results:** In line with data from previous lab experiments we see a significant tempo increase in videos that feature group interactions, but not in videos of solo performances. Interestingly, when comparing small and large groups we find that significant rushing is only evident in large groups, but not in small groups.

**Conclusions and Implications:** While even musicians in small groups cannot resist joint rushing in lab experiments, interaction partners in real world interactions of small groups seem to be able to do just that. One striking difference between the lab studies and the sampled videos that could explain this discrepancy is the rhythmic structure that includes various layers of beat division in all videos, whereas there is no beat division in the isochronous tapping of

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previous experiments. If beat division helps to reduce joint rushing, this could hint at the possible function of work songs to introduce beat divisions to otherwise isochronous instrumental actions to prevent joint rushing in coordinated manual labor.

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## Circling around each other: Interpersonal synchrony of sonified oscillatory motion

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Interacting musicians must synchronize sound-producing movements that are either discrete (e.g., tapping on a drum) or continuous (e.g., legato violin bowing). A large body of work on discrete movement synchronization indicates that auditory feedback from a musical partner determines Leader-Follower dynamics during performance [e.g., 1,2,3]. However, it remains an open question as to whether similar dynamics arise during musical synchronization of continuous sound-producing movements, where auditory feedback from a partner provides real-time continuous information about the spatial trajectory of their actions. The present study addresses this question in a novel sensorimotor synchronization paradigm in which musical partners produce continuous circular movements that are sonified to produce a continuously changing pitch. Consistent with paradigms investigating the role of auditory feedback on discrete movement synchrony [2], partners' auditory feedback was manipulated to be either Unidirectional (both partners heard only Partner A or Partner B), Bidirectional (both partners heard one another but not themselves), or Uncoupled (partners heard only themselves, Control condition). Findings revealed that synchronization dynamics of continuous movement synchrony are indeed shaped by the presence of feedback from a partner, and specifically are optimized in the presence of bidirectional feedback relative to Unidirectional and Uncoupled conditions.

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## Empathy affects body coordination in piano-singing duo performance

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**Background:** Ensemble musicians’ body motion supports sound production, boosts performance expressiveness and contributes to communication and coordination between musicians and the audience. Early investigations on joint music-making suggest that synchronization ability relates to musicians’ empathic perspective taking (EPT) trait. This research focuses on how rhythmic body motion in semi-professional piano-singing duo performances relates to musical roles and empathic profiles of the performers.

**Method:** Twenty-four advanced piano and singing students were matched based on their EPT scores, pre-assessed using a standardized personality questionnaire. High and low EPT duos were formed and musicians were paired with a co-performer from the same and the other EPT group. Music duos rehearsed two pieces, Fauré’s *Automne* and Schumann’s *Die Kartenlegerin*, differing from each other in their melodic contour and harmonic and formal structure, and feasible for mastery within a short rehearsal session. They performed the pieces one time before and three times after rehearsal. Motion capture data of the musicians’ upper bodies, audio, and piano MIDI recordings of the repeated performances were collected. Similarity in musicians’ head movement and tendency to lead and lag their co-performer were computed by extracting, respectively, power and phase of the cross-wavelet transforms of the three dimensional velocities curves of each paired marker. Quantity of motion of each duo was also measured by aggregating marker velocities related to musicians’ head and upper body trajectories. The impact of EPT score on quantity of motion, and power and phase of the cross-wavelet transforms was investigated by implementing multilevel linear models.

**Results:** Results show that musicians’ empathy did not impact the power of their interactions nor the overall quantity of motion. Interestingly, EPT predicted the tendency to lead or lag, depending on piece and take number. In the Fauré piece, the higher the singer’s EPT score, the higher the tendency for the singer to lead and pianist to follow in take 3, and the lower the tendency for the singer to lead and pianist to follow in take 2.

**Conclusions:** These results advance our knowledge of the principles underpinning social interactions, by revealing for the first time to our knowledge the complexity of the link between empathy and body motion in an ecologically valid situation, in promoting and diffusing leadership between musicians.

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### Session 3: Musical interaction in large groups

#### Collectively classical: Social connection at a classical concert

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**Background:** Concerts are fundamentally social experiences in which an audience and musicians gather to witness and create an aesthetic experience, together. Concerts and the music featured there may facilitate connectedness and the sociorelational emotion *kama muta* (frequently labelled “feeling moved”) through a variety of mechanisms. *Kama muta* is considered a self-transcendent emotion as is awe (Yaden et al., 2017). Recent research suggests that in virtual concerts, both concert characteristics (e.g. liveness, technological platform) and individual characteristics (e.g. empathy, loneliness, concentration) influence feelings and behaviours associated with social connectedness (Swarbrick et al., 2021; Onderdijk, Swarbrick et al., 2021). Social bonding during collective music listening has previously been demonstrated in the context of dance (Tarr et al., 2016).

**Aims:** In a live concert experiment, we aimed to examine how concert and personal characteristics influence social connectedness, *kama muta*, and awe at a live concert and how the effects of live and virtual concerts differ.

**Methods:** MusicLab Copenhagen was a concert experiment in which the Danish String Quartet performed to a live ( $n = 91$ ) and a livestreaming audience ( $n = 67$ ). Participants listened to three distinct pieces of music and responded to a questionnaire that captured their personal characteristics and their social and emotional concert experience. Specifically, participants reported feelings of social connectedness that they felt towards the performers and the other audience members, and they responded to the *kama muta* scale (Zickfeld et al., 2019) and to a selection of items from the awe experience scale (Yaden et al., 2019).

**Results:** The live audience members felt more connected to other audience members than the virtual audience members, but both live and virtual audience members felt equally connected to the performers. The live and virtual audiences felt similar levels of *kama muta* and awe. However while the pieces of music showed similar effects on both social connectedness and *kama muta*, the pieces had an opposite effect on awe.

**Conclusions:** Even though live concerts facilitate more togetherness among audience members than livestreamed concerts, livestreaming and virtual audience members experience similar levels of connectedness towards the performers, *kama muta*, and awe. This indicates that virtual concerts may still be useful tools for performers to strengthen their bonds with their fans.

**Implications:** This research will help us to continue to uncover the benefits of concert attendance on audiences. Furthermore, this research contributes to a burgeoning field comparing the effects of live and virtual experiences and the implications of their differences on our social well-being.

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# Continuous real-time rating of musical performances using connected mobile devices with emoTouch Web

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The production and perception of musical performances are dynamic phenomena that evolve and change over time. Researching these dynamic phenomena therefore also requires dynamic research instruments that make the development processes continuously observable in real time. This requirement for a valid research approach for time-bound phenomena is basically similar to the situation in other time-bound fields, e.g. theater, dance, films, lectures, or sports.

emoTouch Web is a web-based research system developed at the University of Osnabrück (Germany) for the continuous real-time evaluation of videos, music or live events of any kind. The system turns any networked smartphone and tablet as well as any desktop computer into a flexibly configurable and easy-to-use tool for real time research. For example, the audience of a concert can participate in a previously designed continuous evaluation study simply by accessing a website with the smartphones they carry anyway ('Bring-Your-Own-Device'). This makes it possible in a simple and cost-effective way to comprehensively conduct studies at live events with possibly hundreds of participants at the same time. However, it is of course also possible to conduct studies with desktop computers in a laboratory setting or as an online real-time survey.

emoTouch Web was originally designed and developed for empirical audience research in music psychology. However, the system is completely flexible and freely configurable and thus not limited to a specific research question or discipline. In the graphical editor of emoTouch Web, the study layout can be freely designed with numerous interactive elements (e.g. horizontal and vertical sliders, 2D rating areas, categorical scales, images, videos). The layouts dynamically adapt to the various mobile devices. The execution of a study can be controlled, monitored and observed by the researcher in real time. For the evaluation of the collected real-time data, coordinated tools for graphical and numerical analysis as well as interfaces to the scripting languages Python and JavaScript and flexible export options are integrated. At <https://www.emotouch.de>, a demo study shows the various possibilities of the study layout. Via a test access, the system can be tried out and own test studies can be designed, conducted and evaluated.

The presentation shows the possibilities of emoTouch Web by means of selected pilot studies and explains possible application scenarios in research related to the togetherness experience in musical performances. The development of emoTouch Web was funded by Volkswagen Foundation. The system can be used free of charge for scientific purposes.

**Intra-Audience effects: The social experience of a live western art music concert influences people's overall enjoyment of the event but not the emotional response to the music**

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**Background:** Social experience is often considered to be a key motivating factor for engaging with leisure activities and attendance at music concerts is no exception. Despite this, until recently, there has been limited interest in measuring the collective or social experience of live concerts in a quantitative way. Therefore, we created and validated a new measure of the social experience of a concert. Two key theories were employed to derive a suitable model for the social experience: The attention paid to other members of the audience (based on parasocial

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interaction theory), and the extent to which an individual identifies with other members of the audience (based on in-group theory).

**Aims:** The aim of this research was to validate a tool that can be used to quantitatively measure the social experience of western art music concerts. Our research questions:

- Can sociological theories of parasocial interaction and in-group theory be applied to audiences of western art music concerts?
- Does the social experience of a concert influence participants' emotional response to the music and/or their enjoyment of the event?

**Method:** In the pilot study, 103 participants were recruited across two concert settings. An extensive list of 65 items was used to measure the social experience of a concert. Based on the results, the measurement scale was reduced to 22 items.

In the main study, a further 113 participants were recruited at several concerts from a weekly series with a range of musical genres. Participants provided self-ratings of their social experience, emotional response (GEMIAC), enjoyment and demographic information in a paper survey.

**Results:** Based on the results of exploratory and confirmatory factor analysis we were able to reduce the number of items in the Social Experience Measure to 17 validated statements with a five-factor model: Depth of Processing, Attention, Solidarity, Satisfaction and Self-Definition. Using a MANOVA, we tested the influence of these factors on the emotional response of participants to the music and found that they are not significant predictors; however, the social experience of a concert was found to be a significant predictor of enjoyment.

**Conclusions:** We have developed and validated the first quantitative measure of the social experience of a western art music concert. Our results also suggest that the emotional response to music and the overall experience of a concert are separate and that only the latter can be influenced by the social experience of a concert.

## What does it mean to be “together” within a free improvisation orchestra?

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**Background:** There is a recent and growing tendency within the world of collective free improvisation (CFI) of performing in very large ensembles, in which typically more than fifteen musicians freely improvise together, without the help of an external conductor or a pre-established score or structure. Given the generally high flexibility and unpredictability of CFI (Pressing 1984, Corbett 2016), and the increased difficulty of coordinating as group size increases (Mueller 2012), one can wonder whether musicians can achieve coordination at all in the context of large-group CFI, and, if so, how such coordination relates to the sense of togetherness actually felt by the musicians.

**Aims:** Our goal was, first, to assess musicians' coordination within a CFI orchestra; second, to analyze the social and musical factors that might modulate such coordination; and third, to investigate the relationship between the interaction and coordination dynamics that are at play over the course of a CFI performance and the musicians' phenomenology of togetherness.

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**Methods:** We invited the 16 musicians of a CFI orchestra (the Orchestre des Nouvelles Créations, Expérimentations et Improvisations Musicales) to participate in our study. They were first asked to record a 20-minute freely improvised performance. Immediately after the performance, each musician was provided with a touch-screen device and asked to indicate, as the recording was playing, what their musical intention was at each time of the improvisation (using a continuous slider from “intending to change the direction of the music” to “intending to support the direction of the music”). The recording was then played a second time, this time broken down into sequences. For each sequence, musicians were asked to answer a questionnaire regarding five dimensions of their phenomenology (We-agentive identity; Integration; Reflexivity; Dependence; Sense of agency).

**Results:** First, we found that the improvisers’ intentions to change or support the music were only clearly coordinated at specific target points, corresponding to moments when improvisers needed to consolidate a shared direction after having entered a new sequence of their performance. Second, we found that familiarity between musicians played a large role in explaining the musicians’ coordination within the orchestra: familiarity acted as a kind of “glue” here, helping to create poles of greater stability within a very unstable interactional dynamic overall. Third, and finally, we found that the sense of integration and the sense of We-agentive identity appeared to differ in crucial ways within the orchestra. Musicians could experience a sense of integration even when they had divergent intentions—provided that these intentions were organized within the group in a consistent manner, with some musicians systematically converging or systematically diverging with one another. By contrast, a stricter condition of intentional alignment was necessary for a sense of We-agentive identity to emerge.

**Conclusions and Implications:** Taken together, these results shed light on the specificities of togetherness within a free improvisation orchestra. More generally, they invite us to consider how the very notion of musical togetherness might vary as a function of group size and aesthetic context.

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## Session 4: Artificial and virtual togetherness

### Joint-action dynamics of polyrhythmic music interactions in augmented-reality

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**Background:** Extended reality technologies initiate and facilitate an increasingly diverse set of musical interactions [1]. However, when physical co-location is not possible, people musically engage with each other mainly through two dimensional screens. Augmented and virtual reality technologies offer an affordable and flexible alternative promising social presence [2], virtual embodiment [3], perspective taking [4], and unique affordances [5]. However, it is unclear whether these new technologies can mediate the rich and fine-grained expressions and intentions inherent to musical interactions [6].

**Aims:** This research investigates whether two, physically separated partners can couple effectively in a musical interaction mediated by augmented-reality technology. The investigation takes a dynamical systems approach, considering the coordinating dyad as a coupled, complex system with homeostatic principles out of which interaction qualities can emerge [7]. The goal of this research is to map the system's inherent dynamics across performative, behavioral, and experiential layers [2], while varying the musical background and virtual realism of the partner.

**Method:** 17 dyads with varying levels of musical expertise participated in this study. They engaged in polyrhythmic music interactions across six conditions that varied in virtual realism (seeing-as-real, seeing-as-avatar, not-seeing) and musical background (music, metronome). Participants tried to produce a shared polyrhythmic, binary-ternary pattern by tapping at a fixed tempo following an augmented reality visual stimulus. Participants were allowed to improvise by skipping taps.

Performance data was recorded as tapping onsets in Ableton, movement data was recorded using a Qualisys motion tracking system and self-reports were collected from questionnaires. The augmented reality system consisted of two HoloLens head-mounted displays receiving avatar visualizations rendered using a Unity application. Performance data were used to compute asynchronies and analyzed using linear mixed-effect models. Movement data were used to compute postural sway time-series and analyzed using recurrence quantification analysis and wavelet coherence spectra. Self-reports inquired about quality of the performance, feelings of (shared) agency, social presence, self-other integration, and flow.

**Results:** Preliminary results indicated differences in tapping onset asynchronies between musical and metronome conditions. Specifically, asynchronies varied less and were negative in the music condition with this effect being reinforced in the seeing-as-real condition. Music improved performance quality with participants anticipating both their instructed and musical partners' tap. Recurrence rates and wavelet coherence power of postural sway were respectively lower and higher for the musical condition and increased with the level of virtual realism. Virtual realism seemed to positively correlate with coordination between players.

Self-reports indicated differences in shared agency, self-other integration, flow, and social presence across the virtual realism factor. Self-rated performance quality and agency differed across the musical background factor.

**Conclusion:** Playing music together is a complex phenomenon requiring high levels of bodily coordination and involvement. Enabling these complex interactions in virtual settings presents opportunities for creativity and ease-of-access, yet the consequences on the musical outcome and experience remain to be seen. This study presents an overview of the performative, behavioral

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and experiential dynamics underlying a musical interaction in augmented reality and offers first insights for future research and design into more meaningful, virtual interactions.

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## Exploring the potential of augmented reality (AR) in instrumental music learning

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**Background:** Researchers increasingly explore the potential of mixed-reality (MR) environments in instrumental music learning [1]. For instance, MR has been used to create a variety of concert scenarios, that have been used in studies of musicians' performance anxiety [2]. However, the effectiveness of augmented reality in orchestra training is still underexplored.

**Aims:** The aim of this study is two-fold: 1) to investigate augmented reality (AR) as effective tool in enhancing performance quality of amateur violin players 2) to obtain players' feedback on learning within AR environments.

**Methods:** Eleven amateur violin players (6 first violins, 5 second violins; 6 females, 5 males; M age = 21.27, SD age = 2.24) rehearsed two orchestral excerpts with a virtual audiovisual rendering of a concertmaster within an AR environment. Violin players were randomly divided into two groups: 1) Rehearsing with a 3D avatar on the first excerpt and 2D video on the second excerpt (3D/2D), 2) Rehearsing with a 2D video on the first excerpt and 3D avatar on the second excerpt (2D/3D). The violinists participated in 4 sessions (one session per week) in which they practiced each excerpt for 20 minutes in randomized order.

We recorded audio, video and movement data (with Qualysis motion tracking system) to measure performance quality. In addition, we collected data about the violinists' feelings on immersion, social and physical presence, performance quality, and experience of the application's interface using standardized questionnaires [3,4], as well as open-ended questions. These qualitative and quantitative data were compared within and between subjects.

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**Results:** Participants had greater movement smoothness (measured with SPARC metrics) and played more accurately with the avatar in the 3D condition independently from the group and the session number. Analysis of questionnaire data suggests all participants favoured rehearsals with 3D avatar independently from the aforementioned factors. Furthermore, there were significant differences between the 3D and 2D conditions regarding participants’ judgements of social and physical presence as well as the interfaces of the AR environments.

In relation to 3D avatar condition, 50% of participants responded neutral or positively to a seven-point Likert scale inquiring “how similar the experience was to practicing with your colleague?” (Median = 4, IQR= 2). As one participant noted: “It is still not the same, although a good alternative.”

Suggestions for application improvement include the possibility to incorporate audio of the orchestra, the possibility to play in different tempi (especially difficult passages), and the generation of audio feedback (in form of verbal comments) or visual feedback on the performance quality.

**Conclusion:** Amateur and beginner musicians need more assistance and guidance during their practice sessions than professional musicians. Therefore, receiving regular feedback and partaking in weekly orchestra rehearsals is crucial for their musical development. AR training might be a valuable addition to traditional instrumental training when attending orchestra rehearsals is not possible. This need has been highlighted by the recent covid pandemic and the ensuing closure of all musical and group activities. This study presents the evaluation of an AR environment for instrumental music training and offers insights to improve interface design and feedback options in such applications [5].

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## If Turing played piano with an artificial partner

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**Background:** Turing famously devised a simple test to evaluate the ability of computing machines to emulate human reasoning. The validity of the test is problematic, however, because it depends on human participants’ ability to verbally report on their first-person experiences and be aware of their task-oriented non-verbal interactions with a partner, be it a machine or

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another human. Recent proposals for tests that focus on specific aspects of intelligence include an Embodied Turing Test (Ortiz, 2016; Swisher, Dotov, & Chemero, 2006), a Non-Verbal Turing Test (Pfeiffer, Timmermans, Bente, Vogeley, & Schilbach, 2011), and measuring emotional response and affiliation in coordination tasks (Kostrubiec et al., 2015; Launay, Dean, & Bailes, 2014; Zhang, Dumas, Kelso, & Tognoli, 2016), among many others. In the context of musical performance, “[i]f a musician could ‘jam’ with an unseen Jam Factory and with an unseen human musician for as long as desired and was unable to tell which was the human, then, according to the Turing test, Jam Factory would have exhibited ‘intelligence.’” (Belgum, Roads, Chadabe, Tobenfeld, & Spiegel, 1988).

**Aims:** We developed a task for playing piano with an artificial partner in a call-and-response format. The objective is to evaluate whether state-of-the-art AI models are advanced enough to enable some aspects of social interaction. To this end, we collect the participants’ reports of self-other integration with their partner, along with measures of performance quality and creativity.

**Methods:** Participants play piano in a call-and-response format with a partner. They are instructed to improvise simple melodies and exchange ideas with their partner. The duration of the turns is fixed and indicated visually on the computer screen. Half of the trials involve another human participant and another half, artificial partners. We test two different deep neural network architectures, a variational auto-encoder and an LSTM model. Both of these, openly accessible from Google Brain’s Magenta project (Roberts, Engel, Raffel, Hawthorne, & Eck, 2018), were pre-trained on a large corpus of piano performances recorded in the MIDI format. Following each trial, participants complete questionnaires on performance quality, self-other integration with their partner, and flow.

**Results:** Data collection is ongoing at the time of writing.

**Implications:** There is a long way before AI becomes capable of emulating musicians so skilled that they can fool a human in a freely improvisational task. The present research can show whether emphasizing interactive rather than generative capabilities can enable social experiences with musical AI.

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## Can we achieve togetherness with an artificial partner? Insights and challenges from developing an automatic accompaniment system

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**Background:** What does togetherness mean in the context of human-computer interaction? While it is clear that, with the current generation of artificial intelligence, a computer partner cannot *experience* togetherness, the question whether humans can experience togetherness with a machine does not have a clear answer. With advances in machine learning, there is a rising interest in developing interactive interfaces that allow people (both musicians and non-musicians) to explore music performance. One such kind of interface is an *automatic accompaniment system*.

In the context of the ERC funded Con Espressione Project, we developed an automatic accompaniment system, the ACCompanion, that is able to perform duets with a human partner on a computer controlled grand piano. The system has gone through several incarnations, from being a system that could only deal with monophonic music, to the current state where the model is able to play polyphonic music. Based on our experience developing and performing music with the ACCompanion, we would like to argue that humans could experience togetherness with an artificial partner.

**Aims:** The aims of this paper are two-fold: first, we want to discuss the properties of automatic accompaniment systems that could allow humans to experience togetherness with them and second, we want to address some of the main technical challenges of creating a truly musical artificial partner.

**Main Contribution:** In the context of score-based music (e.g., Western classical music), Dannenberg (1984) identifies three tasks that accompaniment systems must solve in order to successfully perform together with a human:

1. *Detecting the solo part*, i.e., capturing a human performance in real time (either from a microphone or a MIDI instrument) and identifying the performed notes.
2. *Score following*, i.e., matching these performed notes to notes in the score (also in the presence of errors).
3. *Generating an expressive accompaniment part*.

In our experience, however, a missing fourth point should be added to this list: *modeling the feedback loop with the human partner*. For example, is that if the system “believes” that the human is slowing down (even when they are not), it will slow down, which will cause the human to slow down, and then it will slow down even more in response. In this case, the systems responds differently from how a human partner would respond, decreasing the feeling of togetherness.

In order to address the feedback loop with the human partner, certain technical challenges would need to be overcome. In particular, the system needs to be not entirely *reactive*, but *predict* what the human will do, as well as to understand when to follow (i.e., be more reactive) and when to “lead”.

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The development of accompaniment systems requires an interdisciplinary team that can understand both the musical as well as the technical problems. In spite of the challenges of developing truly musical accompaniment systems, we believe these systems could provide a way to understand togetherness in humans, by serving as a platform in which to test hypotheses about the process of togetherness, as well as being a useful tool for music education and foment the engagement of non-musicians with music. These models can also be fun to play with.

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## Session 5: Interaction dynamics I

### Beyond togetherness: interactional dissensus fosters musical creativity in collective free improvisation

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**Background:** Coordination in joint-music making is often associated with synchronized and/or converging behaviors. But research on group creativity routinely emphasizes the importance of divergent thinking and autonomy in collective creative endeavors (Sawyer 2017). There might thus be a tension between the demands of coordination and that of creativity, which could lead musicians to inject some degree of dissensus in their interactions to foster the creativity of their musical output.

**Aims:** We investigated the idea that dissensual interactions between musicians might increase the perceived creativity and expressivity of the musical output in two listening experiments, using collective free improvisation (CFI) as a paradigm for creative joint action (Cook 2018). CFI performances do not rely on a pre-established blueprint but rather emerge entirely from the interactional dynamics at play between the improvisers. As such, they provide an ideal paradigm to experimentally assess how improvisers' relations to one another might impact their musical creativity.

**Methods:** Our two listening experiments relied on a previously recorded corpus of forty tracks of freely improvised duos (see Golvet et al. 2021), in which improvisers annotated their performances in terms of the various interactional intents they had towards one another (playing “with”, “against”, or “without” the other). In Experiment 1, musician and non-musician participants listened to eighteen 90-second excerpts of our corpus. They were asked to continuously rate the amount of expressive tension they perceived in the music with a digital slider. For Experiment 2, we extracted 20-second snippets from our corpus. In these snippets the two musicians were either intending to play with each other (“with-with”); one musician was intending to play with the other, but the other musician was not (“with-else”); or both musicians were not intending to play with one another (“else-else”). In a 2-AFC procedure musicians and non-musicians were asked to listen to pairs of these snippets and select the snippet in which they found the musicians to be more creative.

**Results:** The analysis of the data is still underway for Experiment 1: we will examine in a linear mixed regression the relationship between perceived musical tension and the intended relational dissensus between musicians. For Experiment 2, in line with our hypothesis, we found that musicians tended to rate dissensual excerpts (i.e., “else-else”) as more creative. No significant differences were found for non-musicians.

**Conclusions and Implications:** Our experiments constitute the first attempt to empirically evaluate the impact of interactional dissensus on musical creativity. They extend theories and ideas that have mainly been studied in the context of verbal interactions (Nemeth & Nemeth-Brown 2019) to the musical domain. We will also discuss the role of expertise in the assessment of creativity and to relate our results to the consensual assessment technique of creativity (Amabile 1982). More generally, our results show that the relation between togetherness and aesthetic success is more complex than is sometimes assumed in the literature on joint music-making.

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## Applying a tight-loose paradigm to musical performance: Revealing the social structures underlying different musical genres

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**Background:** The impulse to improvise is an essential part of the history of musical performance (Baily, 1992), and yet research-wise, not a lot of advances have been made in the field in the past few decades. In addition, comparing between different modes of performance such as Western Classical, classic Arabic, Hindustani, and Jazz, portrays salient differences in relation to the performers' experience, implying that the umbrella concept of "performance" and "improvisation" might account for very different phenomena among varied cultures and societies.

While the Classical musician is occupied in executing strict instructions provided by the composer (Thom, 2020), their fellow Hindustani performer is focused on reaching an emotional catharsis ("Rasa"), bounded by melodic (raga) and rhythmic (tala) aesthetic guidelines to varied degrees of constraint (Pudaruth, 2016). The performer of Arabic classical music, though subscribing to strong traditions of tonal structure (maqam), has the responsibility to fully develop the piece in the moment of performance (Touma, 1971). The jazz musician on the other hand, is actively conceiving a way to individualize their solo, while trying to break from the original form (Fischlin & Porter, 2020).

The different musical genres incorporate different degrees of freedom and creativity in the moment, leading to our main concern: How does the level of musical freedom influence the social structures created by the musical interaction? Do different musical genres account for different social relationships and dynamics also outside of the musical context?

**Aims:** We wish to expand on the possible social structures underlying different modes of performance: improvisational as well as more structured ones. Following a review of several musical genres, we will present a novel theoretical model based on the tight-loose paradigm and expand on the intricate social affordances that are embedded in different musical performances.

**Main Contribution:** Regardless of its wide global distribution (Nettl, 1974), improvisation remained in the margins of musicological and psycho-musical discourse. We claim that the level of freedom and improvisation embedded within each performative genre plays a crucial role in the nature of the social experience that the musical interaction may afford. Gelfand et al. (2006) contend that societies incorporating stricter social norms and sanctioning exhibit more conformity, in-group alignment, and less group dissent, as compared to societies that value looser structures and openness to norm violation. We argue that this tight-loose paradigm can expand our understanding regarding the diverse social norms embedded within different musical performances and their extra-musical social affordances.

The first phase of our study includes a theoretical model for understanding the social structures

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embedded in different types of performances. In the next phase we plan to test those assumptions in a study that will examine the effect of different types of performances on listeners' social experience (e.g., enjoyment, sense of freedom, creativity; group dissent). In the talk, we shall discuss both theoretical and empirical aspects.

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## Musical ensembles as dynamic social networks

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**Background:** Though the term “social network” is commonly associated with online social media platforms, research on the topic dates back to studies of group dynamics from the 1930s (Scott, 2013). Any social network consists of nodes and links. The nodes represent agents (e.g., co-workers, Twitter users, scientists), which may be connected via the links (e.g., friendships, Twitter mentions, co-authorships). Network science offers quantitative methods for examining the overall structure of a network, smaller clusters within it, the closeness of paired nodes, and relational properties of individual nodes—as well as changes in all of these parameters over time. These methods offer a fundamentally relational approach to social organization.

Network analysis is important for many fields, including sociology, neuroscience, and physics (Barabási, 2016). Yet it is relatively uncommon in music research. In music theory, networks have been used to model intervals and transformations involving pitches, harmonies, rhythms, and other musical materials (Lewin, 1987). In cultural sociology, social networks have supported studies of professional relationships among composers and other creative collaborators (McAndrew & Everett, 2015; Uzzi & Spiro, 2005). Musical networks, then, have most often been used to investigate either sounding relations or social relations in isolation. Nonetheless, social networks can potentially integrate both sonic and social aspects (e.g., Müller, Delius, & Lindenberger, 2018; Müller & Lindenberger, 2019), and such integration is particularly valuable for studies of collective music-making.

**Aims:** This paper models large ensembles as dynamic social networks. It addresses various questions about interpersonal coordination in music. For example, which parts are most central to the ensemble at any given moment? Which parts are most independent? How does the overall amount of interconnection change over time? What clusters or communities emerge within the ensemble?

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**Main Contribution:** The network model proposed here has several novel features. Links are based on “directed onset synchrony” (the proportion of shared onsets, measured from one part to another). Synchrony affects auditory perceptual organization: when parts share a high proportion of onsets, they are more likely to be heard in terms of a single textural stream (Bregman, 1990; De Souza, 2019; Duane, 2013; Huron, 1989). Moreover, interpersonal synchrony is highly sought after in musical performance and facilitates social bonding (Goebel & Palmer, 2009; Hove & Risen, 2009; Trainor & Cirelli, 2015; Wiltermuth & Heath, 2009; Zimmermann & Richardson, 2016). As such, networks based on synchrony address both sonic and social aspects of music.

Analyses in the paper focus on repertoire for symphony orchestra, choir, and jazz big band. They look at changes in interaction on multiple levels, attending to variables for individual parts (e.g., average edge weight, out-strength), clusters, and the ensemble as a whole (e.g., weighted network density). These analyses are based on scores or transcriptions, so the paper essentially applies social network analysis as a music-theoretical tool. Still, while the investigation is grounded in music theory, it also opens up possibilities for studies of musical togetherness that cross disciplinary boundaries.

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## Session 6: Interaction dynamics II

### Birds flock; insects swarm; musicians affiliate

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**Aims** How are musical ensembles affected by individual members' group affiliation? We consider two important theoretical perspectives on group dynamics. One is social dynamics, which addresses how individuals are influenced by relationships with group members, and how the group sustains those relationships. The second is nonlinear dynamics, which focuses on interactions among group members.

**Background** Previous studies suggest three factors that influence group dynamics in musical ensembles. The first factor is the **group's size**. Small groups tend to be more cohesive than large groups, often attributed to the fact that each individual's performance in a small group is identifiable, whereas an individual's behavior in a large group is not as perceptible. A corollary is that individuals will work harder in small groups than in large groups (Feltz, 1992). Studies distinguish between groups based on size: "primary" social groups (such as musical ensembles who remain together over time) tend to be small and long-lasting, with individuals who share meaningful relationships. "Collectives" (such as a music concert audience doing the "wave" arm movements together) are large groups that tend to be loosely formed, spontaneous, and brief. An important prediction is the bonds that form among members based on group size; nonlinear dynamics model the coupling that develops between small versus larger groups of ensemble members (Shalal et al, 2020).

A second factor is the **roles played by group members** and how those roles shape group behavior. Social dynamicists have proposed a scale of individualism to collectivism that affects attitudes toward the group. Individualism promotes that people are free to act and think in ways they prefer, whereas collectivism promotes group goals before those of individuals (Oyserman et al 2002). Extreme musical cases of individualism include piano soloists who make unwilling / unable accompanists; an extreme collectivism example is an instrumentalist who cannot adapt to a solo role. Social measurement tools can identify individuals best balanced for individualism /collectivism (Forsyth, 2014). Nonlinear dynamics models (Demos et al 2019; Vallacher & Nowak, 2017) offer ways to implement asymmetric roles between group members.

A third factor is **group cohesion**, or the tendency for individuals to form mutual interpersonal bonds while working toward a shared goal (Carron & Brawley 2000). Perceptions of high group cohesion can cause high task performance, and vice versa (Forsyth et al, 2002; Mullen et al, 1994; Zaccaro et al, 1995). This dual causality between cohesion and group performance has implications for musical ensembles: increased synchrony among performers tends to yield more positive affiliation and social cohesion among partners (Hove & Risen, 2009). The social framework also predicts that increased prosociality should yield increased synchrony, which is yet to be tested.

**Main Contribution** Group dynamics offers testable predictions for musical ensembles based on the group's size, roles that members play, and the group's cohesion. An ensemble's success reflects navigation of factors such as affiliation and control (Aucouturier & Canonne, 2017) that arise from group members' interactions. Social dynamics and nonlinear dynamics offer broader implications for discriminating among successful and less successful ensembles.

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## Neural correlates of interpersonal coordination in ensemble music performance: an exploratory fNIRS study

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**Background and Aim** Achieving musical togetherness during ensemble performance requires precise yet flexible interpersonal coordination. Recent advances in neuroimaging have enabled the investigation of cerebral correlates underlying the sensorimotor, cognitive, and social mechanisms mediating this complex joint action within more ecological settings. Technologies such as functional near-infrared spectroscopy (fNIRS) allow the measurement of the brain activity elicited in two or more individuals engaged simultaneously in naturalistic ensemble music performance. In this study, we investigated brain correlates underlying violin duet interpersonal coordination during the performance of structurally significant portions of the music score.

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**Methods** Seven pairs of violinists played the Duo n. 37 (Prelude and Canon) by Béla Bartók while hemodynamic response correlates of functional neural activity were recorded with hyper-scanning fNIRS during the naturalistic and continuous performance of the music piece. For this analysis, we identified pivotal points in the music structure, which included the beginning of musical phrases, following sustained notes or long pauses, and interchanges of thematic material between musicians. Windows of 5-sec duration from the beginning of each moment of interest were considered active events, whereas baseline events consisted of 5-sec windows before each trigger. Optodes placement was restricted to the right hemisphere not to constrain the position of the head of the violinist on the instrument. In total, 23 channels covered regions of the frontal cortex, sensorimotor area, and the temporoparietal junction (for details, see Vanzella et al., 2019). The contrast of beta estimates between event and baseline were averaged by participants according to the part they played (Violin 1 or Violin 2) and compared using paired Wilcoxon non-parametric test. Experimental sessions were divided into two identical runs, except that the violinist that performed the Violin 1 part in the first run performed the Violin 2 part in the second run, and vice-versa.

**Results and Conclusions** Results revealed a significant difference in oxy-hemoglobin activation during the performance of structurally significant events in relation to baseline in the temporoparietal region for both Violin 1 ( $p = 0.01$ ) and Violin 2 ( $p = 0.04$ ). On the other hand, no significant differences in activation were observed in sensorimotor areas between musicians. These findings thus suggest an increased demand in brain networks implicated in the processing of dynamic social information and the mentalizing network during the performance of portions of the music score requiring higher interpersonal coordination. Overall, these results suggest that the methodological approach seems to accurately capture correlates of functional neural activity elicited during naturalistic and continuous music ensemble performance and might be a feasible approach to examine brain states during real-world experiences.

## On the role of inter-brain synchronisation in social interactive learning of music

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Much of music learning emerges as a result of interaction with others. What neurophysiological processes support efficient information transfer from a music teacher to a student? In a first fNIRS experiment, we show that brain activity recorded from the inferior frontal cortex (IFC) synchronizes across teachers and students engaged in a social interactive song-learning task. Furthermore, inter-brain synchronization predicted learning performance. In a second experiment, we exogenously stimulated IFC using transcranial alternating currents (tACS). Delivering 6 Hz currents, being in-phase between the teacher and the student, led to enhanced learning performance in the student. These effects were both phase- and frequency-specific: 6 Hz anti-phase stimulation, or 10 Hz in-phase stimulation, did not yield comparable results. Together, the two experiments provide correlational and causal evidence demonstrating that inter-brain synchronization of IFC supports social learning of music. Besides providing a neurophysiological characterization of social interactive learning, these results also hold relevance for widespread clinical and pedagogical practices.

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## Session 7: Attention in music ensembles

### What makes musicians infer teaching intentions?

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**Background:** Perceiving pedagogical intentions is vital when learning skills from others. Our previous research demonstrated that expert pianists systematically modulated their sound so as to teach musical expressive techniques such as articulation and dynamics (Tominaga et al., 2021, preprint). For example, pianists played slower and exaggerated each technique when they had an intention to teach.

**Aims:** Here we investigated whether the modulations that expert pianists produce when they intend to teach are also perceived by listeners as conveying pedagogical intentions.

**Methods:** Participants who had at least six years of musical training and knew expressive techniques of articulation and dynamics were included for data analysis (Experiment 1: N = 20, Experiment 2: N = 20). They listened to piano recordings where either articulation or dynamics was implemented. After listening to each recording, they were asked to judge whether or not each recording was produced to teach a designated expressive technique related to articulation or dynamics. We quantified recordings with regard to tempo, articulation and dynamics. We performed correlation and multiple regression analysis to investigate which features of piano performance made musicians infer teaching intentions. In Experiment 1, one simple musical scale was selected as stimuli. Experiment 2 aimed to replicate the findings of Experiment 1 with a more naturalistic piece.

**Results:** The findings in Experiment 1 with a simple musical scale demonstrated that slower tempo contributed to musicians' judgments as teaching regardless of technique. Moreover, performances with exaggeration of each technique (e.g., longer legato, shorter staccato for articulation; larger contrast between forte and piano for dynamics) were more likely to be judged as teaching. In Experiment 2 with a more naturalistic piece, we replicated the findings related to dynamics (in particular, larger contrast between forte and piano was associated with judgments of teaching).

**Conclusions and Implications:** Taken together, modulations of loudness (dynamics) seem to be reliably used to infer teaching intentions regardless of the complexity of a musical piece. Typical pedagogical behaviour such as slowing down may not necessarily be perceived as teaching when it comes to complex skills involved in artistic expression. We believe that these findings can inform discussions on musical togetherness because they contribute to our understanding of what listeners can infer about performers' intentions.

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## Attention focus affects togetherness and body interactivity in piano duos

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**Background:** Group music-making is a socially rewarding activity that strengthens social bonds and leads to feelings of togetherness. For skilled ensembles, social rewards like feelings of togeth-

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erness are closely tied to aesthetic rewards that come from high-quality performance. What playing conditions encourage or discourage togetherness experiences among skilled classical ensembles? Research has shown that during some joint action tasks, mutual attention between interaction partners promotes social bonding, while joint attention to shared goals facilitates coordination. In classical ensemble playing, individual attention to distinct expressive goals, instead of joint attention to shared expressive goals, can negatively affect performance quality. Research has also shown that classical ensemble musicians move in a more communicative way under conditions that promote joint attention; however, it remains unclear how communicative body motion and experiences of togetherness relate.

**Aims:** This study addressed two questions: 1) How does joint attention affect togetherness experiences and communicative body motion during classical piano duo playing; 2) Can measures of communicative body motion be used to index strength of togetherness? Stronger togetherness and more communicative body motion were hypothesized to arise when pianists' attention was focused on the group rather than the self (mutual attention) or on the same musical feature rather than different musical features (joint attention). A positive link was also hypothesized between togetherness and communicative body motion.

**Methods:** Skilled pianists performed two pieces with a duo partner under seven conditions. The first (baseline) and last performances were given freely without any specific instructions. In the remaining five performances, pianists' attention was manipulated through instructions (e.g., focus on note accuracy; focus on synchronizing with your partner; focus on emphasizing dynamics). After each performance, they rated the quality of their playing and experience. Body motion data were collected and three measures were extracted: coupling strength, quantity of motion, and surprisal.

**Results:** Joint and mutual attention improved togetherness ratings, while self-directed attention reduced enjoyment. Pianists moved their head and arms less when focus was self-directed and more at the end of the session than during the baseline performance. Coupling of motion periodicities, contrary to expectations, was lower in conditions that promoted joint attention and at the end of the session than during the baseline. A condition that discouraged joint attention by drawing one pianist's attention to timing and the other's attention to voicing resulted in a greater quantity and more predictable head motion, compared to the baseline.

**Conclusions and Implications:** Joint attention promoted togetherness, as evidenced through pianists' performance ratings, but its effects on communicative body motion were more variable. Individual measures of body motion sometimes diverged from each other, suggesting that the measures that were analyzed are unreliable indicators of togetherness. Overall, the study promotes a more thorough understanding of musical togetherness and how it can be measured.

## Listening and coordination in the performance of Eliane Radigue's *Occam Delta XV*

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**Background:** Éliane Radigue's music is well-known for its trance-like quality—with performers blending each other's sounds to the point where they often lose the perception of their own individual contribution to the mix (Eckhart 2019). *Occam Delta XV*, for string quartet, provides a clear example of the challenges musicians face when performing such music. The piece is organized into three parts, the duration of which is not specified beforehand. In each of these

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parts, musicians must play slowly evolving sounds, in such a way as to create ever-changing microbeats. Once a musician feels that a given part has lasted long enough, they can start transitioning—very gradually—to the next section. This raises the question of how musicians collectively navigate within the piece, given the extreme fusion of individual instrumental sounds and the open-ended nature of the composition.

**Aims:** The goal of the current study was to track musicians’ auditory attention throughout their performance of *Occam Delta XV*. We were interested in investigating the individual differences between musicians’ listening strategies, whether such strategies evolved in the course of the performance, and, more generally, whether joint listening (i.e., the fact that musicians are paying auditory attention to the same thing) supported musicians’ coordination in their performance of *Occam Delta XV*.

**Methods:** The four Quatuor Bozzini members—the dedicatee of *Occam Delta XV*—were conveyed to participate in our study. They were first asked to record a performance of the piece. Immediately after the performance, each quartet member was provided with a touch-screen device, and asked to indicate, as the recording was playing, what their main focus of auditory attention was throughout the piece: listening to oneself, listening to the musician at their left/right/in front of them, listening to the overall quartet sound. Finally, each musician was asked to listen back again to the performance and indicate their transition points.

**Results:** First, we found striking differences in individual listening strategies, with e.g. the first violin listening to himself for 51.6% of the performance time, while the cellist was only listening to herself for 4.5% of the performance time. Second, we found that musicians tended to engage more in joint listening in “unstable” zones as compared to more “stable” zones (i.e., whether they were in different parts of the piece vs whether they were all together in a same part of the piece), which suggests that joint listening was used preferentially when the need for coordination was higher.

**Conclusions and Implications:** The results of this study constitute the first in-depth analysis of performance dynamics in Eliane Radigue’s music, shedding light on musicians’ listening states in such “trance-like” music (Rouget 1985). More generally, our results contribute to our understanding of the role of joint attention in joint action (Vesper et al. 2017), by extending the study of joint attention in collective music-making to the auditory modality, over and beyond the sole visual modality in which it has almost exclusively been investigated (Glowinski et al. 2012).

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## Session 8: Physiology

### Respiratory synchronization in Lied duos

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**Background:** Respiration in music ensemble performance involves many physiological and cognitive processes that are highly intertwined and therefore are difficult to disentangle. Metabolic demands, movement due to tone production and/or communication, as well as mechanisms of sound production and the musical structure are some of the processes that contribute to shaping the patterns of respiration that emerge as co-performers try to coordinate with each other in the collaborative task of making music together. Little is known about how closely co-performers synchronize their respiratory patterns during Lied-Duo performance or how rehearsal or musical structure might influence respiratory synchronization. It is also not clear if pianists or singers demonstrate leading and following behavior in their breathing during Lied-Duo performances.

**Aims:** This research investigates the effects of the opportunity to rehearse and musical piece on the degree of co-performers’ synchronization in respiration during Lied-Duo performance, as well as the emergence of leader/follower roles.

**Methods:** Seventeen duos consisting of singers and pianists performed two pieces of Lied repertoire. The musicians performed each piece together one time prior to and three times after a rehearsal period. We measured respiration as the relative combined circumference of the thorax and the abdomen for each performer. Respiratory synchronization was investigated using cross-wavelet transform (CWT) analysis. Linear mixed effects models were used to test the effects of piece and rehearsal on CWT power (indicating respiratory synchronization) and phase difference (indicating leading/following).

**Results:** Results for the comparison of the performances overall show significant effects of rehearsal on respiratory synchronization for one of the pieces (Schumann: Estimate = 1.10,  $SE = .0425$ ,  $t(47) = 2.598$ ,  $p = .0125$ ), and a significant difference in power between pieces (Estimate =  $-1.98$ ,  $SE = 0.28$ ,  $t(63) = -7.04$ ,  $p = 0$ ). According to our analysis of CWT phase difference, there was no consistent leader and no follower in the performances overall (Estimate =  $-1.60$ ,  $SE = 2.81$ ,  $t(95) = -0.57$ ,  $p = 0.57$ ) and no change in the leader-follower patterns between pieces or rehearsal conditions.

**Conclusions and Implications:** This study shows that respiratory behavior during Lied-Duo performances changes as a result of differences in musical structure between pieces and evolves as performers rehearse and create a shared interpretation. The lack of evidence of leading/following suggests that neither performer consistently leads with their breathing, but rather the leader/follower roles are shared by the pianist and the singer. With these results we are able to show that coordination emerges in Lied-Duo performance in respiration, indicating that the performers establish a musical relationship that is evident even at a peripheral physiological level.

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## Singing together on stage: Is there an influence of ensemble parameters on physiological stress?

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Performing music in front of a critical audience while making sure to be “together” with colleagues and a conductor is a stressful experience: Research indicates systematic differences in heart-rate variability (HRV) – an indicator of physiological stress, such that reduced HRV corresponds to higher stress – between different phases of a performance, including before and during a performance, or offstage or onstage periods (Chanwimalueang et al., 2017; Cui et al., 2021). However, little is known about the influence of other parameters on HRV during a performance. To the best of our knowledge, only one case study has investigated the influence of musical parameters (Williamon et al., 2013), showing that technically challenging material may reduce HRV. Here, we investigate whether ensemble parameters, i.e., whether a performer is singing solo (their own melodic line without coordinating with another singer), in an ensemble (their own melodic line coordinating with at least one other singer), or in a chorus (sharing melodic lines with other singers), influences opera students’ physiological stress during professionally staged opera performances.

HRV data were collected during ten performances of four different operas from 23 different opera students. Performance excerpts were selected such that each excerpt was consistent in its ensemble parameters (solo/ensemble/chorus piece) and at least 30 s long. This selection process resulted in  $n = 356$  excerpts. We evaluated a causal model, in which the ensemble parameter may influence HRV. We further included two musical parameters, melodic range and tempo, which may also vary systematically with HRV. These parameters were coded by two independent coders in semitones and beats per minute respectively.

Bayesian modeling indicated that the ensemble parameter influenced HRV such that performing solo or in an ensemble is associated consistently with decreased HRV compared to performing a chorus excerpt. The ensemble parameter also influenced melodic range, such that solo excerpts had the largest melodic range, and the relationship between melodic range and tempo, such that a positive relationship between those parameters was consistent only for ensemble and chorus excerpts. Although melodic range per se was not associated with HRV, the ensemble parameter conditioned this relationship such that higher melodic range was associated with decreased HRV only in the solo excerpts. Lastly, while our models are suggestive of a negative link between tempo and HRV, this relationship was more consistent for ensemble and chorus excerpts.

Our results indicate thus that whether or not opera singers are singing together with others influences their physiological stress. Interestingly, the influence of technical difficulty on HRV is mediated by the ensemble parameter. While performing a solo opera excerpt, a larger melodic range is associated with lower HRV and thus higher physiological stress while the relationship between tempo and HRV is inconsistent. In contrast, while performing an ensemble or chorus excerpt, melodic range is not associated with HRV while higher tempo is now associated with lower HRV and higher physiological stress. Thus, whether a singer is performing together with others could determine what musical parameter makes an excerpt challenging and thereby more stressful.

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# From Intonation Adjustments to Synchronisation of Heart Beat Variability: Singer Interaction in Traditional Georgian Vocal Music

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This study is concerned with how singers of Georgian traditional vocal music interact when singing together. Applying a variety of computational methods from audio signal processing and music information retrieval (MIR), we examine two existing corpora of (field) recordings for manifestations of a high degree of mutual coordination of the singers' voices. We find numerous examples of harmonically controlled mutual intonation adjustments on both short and long time scales. Furthermore, we believe that the observed differences in melodic and harmonic scales can also be interpreted as (side) effects of the singers' interaction with the possible goal of achieving harmonic togetherness (or consonance) on the time scale of individual (important) notes. In Addition, together with the ensemble Khelkhvavi from Ozurgeti, we conducted an experiment demonstrating the synchronization of singers' heartbeat rates during the performance of the Gurian song Chven Mshvidoba. The results of our analysis show that a variety of measurable signs of interaction between singers can be observed and documented in Georgian traditional vocal music. Our experiment also shows relevant information can be obtained by using different types of sensors together during ethnomusicological recording sessions.

## Synchrony, physiology, and flowing together in Javanese gamelan

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**Background:** The experience of flow in collaborative contexts refers to tasks in a group setting in which participants are aware of their simultaneity. Components of collective flow are related to components of individual flow state with the addition of empathy (Hart & Di Blasi, 2015), and are coupled with numerous physiological components of the autonomic nervous system on both individual (Peifer et al., 2014; Tian et al., 2017) and group levels (Ruiz-Blais et al., 2020). Javanese gamelan requires all individual parts to work harmoniously, allowing for the occurrence of collective flow and its native equivalent, *ngeli* (Tan et al., 2020). Underpinning the egalitarian ethos of gamelan is interlocking synchrony and repetitive cyclical patterns, whereby governance is distributed throughout the ensemble, and individual and combined outcomes are reciprocally predicted and monitored (de Bézenac et al., 2018).

**Aims:** There is a necessity for further study into collective flow through quantitative naturalistic experimental designs (Chabin et al., 2020), and the outlined research indicates links between synchronisation in musical activity, collective flow, and positive affect. No study has yet captured these effects in relation to physiology, nor within the context of group music settings. Gamelan presents the ideal setting in which these effects can be studied, and consequently, this study aimed to test whether there are associations between physiological measures, individual and collective flow, level of prior experience with playing gamelan, and positive affect.

**Methods:** The first group of participants with prior experience of gamelan playing were recruited from the current members and tutors of Gamelan Sekar Petak, based at the University of York (N=13). The second group of participants were recruited from the music department and wider university, requiring students to have no, or very minimal, prior experience of play-

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ing gamelan (N=16). A variety of pre- and post-test self-report measures were taken, and skin conductance and electrocardiogram measures were recorded using Shimmer Sensors.

**Results:** Our findings show that some dimensions of collective flow experienced when playing gamelan are dependent on dimensions of individual dispositional flow levels and individual subjective flow. Following this, we tested for a relationship between collective flow and physiology, in which we looked at general measures of skin conductance and heart rate across several time points. Finally, we tested for relationships between collective flow and mood, and the influence that instrument type and background have on the collective flow experience while playing gamelan.

**Conclusions:** Firstly, collective flow experience is highly dependent on dispositional flow and individual flow state. Secondly, collective flow experience is reflected through general patterns in physiology, and is associated with positive affect.

**Implications:** This study has potential methodological implications for the quantitative study of collective flow in music-making contexts. Using the data we have collected during this experiment, we intend on exploring whether the experience of collective flow is associated with physiological synchrony across participants. In general, the findings could imply that the physiological and affective quality of collective flow in ensembles can contribute to overall wellbeing, which should be explored in further study.

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## Posters

### A framework for joint music making: behavioural findings, neural processes and computational models

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Musical ensembles constitute a microcosm of social interaction. In this work, we aim to provide an overview of the existing experimental (behavioural and neuroimaging) and theoretical (computational modelling) studies from this emerging research area. We propose a simple framework to encapsulate the most prominent themes orbiting the topic of joint music-making. Our framework is grounded in interpersonal coordination; studies of this phenomenon have explored the interpersonal exchange of information that promotes temporal synchronization, in addition to the cognitive processes that facilitate joint action. We also highlight the influence of experience (familiarity and expertise) and future goals (strategies) on coordination. The former entails previous knowledge of the co-performer's performance style or the musical material, among other factors, and the latter includes elements such as personal roles, body movement, and eye gaze: both dimensions variably affect musical performance. Lastly, we consider the influence of social factors, such as personality differences, that might directly or indirectly modulate the previously-mentioned elements. Our proposed framework may be useful to inspire novel research questions in joint music making and to compare research outcomes with results in non-music-specific fields that examine social processes.

### Leaders on (and off) Stage: Orchestrating Positive Change

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**Background:** Leading people is tough, orchestral life is highly pressurised, unpredictable, exhilarating and fast paced. For tomorrow's musician-leaders to have the necessary tools, skills and confidence to enable them to rise to these challenges, we need to address a missing link – the interpersonal, non-musical leadership skills – in the training of our leaders and future leaders. Jane Booth and Trudy Wright (Guildhall Coaching Associates) surveyed orchestral principals and section players from a range of UK orchestras to establish what skills are needed to support a positive and healthy culture and the well-being of all orchestral players. This presentation charts the survey results and the outcomes and learnings that have emerged during the first cohorts of training.

**Aim:** In a successful ensemble, all players are equipped and supported to bring the very best of themselves to their work. Individual needs vary, people carry their life struggles with them wherever they go, and the expectations placed on orchestral principals (from other players and management) is rarely discussed at auditions or articulated in Job Adverts. It often falls to principal players to manage interpersonal struggles, to ensure the show goes on, the ensemble performs 'as one'. On stage, principals must look and sound at ease and in control. The skills and tools to manage and even thrive may lie with professional development coaching programmes sharing non-musical leadership skills. Tools from Positive Psychology, Neuroscience and Emotional Intelligence (EQ) build self-awareness, competence in self-management, motivation, social awareness and social skills. These give individuals a greater chance of building strong relationships, leading and influencing others with skill, collaborating and communicating effectively with partners and colleagues.

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**Methods:** Our Leaders on (and off) Stage work offers training in these essential but overlooked skills. We teach the skills and practice them in a confidential space drawing on real issues for people to work through. Practice in this work builds confidence, bringing both positivity and authenticity to the working environment. This training creates frameworks for working through conflict and challenging conversations and makes space for all voices to be heard.

**Results:** Reflecting on both their verbal and non-verbal communication, Principal players have found our training builds skill in handling the challenges of orchestral life. Principals learned how to hold difficult conversations that move situations forward; they learned how to build relationships offstage to allow the work onstage to flow more easily and creatively; they have found ways to understand and manage their own responses. These factors allow them to be fully present and alert to the needs of those around them in the crucial moments of a fast moving rehearsal.

**Conclusions and Implications:** There is more to do and especially more to say to the guiding authorities. I have now begun a PhD research project looking at the impact of this non-musical leadership training on players, orchestras and the wider sector and look forward to speaking more about that in the future.

## The roles of synchrony and perceptual distinguishability on joint agency and individual control in musical duetting

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**Background:** When people perform music together, they often experience a sense of joint agency or shared control over their joint performance in addition to their feelings of individual control over their own part. For instance, while self-agency is experienced as a feeling of voluntary control over both an action and its consequence (Haggard & Tsakiris, 2009), joint agency is not only the summation of individual experiences and intentions, as a particularly salient feature of the action is an irreducible feeling of ‘jointness’ (Bolt, Poncelet, Schultz, & Loehr, 2016; Le Bars et al., 2020; Tollefsen, Kreuz, & Dale, 2014). However, even with joint agency’s distinctive quality, we still know little about the specific factors that generate and affect feelings of joint agency.

**Aim:** The goal of the current study was to use Bregman’s work on auditory stream segregation and integration to investigate whether perceptual cues would specifically affect joint agency in a way that was separable from experiences of self-agency (Bregman, 1990). To do this, we firstly wanted to investigate whether a performance would be more strongly experienced as shared when the pitches between parts were closer together due to the increased ease in experiencing the musical parts jointly. Secondly, we wanted to investigate whether participants would experience an increased feeling of individual control over their own part when the pitches between parts were farther apart due to the increased ease in distinguishing their own part.

**Methods:** Pairs of participants used electronic music boxes, which transform rotational movements into digital musical output, to perform simple duets together. Participants alternated between performing the melody, performing an accompaniment near in pitch to the melody, and performing an accompaniment farther away from the melody. After each song, participants rated their experience of control over the melody and the accompaniment, and their experience of joint agency over the duet.

**Results:** Participants’ ratings of joint agency were unaffected by either the distance between

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musical parts or the part they played. Instead, coordination performance was the main driver towards trials being rated more strongly as shared. Differing from this, participants' ratings of control over their own part was significantly affected by the distance between parts, with parts farther apart from one another eliciting stronger self-agency, and with melody eliciting a stronger sense of self-agency than accompaniment.

**Conclusions and Implications:** Our findings demonstrate that joint agency is distinct from self-agency, while also suggesting the possibility that coordination is a primary cue for joint agency in tasks whose primary goal is precise temporal coordination, and that joint agency may be less strongly affected by perceptual distinguishability than self-agency. More work needs to be done to explore the role of coordination as a primary cue for joint agency in synchronous action, in part by investigating how the temporal indistinguishability associated with high degrees of synchrony can be separated from the feelings of “we did it” that are associated with a good performance. Continued work to find other cues that influence joint agency separately from individual agency is also needed.

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## Using virtual reality technology to investigate togetherness in singing ensembles

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**Background:** The VIIVA (Vocal Interactions in an Immersive Virtual Acoustic) system is a virtual reality (VR) choir experience developed by the AudioLab, University of York, UK (Kearney et al., 2016). The system allows the user to experience singing in a choral setting, by enabling them to see and hear a pre-recorded performance by a choir in 360 degrees. The VIIVA employs head-tracking to maintain the correct position of the other singers as the user turns their head. When wearing a microphone, the participant also hears themselves singing as if in the same shared space with the choir singers captured in the VIIVA system.

**Aims:** The VIIVA system provides a more realistic auditory scene for presenting stimuli in an experimental setting, allowing repetition of multi-voice choral stimuli in an immersive environ-

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ment, and to facilitate control of repeated stimuli for musical performance. The interactions of the participants in the VR scene can be observed as one-directional relationships with the other members of the group (who are pre-recorded so will not respond to the participant), shedding light on aspects of togetherness in the act of music-making in vocal ensembles (Daffern et al., 2019).

**Contribution:** This interactive poster presentation will include a demonstration provided on three VR headsets with headphones, which will be on display for users to try the VIIVA ‘lite’ experience. The VIIVA ‘lite’ includes the 360 degree sound and visuals of the recordings but not the real-time auralization of the user’s voice in the virtual acoustic, as this requires additional hardware (Rees-Jones & Daffern., 2019). The poster will include a summary of how the system has been used to date to consider the impact of singing in a virtual space alone compared to with a virtual choir, and the impact of singing in a VR rather than a real choir. How the VIIVA can be used in different research contexts to further investigate musical performance will also be discussed alongside the practicalities of utilising VR in experimental protocols to investigate specific parameters associated with ‘togetherness’ in performance. Applications of the VIIVA for engaging communities who are excluded from the activity of group music making will also be discussed in the context of understanding the benefits of singing together for health and well-being.

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## Valuing personality type differences and maximizing the artistic potential of early-career-stage singers

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Personality type differences color the ways in which voice students learn, practice, interpret music, relate to their teachers and coaches, and choose careers within the field of music. The Singing in Color Research Study is a qualitative study that examines the impact of personality type on the education, leadership, and career decisions of early-career vocal students. The study is built on the premise that individual differences “color” the way in which we as individuals see the world, behave, learn, and thus affect the creativity and artistry of the singer. It is proposed that music educators can leverage personality type theory to enhance their teaching style and can impact the leadership styles and career decisions of early-career voice students. Examination of the Myers-Briggs Personality Type Indicator helped instruct voice teachers in the most effective methods for pinpointing differences in student learning styles, engagement triggers, communication preferences, and potential “fit” in certain musical fields. Key findings will be applied to the classroom practices and mentorship approaches of vocal music educators, while also driving greater self-awareness among aspiring young singers. The proposed research

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solution for this study is a qualitative study leveraging the MBTI instrument along with a specially designed survey to gather information pertaining to grade level, voice part, and level of musical involvement. Early career vocalists, age 16 to 25, with at least 1 year of singing experience, who are enrolled in a college music program, study with a private voice teacher, or intend to pursue music as their college major or minor, will be targeted for participation. Survey results highlighted that a significant relationship between personality and the abovementioned outcomes does in fact exist, specifically participants can leverage type to enhance their ability to learn, build relationships, and perform more effectively.

## Duo performance at sight, cognitive-social abilities and emotional context cues: A novel way to study synchronization with string and wind instruments

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String and wind musicians are usually involved in band, orchestra or small music ensembles of different sizes and instruments. Whereas in bands and orchestras synchronization is typically guided by a conductor, small ensembles are self-directed and performance outputs require high levels of interdependence and adaptations to express shared goals (Pennill & Breslin, 2021). From the perspective of Western Classical Music, Keller (2014) described different kind of factors that may influence synchronization in ensemble performance. Among others, the author considered musical elements (timing, intonation, articulation or dynamics), cognitive abilities (intelligence, flexibility or anticipation), social profiles (empath or personality), and contextual constraints (musical structure, expressive intentions or stylistic tendencies). In addition, other factors such as familiarity, experience or repertoire choices (Pennill & Davidson, 2021), together with interpersonal relationships or leader-follower behavior (Novembre et al., 2019), have been considered relevant in the assessment of synchronized performance.

The study of synchronization has been carried out through different perspectives including naturalistic observations (Davidson & Good, 2002), laboratory studies (King & Ginsborg, 2011; Novembre et al., 2019), or questionnaire methods (Blanck & Davidson, 2007), reporting relevant knowledge in the field. However, some questions are still open: is it possible to isolate the role of cognitive-social abilities in synchronization from musical knowledge and experience? may the emotional context interfere synchronization abilities? Taking as starting point Keller's model of expressive performance (2014), we propose a novel way to study synchronization in duo performance by controlling some relevant factors described and adding contextual manipulations. Specifically, we intend to develop a set of duo pieces for any string-wind combination that include tonal and atonal sections and leader-follower interchangeable parts. Musicians individually practice the score and then will be randomly paired to perform the duo at sight. As music sight-reading research has revealed the significant involvement of executive functions in performance (Herrero & Carriedo, 2020; Mainz & Hambrick, 2010), we suggest that sight performance may be a novel way to isolate the role of cognitive abilities in synchronization. In addition, as empathy seems to promote interpersonal coordination through music (Novembre et al., 2019), we consider that an interchangeable follower-leader roles may reflect different social abilities during synchronization. Finally, as emotions may interfere in musical responses (Chapin et al., 2010), external context will be manipulated by suggesting neutral, positive and negative emotional cues just before performance. Possibilities and limitations of the proposal are open to discussion.

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## The case of “sonic bridges”: Examining pitch-based bonding in ensemble performance

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In this poster presentation I shall argue that when ensemble members share the same musical lines, such as unisons or pitch repetitions, they potentially increase and intensify the sense of bonding between performers. While in traditional music theory, joint pitches and parallel lines are usually approached from a textural or contrapuntal point of view, I propose that parallel lines, especially unisons, also have another, more performative dimension which I refer to as “sonic bridges”. To give a concrete example, I will briefly discuss two songs for soprano and piano by Kaija Saariaho, “Parfum de l’instant” (2002) and “Rauha” (Peace) (2007), from the viewpoint of a music theorist and a pianist who has rehearsed a performed the works with a singer. As a conclusion, I propose that rather than merely following the leader-follower relationship in unison lines, Saariaho’s use of sonic bridges enables two very different instruments – piano and voice – to blend together in an aurally exciting way and strengthen the empathy and bonding between singer and pianist, which further increases to bring out intimate, multisensory quality of these songs.

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# Re-Thinking Musical Togetherness in an Online Music Theatre Program for Older Adults

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**Aims & Background:** The aim of this study is to examine the ways that musical togetherness is experienced in an online music theatre program. We define music theatre as the combination of singing with another theatrical element, such as dance and/or drama (Bawtree, 1991; Salzman & Dési, 2008). Previous research has noted that the epicenter of musical togetherness is in the co-creation of a temporally synchronized and coordinated sonic experience (Clayton et al, 2020; Hart 2016; Kim, Reifgerst, A., & Rizzonelli, 2019). People feel a sense of togetherness through the understanding of a shared goal, and through the creation of a unified and cohesive performance (e.g., Leman & Maes, 2015; Montague, 2019). However, little is known about how togetherness can be facilitated through a virtual music theatre environment.

**Methods:** We use a research-creation methodology to explore the ways that togetherness is experienced through participation in Rise, Shine, Sing!, a weekly singing and dancing program that is delivered through zoom. We collected observation, interview and questionnaire data from our weekly participants, mostly older adults, over a two-year period. The authors were research-participants.

**Results:** The virtual environment features surprising affordances where co-presence and togetherness are concerned (see Renihan, Brook, & Draisey-Collishaw, 2020). Participants felt part of the same time and space, and stated that they felt connected to the group, despite joining from disparate locations, and despite the absence of aural synchronization of sound and visual synchronization of movement. Our findings revealed that togetherness was maintained and fostered through a shared participation in the endeavor of music theatre. The sense of togetherness was enhanced through the focus on and highlighting of the leader, and a more flexible approach to choreography and musicking. This more flexible approach also created opportunities for agency and independence: the virtual medium allowed participants to express themselves uniquely and independent of others, in ways that face-to-face musicking prohibits. These findings illuminate a need to re-frame the possibilities of online musicking (including, but not limited to singing, listening, responding, harmonizing, and moving) as a site of potential musical togetherness.

**Conclusions and Implications:** This research contributes to the growing body of research on evolving dimensions of musicking in the digital age, and illuminates new ways that virtual music theatre supports togetherness and individual agency. Implications for further research include an examination of the physical experiences of synchrony and co-presence and how those may be experienced when in a shared virtual space, but different physical spaces. Implications for practice include a need for the diversification and inclusivity that is possible in the virtual musicking space for those who may not feel comfortable with the conformist expectations of traditional musicking and dance spaces, or for those who would benefit from an experience of expressing themselves as individuals within a space that nevertheless also celebrates a group dynamic and multiple forms of togetherness.

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## Structured musical improvisations in collectives during 2006–2018

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This article will describe an experience of musical creativity that has been carried out in various groups, to which it has been proposed to use musical coordination techniques, called “creative techniques,” to generate new music through improvisation. This creative induction work began in 2006 in Caracas, where it had a wide and diverse population of participants, and in 2018 it has been practiced with young natives of the Peruvian Amazon. Throughout this period, hundreds of amateur and professional musicians have participated, self-taught along with academics, children and adults. The audio records of the created songs are classified and evaluated. Creative techniques have a theoretical foundation derived from perceptive structural analysis. The musical improvisations through structural principles are verification of the theoretical approaches and the cognitive reality of the structural optimization proposed in theory, as well as other structural principles.

## One to one: composing social dynamics

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**Background:** Emphasizing that music is a multi-modal, social, and dynamic activity (Born 2010; Platz and Kopiez 2012), facilitates dialogue with varied disciplines and opens novel creative pathways in composition. For example, James Saunders (2021) translates insights from social psychology to explore group behaviors as music in his series *Things to do* (2014 - 20). Pauline Oliveros’s *Deep Listening* (2005) holistically casts musicking as an embodied, relational activity through multi-modal process training, including group exercises drawn from kinesthetic and meditation practices (Oliveros 2005, 2). Still others have highlighted music’s social register via rule-based games or contingency and cuing more broadly, as in Christian Wolff’s *For 1, 2, or 3 People* (1964).

**Aims:** Within the above field, I aim to develop compositional frameworks, which facilitate emergent nonverbal interactions between performers and audiences. From social cognition and dynamical systems, I use interpersonal entrainment to define the temporal processes underlying behavioral coordination (Clayton, Sager, and Will 2004; Patterson 2013), thereby framing rhythm in overtly social terms. From nonverbal communication studies, I derive the (quasi-)periodic behaviors performers and audiences may respond to when interacting—respiratory cycles, gaze and facial behavior, kinesics, proxemics, etc. (Hall, Horgan, and Murphy 2019; Harrigan 2013).

**Main Contribution:** This approach is enacted in *one to one* (2018-20), an intimately staged

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sequence of three pieces for one performer and one audience member (audient) at a time. Each pair coregulates one another's nonverbal behavioral rhythms live to develop rapport (Hove and Risen 2009; Kokal et al. 2011) characterized by intimacy, nuance, and quietude. For instance, a violinist aims to gradually synchronize their soft bowing and breathing with the audient's respiratory cycles. However, the audient often spontaneously coordinates (Codrons et al. 2014) and alters their breath lengths as the violinist plays, which precipitates cycles of mutual adaptation. These interactions may clue the audient in to what is going on and open the door to conscious involvement and play. Other pieces in the sequence coordinate with and reciprocate the qualities of audients' postural shifts, blinking, hand gestures, etc.

*one to one* offers space to reflect upon and develop behavioral attunements (Zebrowtiz, Montepare and Strom 2013, 285-286) by drawing attention to the interplay of subtle nonverbal cues in musical settings. In contrast to prevailing models of audience participation, which tend to reductively construe audiences as passive consumers in need of activation after the image of practitioners (Bishop 2012; Sdraulig and d'Heudieres, 2022), *one to one* admits diverse qualities and degrees of involvement that are dynamically negotiated within the encounter—roles bidirectionally blur beyond generic performer-audience relations by accepting typically nonconscious audience behavior as a performance of a kind. This project demonstrates how a dynamical systems approach to embodied interaction can generate novel exchanges, hybrid identities, and formats in creative practice.

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## The emergence of dialogue in dyadic improvisations: A mixed-methods design and analysis framework for an exploratory feasibility study

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**Background:** Dialogue is one of the core qualities of a relationship as described by humanistic and/or psychodynamic music therapy approaches. Assuming that dialogue is a highly individual but at the same time intersubjective process between therapist and client, when self-awareness and self-other distinction have been achieved, we focused on the question of how dialogue emerges and intersubjectively manifests in dyadic improvisations in music therapy: When and how do the two players experience that they are in dialogue—and how do these subjective experiences overlap and therefore occur as intersubjective qualities of relationship? And further: a) How do they show up in terms of musical parameters, and b) Are they also apparent on a physiological level?

While the role of nonverbal attunement and matching between a therapist and a client is in the focus of many research approaches in music therapy, little insight has been given into the client’s subjective experience and the interweaving processes of intersubjectivity between a therapist and a client during ‘meaningful moments’, which represent the complexity of dialogue.

**Aims:** In this poster we want to present the design, analysis-procedure, and first results of an interdisciplinary, mixed-methods feasibility study on dialogue and intersubjectivity in non-clinical, dyadic piano improvisations with healthy participants. The aim of this study was to combine the perspectives from music therapy, music psychology, and cognitive sciences with the goal to shed light on intersubjectivity as it shows up in dyadic improvisations.

**Methods:** Data from 17 experiments with healthy adults (n=9) and trained music therapists (n=8) were collected: Free piano partner play improvisations were recorded (video, audio, MIDI)

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and evaluated in questionnaires and semi-structured debriefing interviews. In addition, physiological measurements (ECG, EDA) from both players were conducted. The interviews focused on “meaningful situations”, i.e., moments or time periods where one or both improvising people had the feeling that something ‘pivotal’ happened between them.

**Results:** Using a summarizing content analysis method, a qualitative framework, consisting of a two-part category system covering the evidence of intersubjectivity and the quality of meanings regarding relational, self-centered, or intra-interpersonal phenomena, was developed.

The qualitative results were then compared to quantitative analyses of musical parameters that indicate musical togetherness (key velocity, pitch contour, and timing) and also to relevant physiological data (ECG, EDA). We found that periods of intersubjectivity were characterized by experiences of relational qualities that included aspects of closeness and conflict between players. This finding was mirrored in the musical analyses, which showed that intersubjectivity co-occurred with periods of dissimilarity between players in key velocity and similarity in pitch contour and timing. Analysis of physiological data is still underway.

**Conclusions and Implications:** Manifold multi- and interdisciplinary perspectives of the three researchers helped to develop the data analysis process towards a shared understanding of how subjective experiences that arise during dyadic music therapy improvisations relate to measures of musical coordination and physiological arousal. The complex mixed methods design proves to be feasible and can be transferred to clinical settings in the future.

## Wireless detection of proximity and touch for closed-loop auditory interaction

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We present *Sentire* and its underlying wireless sensor technology for sonifying proximity and touch in closed-loop auditory interaction. *Sentire* is both a performance series, which has been presented at numerous international festivals [1], and an interdisciplinary research project. The project investigates how body movements mediated by musical sounds promote interactive behaviours and prosociality, with a focus on its therapeutic potentials [2]–[5]. We developed a new sensor technology for sonifying inter-body proximity and touch in real time. Based on electro-quasistatic coupling, our wireless proximity detection overcomes the disadvantages of established systems that can measure inter-body distance (e.g. ultrasonic or infrared sensors) because it is independent of sensor positioning and orientation. *Sentire* is therefore particularly suitable for dyadic musical interaction; it offers freedom of movement and incorporates the whole body as part of its sensor system. Existing interfaces use proximity sensors for interaction design or explore the sonification of touch. However, to our best knowledge, we are the first group to implement wireless inter-body proximity sensing based on capacitive coupling. Here, we present our new hardware and accompanying software, which generates real-time auditory feedback. Moreover, we highlight the concept of our sound environments. This involves the relationship between parameter mapping, kinaesthetic perception, and our approach to sonic interaction design. The latter aims to intensify the dyadic interaction in intimate and personal spaces, as defined by anthropologist Edward Hall [6]. Furthermore, we provide insight into the iterative and incremental development of *Sentire* and the ongoing research project that combines artistic human-computer interaction, real-world research, and sonic interaction design [3]. Extensive pilot sessions demonstrate that the wireless prototype is equally effective in couple therapy as the original wired version of *Sentire*. In subsequent studies, the usability of the two sensor ver-

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sions—wired and wireless—will be evaluated quantitatively. The results of these studies will help shape the future design and development of the interactive system into a wearable that can be applied easily by different audiences, including therapists, researchers and artists.

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## Interpersonal interconnectedness and artifactual interactions in music: The case of Fandango Jarocho in Mexico

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Focusing on music as how is produced in the moment, directs our attention to the way people’s musical behaviours are shaped by their bodies, artifacts, environmental, and social aspects. The materiality of the instruments affords the acquisition of musical motor knowledge based upon how it feels to hold and play an instrument. In many contexts, this motor knowledge is rarely verbalized (Schacter, 1995). Likewise, it has been argued that this kind of match between the musicians’s bodies and their instruments is deeply anchored in physical and social dynamics rather than in merely mental processes (see Nijs, 2017). So, making music requires being well attuned to the materiality of the instruments, but is also demands being in “correspondence” or being coordinated, with other participants in the practice (Ingold, 2013). Accordingly, music should be understood as something that emerges from dynamic processes of mutual social interaction (Clayton, 2013; Cross, 2001, 2012; Martinez & Villanueva, 2018a; Moran, 2013; Orwin, Howes, & Kempson, 2013), which in turn enhances a feeling of togetherness among the participants. In this paper, I provide ethnographic evidence of Fandango jarocho, a traditional music and dance celebration from Southern Veracruz and neighbouring regions in Mexico (see Garcia de Leon, 2006), to argue that the sense of togetherness enhanced by music can be largely favoured by a good balance between a set of different levels of musical expertise socially distributed among the participants (see Turino, 2008). I highlight that Fandango has been the main channel through which this musical knowledge has been transmitted across generations mostly without any explicit verbal instruction. I use the notion of artifactual intentionality (Martinez and Villanueva, 2018b) to emphasize that Fandango celebration is based upon bottom-up processes of social interaction in which artifacts, musical skills, and social habits play a regulative and stabilizing

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role for this collective practice. Finally, I argue that Fandango can shed light on how making music can keep people interconnected socially at a deeper personal and emotional level during and after a musical performance, allowing the participant to become intimately intertwined with each other and with their entire sociomaterial surroundings.

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## Coordination dynamics in a professional string quartet learning to play unfamiliar pieces together

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**Background:** Musical ensembles often learn repertoire based on a score, which outline notes and their durations but leave many performance aspects ambiguous, such as expressive timing variations, phrasing, and intensity dynamics. Thus, ensemble members not only have to perform together synchronously, but also need to create a joint understanding about how they want to

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interpret the music. To predict how each other will play, ensembles can attend to sensorimotor signals in each other's body sway movements. For instance, in previous work we motion-captured the body sway of expert musicians in small ensembles and used Granger causality (GC) to measure predictive information flow between these time-series. We found that information flow was greater from assigned leaders to assigned followers than vice versa[1]. Musicians may also move more synchronously when they have a common interpretation of a score—for instance, other work has used cross-correlation (CC) between the body sway time-series of musical duos and showed that their body sway become more synchronous after rehearsal[2].

**Aims:** We sought to understand how body sway dynamics changed in a professional string quartet as they learned unfamiliar music together. We hypothesized that body sway synchrony (CC) would be lowest when a piece was most unfamiliar (i.e., trial 1) and would increase over eight trials as the musicians became more familiar with playing the piece together. We predicted that information flow (GC) would be highest when a piece was most unfamiliar (trial 1) and decrease over trials, as the musicians came to rely more on a jointly-developed common internal representation of their musical interpretation and less on direct body sway feedback.

**Methods:** A professional string quartet played two unfamiliar pieces together, each for eight trials in succession in McMaster University's LIVELab. The musicians had never played the pieces together, nor did they see the full score or verbally discuss the pieces. During performances, we motion captured the anterior-posterior position of each musician's head movements to index body sway, and used CC to measure synchrony and GC to measure information flow across the group on each trial. In addition, we are currently collecting performance quality ratings from professional musician judges based on the audio recordings of three phrase ending sections from each piece.

**Results:** Linear mixed-effect modelling showed group CC increased across trials while GC decreased. We are currently investigating CC and GC dynamics at moments that particularly require interpretation (i.e., phrase endings characterized by expressive timing), and how they relate to performance quality.

**Conclusions and Implications:** The increase in synchrony indicates that musicians' body sways became more similar as they converged on a joint interpretation of the pieces. The decreasing information flow suggests that when the pieces are most unfamiliar, the group relies more strongly on predictive feedback from body sway to help them predict how their fellow musicians will play. Overall, these results suggest that body sway reflects musicians' planning processes underlying music production when learning to come to a common interpretation of an unfamiliar musical score.

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## Not just in sync: A mixed-methods investigation of the cues that influence joint agency in duet music performance

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**Background:** When people perform music together, they often experience a sense of joint

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agency, i.e., a sense that “We performed the piece together” (Pacherie, 2012; Tollefsen, 2014). The sense of joint agency can take multiple forms, including a sense that agency is shared among co-performers or that co-performers are acting together as an integrated unit (Pacherie, 2012). Researchers are just beginning to uncover the cues that influence joint agency in tasks that require precise interpersonal coordination such as duet or ensemble music performance (Loehr, 2022). Recent studies suggest that synchronization performance might be the primary cue that influences joint agency in such tasks (Christensen et al., 2021; Reddish et al., 2020).

**Aims:** The goals of the current study were 1) to investigate whether the relations between partners’ contributions to a musical joint action influence their sense of joint agency, above and beyond the degree of synchrony they achieve, and 2) to probe the broader set of cues that influence joint agency in musical joint action.

**Methods:** We employed a mixed-methods approach that combined a quantitative experimental design and analysis of participants’ joint agency ratings with a qualitative thematic analysis of participants’ post-experiment interview responses. Pairs of participants used electronic music boxes to produce synchronized tone sequences that comprised either musical duets (familiar melodies with supporting accompaniment, which entailed both harmonic and more complex temporal relations between duet parts) or constant pitch sequences (pitches spaced a twelfth apart, entailing only the simple temporal relation of synchrony between tone onsets). Participants rated their sense of joint agency after each sequence. At the end of the experiment, participants were interviewed about their sense of joint agency in the two experimental conditions.

**Results:** Participants reported stronger joint agency when they produced musical duets compared to constant pitch sequences, when comparing trials in which partners achieved equally good synchronization performance for both sequence types. Joint agency was weaker and did not differ between sequence types when partners were poorly synchronized. Participants’ interview responses revealed that they perceived a variety of cues as influencing their sense of joint agency for duets versus constant pitch sequences, including their knowledge of the music, their perception of how well they performed, and their perception of the difficulty and enjoyability of producing each of the two sequence types.

**Conclusions and Implications:** Our findings demonstrate that the relations between partners’ contributions to a musical joint action influence the sense of joint agency, above and beyond the degree of synchronization partners achieve. Our findings also reveal that multiple cues influence people’s sense of joint agency during duet performance, which suggests several potential directions for further investigation of how the experience of togetherness emerges and unfolds during ensemble music performance.

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