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Collaboration in and through Music

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Abstract

Music is ubiquitous in our lives, offering us a way to express our innermost emotions and communicate meaning. The messages that we relay to each other through music are not fixed in time or space, as meaning can be transmitted across generations as well as geographical distances. As defined for this Forum, music embodies the basic elements of collaboration: it is a dynamic process involving multiple agents who pursue, through cooperation, a mutual goal. Yet other attributes in music exist to influence the actions and relationships between agents, and these play a role in creating, sustaining, or hindering collaboration. Diverse examples outlined in this chapter provide insight into how collaboration emerges in and through music.

Introduction

It is difficult to imagine a world without music. Beyond its use to entertain or express various emotional states, we use music to communicate, to motivate, to bind us together as well as to teach or transmit beliefs and values. Numerous examples demonstrate the impact that music has on our everyday lives. It is a part of important community events, such as parades, street festivals, graduation ceremonies, political rallies, and national holidays. We sing and chant at sporting events, accompanied by instrumental or percussion groups, to motivate ourselves as well as our team. At countless religious celebrations (e.g., Diwali, Christmas, Hannukah) and societal rituals (e.g., christenings, weddings, funerals), music draws people together in ways that speech or language cannot. Equally, at moments of extreme personal significance, we often turn to music to reflect or to search for a much-needed spark of inspiration.

Across cultures, music accompanies us from an early age, as we use it to nurture, to teach, and to embed us within our social groups (Trehub 2003). Exactly how music does this has been the focus of extensive research and discussion, from the interpersonal nature of music (Turino 2008) to the effects

From "The Nature and Dynamics of Collaboration,"
edited by Paul F. M. J. Verschure et al. Strüngmann Forum Reports, vol. 33,
Julia R. Lupp, series editor. Cambridge, MA: MIT Press. ISBN 9780262548144

that it has on our brains at various developmental stages (e.g., Herholz and Zatorre 2012; Merrett et al. 2013).

Here, we focus on the linkage between music and the phenomenon of collaboration. Using three vastly different musical experiences

- a live performance by a cellist and pianist of *Vocalise* (Rachmaninoff, Opus 34, No. 14)
- an interactive music installation, *Ada: The Intelligent Space*
- a series of *Musical Letters* written during the COVID pandemic and performed remotely

we examine whether the actions and relationships that emerge from these performances are indicative of collaboration. Our analysis begins using the two definitions[1] put forth at this Forum. Thereafter, we review additional attributes that emerge through music—elements that appear crucial in creating, sustaining, or hindering collaboration—and conclude with a discussion aimed at furthering the inquiry into what it means to collaborate.

Examples of Musical Interactions

Vocalise

When people engage in music, sometimes—not always—something transpires to elevate the act of playing music onto a distinct plane of "consciousness" (for lack of a better word). Numerous accounts exist of this happening, as retold by people who play all types of music (Herbert et al. 2019). Similarly, people who listen to music (i.e., who are not actively engaged in making music) have reported analogous experiences (Nicholsen 2019). Some liken what happens to a state of meditation, others to a sense of calm or a physical tingling. Since its introduction in the 1990s (Panksepp 1995), the notion of "chills" induced by music has been intensely investigated, yet when pressed to describe this experience in words, many people have difficulties, perhaps because what has occurred happens outside the realm of language.

Our first example demonstrates this experience. It begins at the reception after a chamber music concert in Berlin—a concert that featured members from the cello studio of a renowned teacher. Many in the audience of this packed concert were accomplished musicians who were well acquainted with, or had played multiple times, the various pieces on the program. At the reception, it was thus natural for these audience members to come together and discuss

[1] Collaboration was defined as (a) cooperation between agents toward mutually constructed goals (Chapter 1, this volume) and (b) the result of a dynamic, multiscale process that comprises multiple substrates from individual agents to institutions and combines priors, cognitive capabilities, and mechanisms for alignment across multiple individuals or institutions (Chapter 16, this volume).

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distinct aspects of the different performances. Soon, their talk coalesced around the performance of the *Vocalise*. Impressed by the performance, they relayed their individual reactions: one person excitedly described a sense of breathlessness; another stated that their eyes welled up; still another reported being enveloped in warmth (all different ways of describing the musical chills; Panksepp 1995). Delving further into the matter, each person pinpointed the exact moment when such a sensation began, and this coincided with the transition into the *poco piu mosso* section.

Simultaneously, on the other side of the reception hall, the cello professor was deep in conversation with the *Vocalise* performers. He expressed being positively "taken aback" by the performance and described feeling the hair on the nape of his neck stand up as they entered the *poco piu mosso* section. Enthralled to hear this novel interpretation, he was curious as to what led them to this point.

In the ensuing discussion, the performers recalled feeling at ease as they settled into the piece. The music seemed to flow effortlessly throughout the first section, and they looked forward to the nuance they hoped to bring forth during its repeat. This, too, they felt went well. Then, as they prepared to enter the *poco piu mosso* section, the pianist inexplicably changed course: through the introductory notes into the section, a new, distinct mood started to emerge—one completely different to that which had been rehearsed. The cellist could have reverted, but did not, to previously rehearsed patterns but instead used this impulse to extend the foray into uncharted musical territory. What resulted was a new, joint vision of the piece—one that reflected a novel musical dialogue that emerged on the spot between the cellist and pianist.

In their discussions with the professor, the pianist relayed feeling a surge of electricity as the *poco piu mosso* section began but did not perceive this to be negative. The cellist felt completely in sync with the pianist and felt propelled to "go further." Both musicians described a "hush" that descended upon the concert hall, as if time were suspended. They did not find this in any way frightening, although it certainly could have been, as performers often hold back a personal "reserve" to avoid losing themselves during a performance. As the piece ended, they felt a sense of "utter completeness."

As members of the audience joined the performers and the professor at the reception to "compare notes," everyone agreed that something "special" had taken place. Not only had the performance induced both emotional and physiological reactions in the performers as well as listeners, connections were created between the performers themselves as well as with members of the audience. It was clear that a unique aesthetic experience had been shared.

RoBoser and Ada

Present-day music often entails varying degrees of interaction between technology and humans, as demonstrated by our next example. In 1998, a synthetic

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music composition system was developed to explore how a small robot, Khepera, behaved in an experimental arena (Manzolli and Verschure 2005). The system consisted of a real-world device (e.g., robot), its control software, and a computer model that generated music in real time. The computer model, EmotoBot (for robotic emotions), produced melodic lines that corresponded to the sensory, behavioral, and internal states of Khepera using the Distributed Adaptive Control (Verschure 2012). In short, the *RoBoser* framework transformed information from real-world systems into complex music structures and autonomously generated music from interactions between real-world artifacts and their human and nonhuman environments.

In 2002, the *RoBoser* framework was presented at the Swiss Expo.02 in Neuchâtel, Switzerland, through an interactive exhibition titled *Ada: The Intelligent Space* (Eng et al. 2003). The aim of the installation was to promote a discussion on the implications of biomimetic technology in society and the shift toward adaptive and intelligent real-world machines. The two basic messages that the creators of *RoBoser* wished to convey were that human brains continuously construct their own interpretation of the world and that future intelligent technologies will share this property with humans (Eng et al. 2003).

The installation was made up of several environments, all of which could be explored by human visitors:

- The "Conditioning Tunnel" prepared visitors to engage with the installation by exposing them to basic components in *Ada*: cameras, microphones, and mechanical sensors as well as sound, graphics, and light-based effectors.
- The "Voyeur Area" allowed visitors to observe, through a continuous one-way screen, how other visitors interacted with the *Ada* space, as they moved to the entry area of the main space.
- The "*Ada* main space" permitted visitors to encounter the artificial organism, *Ada*, during its sleep-wake-interact-group-play-sleep cycle.
- The "Exploratorium" was an area of reflection that included a unique biomechanoid cube, created by H. R. Giger, and various talking heads which communicated notions about the future of technology to the visitors.
- The "Brainarium," a concave area adjacent to the *Ada* main space, contained six windows from which a visitor could view the *Ada* main space and receive explanations about what they were observing, including real-time data. Its purpose was to transmit an understanding of *Ada* without the visitor having to engage with the installation.

Visitors experienced *Ada* through closed-loop interactions. As they traversed through the installation, *Ada* would react to a visitor's presence in a goal-oriented way and communicate "her" synthetic emotional states using the musical framework provided by *RoBoser* (Wassermann et al. 2003). Environmental sound landmarks generated by *Ada* invited people to come into the space and

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interact with "her." Additional stimuli were provided by patterns of moving light and interactive surround graphics (an interactive floor, moving lights, 360 video projections).

Over a six-month period, more than 550,000 people visited *Ada*. Detailed analysis of visitors' behavior and attitudes showed that humans were more than willing to engage with *Ada*, such as during the virtual football game that *Ada* could deploy (Eng et al. 2005). When visitors engaged with *Ada* in the game, their behavior gradually transitioned from a reactive mode, where they thought they controlled *Ada's* reactions, to a state where they learned to follow *Ada's* cues. This process occurred through continuous implicit communication using sound, light, and graphics, which transmitted the emotional states of *Ada* to the visitors—states which arose as *Ada* pursued its goals. Surprisingly, a large proportion of visitors considered *Ada* to be a "kind of creature" (Eng et al. 2005). Detailed experiments showed that the interactive music produced by *Ada* directly affected the behavior of the visitors; decreasing the level of sound caused visitors to reduce their movement in the space, to the same extent as switching off the interactive lights and graphics. Interestingly, in this no-sound condition, visitors rated the ability of the installation to detect sounds lower and to use vision higher, suggesting their inclination to interpret their experience in a holistic way.

In summary, this complex interactive artifact, *Ada*, was able to guide human visitors to any area of the space, to prompt visitors to form groups or to separate out of groups, and to get visitors to play with it as well as with other visitors. Throughout these interactions, music played an important role, enabling *Ada* to communicate meaning and intent. The relationships cultivated between *Ada* and those who visited the installation provide an example of human–machine collaboration (Wassermann et al. 2003).

Musical Letters

The sudden emergence of the COVID-19 pandemic, and the social isolation that resulted, impacted the world of music in catastrophic ways. Many long-standing musical relationships between artists, musicians, and dancers became untenable, shuttering multiple well-established organizations to the public. The result was abrupt. Musicians no longer had a geographical space in which to practice their art. Interpersonal relationships suddenly changed. The complete lack of physical interactions in the same geographical space (vital for musical performances) created a vacuum that many artists tried to fill to adapt to this new reality. Enter computer and virtualization technology, which offered a means for musicians to continue to work together and ward off a total collapse in music production (Fram et al. 2021). Well-known techniques of multichannel recording in the studio were adapted to support collaborative possibilities that could substitute for live musical performances (Mróz et al. 2022).

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Telematics and remote multitrack recording technologies were used extensively to connect geographically separated musicians in a virtual space. Their actions and music could be digitally captured in audio and video recordings and edited into a coherent whole. Using a rhythmic pulse as a point of orientation, for example, musicians from different countries performed their individual parts, which then could be used to complete the piece. On other occasions, videoconferencing was used to capture musicians playing together in real time.[2]

The virtualization of the concert hall emerged out of this extremely rare situation. People did not simply stop and wait for the pandemic to end. Musicians attempted to minimize social isolation for themselves as well as for the public, who turned to their computer screens to connect with others. What resulted was a type of musical production that was different to high-quality live performances or studio recordings.

Among the many efforts to create music during the pandemic, one project that emerged was *cartas@todocanto* (i.e., letters to everywhere) (Manzolli et al. 2020): a series of musical letters were sent to geographically separated musicians, and the received musical answers were compiled and broadcast over social media (Manzolli 2021). The first letter, *Cartas para Amores Distantes* (Letters to Distant Lovers), was inspired by a photo of the *Ponte dos Laços* (Bridge of Ties) in Aveiro, Portugal, where ribbons of various colors are tied to express vows of love. The remote performance of this musical letter featured five musicians who did not know each other before the pandemic (Manzolli et al. 2020). Based on an initial compositional impetus, each musician contributed their musical ideas to the project and shared their individual interpretive visions. This process is similar to the age-old process of cultivating connections and shared meanings between composers, performers, and listeners, similar to the *Vocalise* example. That is, musical meaning was conveyed from the composer to the performers, who in turn communicated their musical message to an audience—a process that was unencumbered by geographical distance (Manzolli et al. 2020).

After the first musical letter, others followed: *Cuerpo Cardinal* (Body from Cardinal Points) was addressed to three percussionists, two of whom lived in the Brazilian cities of Campinas and Artur Nogueira, while the third was in Buenos Aires, Argentina. This composition posed several challenges. First, the three percussionists needed to play rhythmic patterns in synchrony while isolated geographically from each other. Second, they needed to produce percussive body sounds, which demanded a high degree of imagination and skill from each performer. Third, due to the closure of institutes, theaters, and concert halls, the performers did not have access to their percussion instruments, so they needed to improvise using what was available to them in their homes.

[2] See, for instance, members of the Rotterdam Philharmonic Orchestra perform Beethoven's *Ode to Joy*, on Mar 27, 2020, from their homes (https://www.youtube.com/watch?v=unUcOsYapEI).

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The final product was a music video that depicted an imaginary day, during the COVID lockdown, of a nurse, a housewife, and a sportswoman—an ethnographic expression of diverse behavior and emotional states during a most challenging time (Manzolli 2021).

The project sent letters not only to musicians but also to dancers. The latter, known as *Jardim das Cartas* (Garden of Letters), consisted of a multimodal installation comprised of video clips of dancers, soundscapes, and recordings of poem readings controlled by an interactive computer system (Manzolli and Andraus 2021). In June 2022, this collective creative process was presented live at the Art Gallery of the University of Campinas, Brazil, via two mixed-reality performances that involved a duo dance performance, featuring live and remote musicians (piano and computer music) from Brazil and Portugal, and a dance ensemble performance with a live soprano saxophonist and remote musicians (piano and live computer music) (see videos 22 and 23 in Manzolli and Andraus 2021). The mixed-reality orchestration of these two performances took place in a hybrid environment that utilized different artistic languages in dance, music, sound, video, poetic narration, mobile devices, and a computer-based interactive system. In this shared physical and virtual space, the performing agents interacted with each other to create a multimodal symphony of sound, movement, and body images (live and virtual), collaborating toward a common aesthetical goal that emerged and changed based on their interaction (Manzolli et al. 2022).

The *Musical Letters* project offers another example of how music can be used to transmit meaning across time and space. Aimed at overcoming social isolation, the project was successful in connecting geographically isolated musicians. It generated cooperation between musicians and dancers, many of whom did not know each other, and aligned the emergent actions to produce collaborative performances.

Discussion

These examples demonstrate how people communicate using music as an art form, yet music is employed for other purposes as well, such as to market a product or brand an idea or identity. When Starbucks designed their coffee shops, for instance, it purposely chose "flowing music" to create an aural environment as a backdrop to their idea of a "third space" culture, a supportive place for leisure and shopping (Mi et al. 2021). Many social groups (e.g., sports teams, religious organizations, political parties) use music to generate aural cues to solidify a sense of belonging and propagate values and ideas held by that group. Yet the values or ideas attached to a particular song or musical piece are not static; meanings or messages can change over time as people co-opt or repurpose the music to achieve new objectives. The song "Please, Please, Please, Let Me Get What I Want" demonstrates this nicely. Released in

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1984 by the British rock band *The Smiths*, it was used in January 2024, much to the chagrin of the composer, to introduce Donald Trump at a political rally in South Dakota (e.g., Dallison 2024). Needless to say, history is replete with such examples. Independent of purpose or meaning, music is used by people to appeal to a certain group of individuals and to get that target audience to unite around a specific goal.

To analyze how music accomplishes this, we begin by looking at the core characteristics of collaboration, as defined for this Forum, to see whether music satisfies the basic requirements to be considered collaboration. Thereafter, we examine whether the three examples presented above reveal additional elements that may be inherent to musical collaborations.

Core Characteristics

In keeping with the initial definition set for this Forum, behavior can be termed collaboration if it involves a *dynamic process* of *cooperation* between *agents* (individuals to institutions) who combine their *capabilities* and *align* their actions to pursue a *mutually constructed goal*.

In the context of musical interactions, it is difficult to imagine how any music could be produced if *agents* were unwilling to *cooperate*. Think of what is required, for example, when one sings together with others. In some forms of choral music, such as a school or church choir, members learn to blend in with the group while following directives given by a choir director; that is, they produce vocal pitches in ordered phrases (*capabilities*) and work together (*align* their actions) to perform a particular song (pursue a *mutually constructed goal*). In other types of choral singing, the same process is followed even when rules or norms differ. For instance, some choral groups, such as a barbershop quartet, do not use a conductor to align their actions. The same is true for the singing style of the BaYaka: No authority figure organizes the structural components of a song or interprets what a song should mean. Instead, singers learn, according to centuries-old traditions, to achieve the desired thick texture of sound by contributing unique, interlocking melodic lines and rhythms (Lewis 2016). Regardless of style and approach, communal singing requires individuals to *cooperate* according to established rules that are learned from an early age (Trehub 2019). In other words, communal singing involves the core characteristics of collaboration.

Equally, in instrumental ensembles, collaboration is the driving force. Imagine a marching band moving out of step as it parades down the street playing the "Stars and Stripes Forever," a patriotic march composed by John Philip Sousa, or a guitar player strumming away off-key to the rest of a rock band. In all sorts of musical ensembles (e.g., symphony orchestras, jazz ensembles, Gamelan ensembles, opera houses, pop groups), those who participate must collaborate; they must align their skills and cooperate with each other to achieve a successful musical outcome.

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But who, specifically, qualifies as an *agent* in the context of musical interactions? The obvious answer begins with the people who sing, play, or perform the music, but there are others, such as the composer or initiator of a musical piece, the listener or recipient of the music, as well as those involved in the production of music (e.g., technicians, sound engineers). Still others (e.g., administrative staff, donors, support groups) provide requisite environments for music to be produced. For an account of the cooperative networks involved in a professional orchestra, we direct you to the podcast interview of the Intendant of the Tonhalle-Orchester Zürich, Ilona Schmiel[3] (see also Chapters 6, 10, 15, and 19, this volume). Let us now look at the examples described earlier to analyze whether they embody the core characteristics of collaboration.

In the *Vocalise* performance, there are multiple *agents*: the musicians (a cellist and a pianist) who performed the composition, the composer and transcriber of the piece, and the audience members. In *Ada*, the *agents* consist of the human visitors to the Swiss Expo.02, who interacted with each other as well as with the intelligent space, *Ada* (and its sensors, effectors, and algorithmic control system), which was realized by technicians to include various types of musical and visual inputs and powered by a synthetic music composition system created by highly skilled computer scientists, composers and sound designers. In the *Musical Letters*, *agents* include the composer, who elicited responses from geographically isolated, skilled musicians, who contributed solo recordings which were combined using available technology, operated by skilled technicians, and posted online for a remote audience to listen to the resulting unified musical performance.

Different processes were used in each example to *align* the *capabilities* of agents as they pursued a *mutually constructed goal*; namely, to *create and share meaning*.

In the *Vocalise* example, the trajectory of this dynamic process might be sketched as follows: In 1914, the composer, Sergei Rachmaninoff, embedded his musical idea/concept/meaning into a song for soprano and piano. Later, the cellist Mstistlav Rostropovich arranged the song for cello and piano. Still later, two musicians, individually and collectively, interpreted the composer's and arranger's intent and transmitted their own understanding of the piece to a group of listeners. The listeners, in turn, interpreted what they heard and formed their own understanding, both of the performance as well as the composition. This process spans temporal and spatial boundaries and is not unidirectional. Feedback loops exist, for instance, between the performers, between performers and the audience, between audience members, between performers and the concert hall (e.g., acoustics), such that alterations at any stage can affect how the piece is performed and how meaning is shared or interpreted.

In *Ada*, the process began with *RoBoser*, the synthetic music composition system designed in 1998 by two scientists to enable music to be generated

[3] https://esforum.de/forums/ESF32_Collaboration.html?opm=1_3

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autonomously based on interactions between real-world artifacts (robots) and their environments. In 2002, it continued when an expanded group of researchers used *RoBoser* to construct the interactive installation of *Ada*, to examine how humans continuously interpret and shape their environment, to discern under which conditions nonhuman intelligent technologies can do so as well and whether the combination of the two can unlock new forms of aesthetics. Extensive interactions were required between scientists, technicians, graphic artists, composer, architects, light designers, and sound designers to create the installation and pursue its goals. The next step came when human visitors visited and interacted with the installation. Interpreting these interactions was the final step. Again, temporal and spatial boundaries were crossed, and multiple levels of feedback were present.

In the *Musical Letters*, the process unfolded sequentially: The composer initiated a musical dialogue to connect individual, geographically separated performers. The performers answered the letter in the form of a solo recording. Next, technicians integrated the individual performances into a unified musical statement and, in doing so, added their understanding to the project. The final result was subsequently posted online for access by a remote audience of individuals dispersed around the world, who derived meaning and formed their own understanding from what they heard. Due to the geographical separation of agents and the sequential process, feedback loops between agents were minimal (if at all) compared to live performances.

Clearly, each of these examples demonstrate the core characteristics of collaboration, yet we hold that the phenomenon of musical collaboration offers much more.

Additional Elements in Musical Collaboration

Trust. In each of the three examples, trust factored into an agent's willingness to engage in musical collaboration. In *Ada*, trust was cultivated through the physical design of the installation (e.g., the Conditioning Tunnel and Voyeur Area). Visitors could observe the synthetic environment and choose at any time to exit or further engage with *Ada* as they had a well-defined expectation of the elements involved in the interaction. This choice—or viewed differently, not being forced to engage—can be likened to building trust. The *Musical Letters* project aimed to cultivate interpersonal connections between agents in an effort to offset social isolation. Although many of the agents did not know each other, they relied on trust in the goals of the project to engage. In the *Vocalise* example, interpersonal trust between the cellist and the pianist allowed the performers to deviate from previously rehearsed patterns and pursue new meaning under performance conditions.

Common ground. A common reference point or an acknowledged set of norms appears to be important in achieving collaboration in music. In both the *Vocalise*

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and *Musical Letter* examples, the agents (e.g., the composer, performers, listeners) shared a common understanding of the musical elements (e.g., harmony, form, tonality) and conventions that framed each piece. Thus, the agents were equipped to receive, understand, and interpret the music. By contrast, the designers of *Ada* did not take it as given that potential visitors would be equipped with the requisite knowledge to support a meaningful experience with the installation, so they designed the interactive space to permit visitors the chance to gain this knowledge (e.g., the Conditioning Tunnel and Voyeur Area).

In any musical genre, cultural familiarity and expertise or honed skills contribute to a person's perception and enjoyment of that music (Jakubowski et al. 2022). Having a shared set of norms enhances the experience for both the producers (musicians) and receivers (listeners). For instance, a person accustomed to the harmonies of Western choral music might find not "understand" a communal song by the BaYaka,[4] just as a person who is into hip-hop music might not "understand" Schoenberg's 12-tone Piano Concerto.[5]

Yet musical enjoyment involves far more than understanding or appreciating musical norms. The aesthetic value of a musical performance increases greatly when there is nuanced deviations from these norms (Jakubowski et al. 2022). Take phrasing, for instance: In the *Vocalise* example, the pianist introduced a new musical direction by drawing out or stretching the three notes that led into the *poco piu mosso* section. Picking up on this alteration, the cellist expanded things further, communicating to the pianist the opportunity for further extension of this trajectory along a transient shared goal. Whatever transpired between the soloists in this emergent musical collaboration was registered (e.g., musical chills) by some in the audience.

Interpersonal relationships. Just as in many areas of life, how agents interact affects the outcome being pursued. Prevalent in many social interactions is the concept of power, or "the extent to which [a] person has the potential ability to influence another person in a given setting" (Snyder and Kiviniemi 2001:134). In musical ensembles, power is exhibited by different agents in various ways. For instance, one musician may be perceived by peers to be more experienced or successful, leading that individual to feel more entitled to make determinations in the ensemble. In a symphony orchestra, power relationships exist in the realm of the musicians and conductor. Conductors, for example, may perceive their role to encompass the entire interpretation of a piece, including how individual solo parts are to be played. If the musicians inherently trust the conductor, this may work out just fine. However, absent this, a conductor's efforts may be perceived as stifling the musical expression of highly skilled musicians (e.g., the concertmaster, solo wind players) and lead to tensions that could compromise a performance and, by extension, the ensemble. The

4 https://archives.esforum.de/sfr10/index.html

5 https://www.youtube.com/watch?v=rZlB2tRyvQw

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situation becomes even more tenuous between guest conductors and orchestral musicians (Khodyakov 2014). Interpersonal relationships and the power differentials that exist among the various agents must be managed carefully if musical collaboration is to happen.

Synchrony. As observed in different social species (e.g., honeybees, bats, fish, primates), behavioral synchrony establishes a basis for trust to develop which in turn contributes to the social functioning of a group (e.g., Couzin 2018; Gordon et al. 2020). In humans, interpersonal synchrony (i.e., the temporal coordination of actions between individuals) is common in many social behaviors, such as team sports, marching bands, and rave concerts (Rennung and Göritz 2016; Zamm et al. 2021). Specific to music, Trainor and Cirelli (2015:45) find that "adults who engage in synchronous movement to music report liking each other better, remembering more about each other, trusting each other more, and are more likely to cooperate with each other than adults who engage in asynchronous movements."

The example of a marching band demonstrates how music engenders interpersonal synchrony. For millennia, military marches have been used to coordinate troop movements, signaling, and the firing of weaponry, and although technology has drastically changed over time, military music still continues to be used to motivate and create social cohesion (Wiltermuth and Heath 2009). Compositional components of a march include a homophonic structure with clearly defined sections, specific rhythmic cadences, strict harmonic progressions, the use of a duple or compound duple meter (e.g., 2/4, 4/4, or 6/8 time signatures), and melodic familiarity (Dobney 2004; Norris 2012). The rationale for this is fairly obvious: A duple meter is employed because we are bipedal. Homophony primes cohesive behavior. Equally, strict rhythmic cadences make it very difficult to move "out of step" to the music, regardless of whether you are marching in the band or just listening from the sidelines. What better way to create subliminal social cohesion than to get people moving together, especially during times of societal conflict? Still, the potential for nefarious uses can easily be recognized.

The cognitive and neural processes proposed to underpin synchronous social behavior are numerous (e.g., Garrod and Pickering 2009; Hasson and Frith 2016), and how this plays out in a musical context has been the focus of recent research. Gugnowska et al. (2022), for example, found evidence of interbrain synchrony between two duetting pianists. In addition, Chabin et al. (2022) has explored synchrony between members of an audience, pinpointing specific moments in a performance where strong or weak emotions evoked emotional cohesion between individuals. Does this explain what happened in the *Vocalise* example?

Human–Nonhuman Interactions. It is difficult to imagine how any music enjoyed today does not involve some degree of technological influence, be it

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through the lighting in a concert hall, to the equipment used to record a performance, to the influence that a luthier or piano tuner exerts on the performing instruments, to the software and nonhuman devices used in synthetic music.

In the *Musical Letters* project, technology enabled geographically separated agents to perform together. In *Cuerpo Cardinal*, this was accomplished through an audible "tick," which provided an essential cue for the percussionists. In *Jardim das Cartas*, individual dancers' movements were transmitted as impulses generated by smartphone accelerometers to a composer, who used these impulses in real time to create a musical layer that reflected their movements to the composition.

The *Musical Letters* project could not have happened without technology, but does this mean that humans collaborated with technology? Since collaboration has been defined as requiring a shared understanding of common goals by the agents, it would appear that "agency" is a necessary condition for collaboration. Does technology—specifically artificial intelligence (AI)—have agency? Similarly, in terms of mutual goal production, does AI participate with humans in generating goals? Is this all just a matter of definition, and do our definitions need to change?

Since the 1950s, different initiatives have utilized computational technology to compose music. Following the pioneering work of Xenakis (1977, 2001), composers have explored algorithmic compositional techniques and looked extensively at the human creative process in an effort to create synthetic systems that can organize music in real time with different agents. Co-creation systems that enable improvisation between humans and virtual agents have been developed (Assayag et al. 1999; Dubnov et al. 2003). Other studies have explored the notion of creativity in nonhumans (Veale and Cardoso 2019). *RoBoser* and the intelligent space *Ada* demonstrate what it means for humans and AI to interact. Much more remains, however, to be done before these critical questions can be answered.

Conclusion

Because music is so prevalent in our lives, because we use it to express who we are and communicate what we feel is important, musical activities offer a rich repository from which to study different aspects of human behavior. In the context of trying to understand the phenomenon of collaboration, this becomes even more interesting as we engage in music to communicate attributes of our existence, both tangible and intangible, from aesthetic messages to emotional responses to events that hold meaning in our cultures and societies.

Regardless of whether one actively engages in music-making or participates through listening to the outcomes, music creates a backdrop for collaboration to emerge and connect individuals in many forms and for many reasons. This is hardly a static process. In addition, since music is passed on across

From "The Nature and Dynamics of Collaboration,"
edited by Paul F. M. J. Verschure et al. Strüngmann Forum Reports, vol. 33,
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generations, it offers a longitudinal glimpse into how individuals understand and use music, which in turn can inform us about how collaboration unfolds over time.

Each of the musical examples discussed in this chapter demonstrate the core characteristics of collaboration defined for this Forum. They illustrate a dynamic, multiscale process that required cooperation between agents, who pursued a mutual goal—a process that combined priors, cognitive capabilities, and mechanisms to secure alignment between the multiple agents involved. These examples exposed, however, other elements crucial to the generation and sustainability of musical collaboration: the role of trust between interacting agents, the importance of shared common understanding, the significance of interpersonal relationships, as well as the existence and need to manage power differentials between agents. They also point to questions that require far more elaboration than is available to date:

- What exactly is involved in the physiological response (e.g., musical chills) that an agent encounters?
- How does inter-agent synchrony (behavioral and neural) emerge, and how is it sustained?
- How is music used intentionally to manipulate the response of individuals or groups?

Ongoing research has started to investigate these elements yet much more attention is required before we are able to address potential moral dilemmas and destructive consequences that can arise from activities associated with collaboration in and through music (see Chapter 4, this volume). Music is not only a ubiquitous part of our existence; it embodies and engenders collaboration. A thorough understanding of the dynamic processes involved in music will enrich our understanding of the phenomenon of collaboration as practiced in other areas of life.

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