Musical Ensemble Performance: Representing Self, Other, and Joint Action Outcomes

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0. Introduction

Human interaction in musical contexts is a vital part of social life in all known cultures. Types of musical interaction range from intimate duets through medium-sized groups to large orchestras, sometimes including more than a hundred performers under the direction of a conductor. Irrespective of size, musical ensemble performance—as a social art form—entails multiple individuals pursuing shared AESTHETIC GOALS. These goals are typically realized through the nonverbal communication of information about MUSICAL STRUCTURE and EXPRESSIVE INTENTIONS to co-performers as well as audience members. To this end, musical interaction partners engage in mutually coupled, affective exchanges that are mediated by instrumental sounds and body movements (Keller 2008; MacRitchie, Buck, and Bailey 2013). From a psychological perspective, musical ensemble performance thus constitutes a highly refined form of joint action that requires real-time interpersonal coordination at the level of sensorimotor, cognitive, emotional, and social processes (Keller, Novembre, and Hove, in press).

A basic requirement in musical joint action is the alignment of information along multiple musical dimensions, including fundamental elements of music such as rhythm, pitch, and intensity (loudness), across individuals (Keller 2014). Rhythm and pitch are fundamental elements of music. Rhythm generally refers to the temporal patterning of sequential events. In music, this patterning is determined by the durations of intervals between sound onsets, which commonly form ratios such as 2:1, 3:1, and 4:1. Pitch is a psychological aspect of sound that is, in music, related mainly to the perceived fundamental frequency of complex tones (ranging from low to high). Pitched tones can be arranged sequentially to produce melodies, while the simultaneous sounding of two or more pitched tones in chords gives rise to harmony.

Rhythm and pitch are typically structured hierarchically: Individual tones are concatenated into melodic motives (short sequences of tones perceived as a

group, analogous to words in speech) and phrases (short strings of motives, analogous to spoken phrases and sentences). Rhythmic durations can be defined relative to the temporal units of underlying metric frameworks. Metric frameworks are cognitive-motor schemas that comprise hierarchically arranged levels of pulsation that include the beat, beat subdivisions, and groupings of beats into bars (Lerdahl and Jackendoff 1983; London 2012). Metric pulsations are experienced as regular series of internal events, with every nth event perceived to be accented, i.e., stronger than its neighbors. Regularity at the most salient level of metric pulsation—the beat, with which one might tap along with when listening to music—allows it to function as a shared temporal frame of reference that multiple performers use to time their sounds (Nowicki et al. 2013). This function is made explicit in musical contexts that employ a conductor (who provides beat gestures) or a subgroup of instrumentalists who are designated as the 'rhythm section' (e.g., the bass and drums in much standard jazz).

The way in which separate instrumental parts in an ensemble fit together depends largely on the patterning of their rhythmic and pitch elements. On the temporal dimension, separate parts articulate the same rhythm or complementary rhythms that mesh to produce interlocking patterns with varying levels of complexity (defined according to how well the rhythms fit a common metric framework). Similarly, pitch relations between parts can be unison or harmonic (multiple simultaneous pitches), and, in the latter case, consonant or dissonant (depending on the complexity of pitch interval ratios). The more distinguishable individuals' parts are in terms of rhythm and pitch, the more likely they will be perceived to play different roles (e.g., melody versus accompaniment) in a musical texture. Ensemble performance is thus characterized by the hierarchical structuring of musical information and a variety of modes of interpersonal coordination at the level of sounds (Phillips-Silver and Keller 2012).

Hierarchical structuring and different coordination modes likewise characterize the body movements of ensemble performers. A distinction can be drawn

between *INSTRUMENTAL MOVEMENTS*, which are directly related to the production of musical sounds (e.g., the keystrokes of pianists), and *ANCILLARY MOVEMENTS*, which are not technically necessary for sound production but nevertheless accompany performance (e.g., head nods, limb gestures, and body sway) (Nusseck and Wanderley 2009). During ensemble performance, sounds triggered by instrumental movements are coordinated at short timescales in the millisecond range, while ancillary movements such as body sway are aligned at longer timescales associated with higher-order units of musical structure (e.g., phrases). These large-scale movements provide visual cues that, in combination with the auditory cues provided by musical sounds, facilitate the multimodal communication of hierarchical musical structure and expressive intentions (Davidson 2009). Interpersonal coordination in musical joint action therefore evolves at multiple timescales and across different sensory modalities.

A challenge for ensemble musicians is to achieve precision in basic interpersonal coordination without sacrificing the flexibility required to modulate expressive performance parameters (Keller 2014; Palmer 1997). These EXPRESSIVE VARIATIONS may arise spontaneously during performance, though they are also often pre-planned but executed as if spontaneous (Chaffin, Lemieux, and Chen 2007). Variations in performance timing are a particularly effective means by which performers communicate their intentions concerning musical structure and stylistic expression (Friberg and Battel 2002; Gabrielsson 1999; Repp 2002). Expressive timing variations include micro-timing deviations (delays and advances in sound onset timing in the order of tens of milliseconds) and local TEMPO fluctuations (accelerations and decelerations in the order of hundreds of milliseconds). In ensembles, expressive performance is not merely a matter of individual variation, but rather inter-individual co-variation (Keller 2014).

To achieve precise yet flexible interpersonal alignment across the multiple dimensions, timescales, sensory modalities, and coordination modes described above, ensemble co-performers rely to some degree upon mental representations of each other's parts in the musical texture. This is a specialized form of shared task representation that assists performers in keeping track of

who is who (i.e., agency attribution) and dealing with the real-time demands of musical joint action.

1. Shared musical representations

Complex forms of musical joint action require pre-planning. Indeed, musicians in many ensemble traditions spend considerable time preparing for performance through a combination of individual private practice and collaborative group rehearsal. Private practice not only develops the individual's technical skills, but also can also facilitate familiarity with co-performers' parts through the study of sound recordings and MUSICAL SCORES. Collaborative rehearsal is then typically geared towards establishing a shared performance goal, i.e., a unified conception of the ideal integrated ensemble sound (Keller 2008; Williamon and Davidson 2002).

The richness and specificity of performance goals, and the degree to which they are truly shared across ensemble members, vary as a function of the musical context. Members of a symphony orchestra, for example, do not necessarily know the intricacies of each part in the ensemble texture; rather, the conductor functions as a repository of the global performance goal. Moreover, in freely improvised music, co-performers eschew fully preconceived goals in favour of transient shared goals that evolve spontaneously through mimicry and other interactive social processes during live performance. When shared performance goals are strategically pursued during rehearsal, however, ensemble musicians enter into a process of becoming familiar with one another's parts and the manner in which these parts will be played. This process primarily entails nonverbal communication through body movements and musical sounds, though verbal communication usually also takes place (Price and Byo 2002; Williamon and Davidson 2002).

Ensemble cohesion is predicated upon the musicians reaching a consensus on how expressive performance parameters should be modulated in order to communicate the goal interpretation of a piece. As musicians coming together to

rehearse a piece bring their own preconceptions of the music, this consensus must be negotiated (Ginsborg, Chaffin, and Nicholson 2006). A mixture of social, conventional, and pragmatic considerations govern this process. Social factors—including personality, pre-existing interpersonal relationships, verbal and nonverbal communication styles, and gender and instrument stereotypes—are relevant to the extent that they influence the effectiveness of information exchange during rehearsal (Blank and Davidson 2007; Davidson and Good 2002; Davidson and King 2004; Ginsborg et al. 2006; Goodman 2002; Williamon and Davidson 2002). The negotiation of performance goals can also be influenced by how leadership is distributed among ensemble members – ranging from egalitarian piano duos, through democratic mixed chamber groups, to hierarchical regimes where a conductor is expected to impregnate an orchestra with his or her performance goal.

Once shared performance goals are consolidated, they reside in each individual's memory as mental representations of the ideal sounds constituting a musical piece. These representations embody, to varying degrees, the performer's own sound, co-performers' sounds, and the overall ensemble sound (Keller 2008, 2014). Co-performers thus come to co-represent elements of each other's parts (Keller 2008; Loehr and Palmer 2011; Sebanz, Bekkering, and Knoblich 2006). While this process may be grounded in the automatic tendency for individuals engaged in joint action to represent each other's tasks (Knoblich, Butterfill, and Sebanz 2011; Sebanz et al. 2006), the amount of time that ensemble musicians invest in rehearsal suggests that developing shared performance goals can be effortful.

Shared musical representations ensure that ensemble musicians take each other's actions into account during performance. Research on joint action outside the music domain has demonstrated that individuals behave differently when performing a task alone or with co-actor (Sebanz, Knoblich, and Prinz 2005; Vesper & Sebanz, this volume). In tasks requiring interpersonal coordination, individuals increase the salience and regularity of their movements as a strategy to smoothen coordination (Vesper et al. 2010). Musicians similarly

employ coordination smoothers to facilitate ensemble cohesion. An example is when expressive devices, such as tempo accelerations and decelerations, are dampened during ensemble performance relative to when a musician performs their part alone (Goodman 2002). Another example is when an ensemble leader sharpens the contrast between rhythmic durations in order to communicate clear expressive intentions (Marchini, Papiotis, and Maestre 2012), or when the performers exaggerate instrumental movements while simplifying ancillary movements such as head gestures (Glowinski et al., 2010, 2013; Goebl and Palmer, 2009).

Shared representations thus influence the process of planning and executing actions during ensemble performance. Specifically, action plans that guide motor processes involved in translating goal representations into body movements that are appropriate for generating the intended sound (Chaffin, Imreh, and Crawford 2002; Gabrielsson 1999; Palmer 1997) are modified by knowledge of a co-performer's task. Importantly, action plans will differ across co-performers when their parts are complementary (rather than identical), even if the individuals play the same instrument. Ensemble musicians therefore develop systems of shared performance cues to regulate and coordinate their actions (Ginsborg et al. 2006).

Performance cues are features of the music (e.g., phrase boundaries and intensity changes) that group members collectively attend to during performance in order to ensure that things take place as planned (Chaffin and Logan 2006; Ginsborg et al. 2006). The selected features provide landmarks in a mental map that reflects the hierarchical organization of sections in a piece's formal structure. Hierarchies of performance cues thus serve as retrieval schemes that enable performers to deal with the real-time demands of performance by utilizing domain-specific expert memory processes (Lehmann and Ericsson 1998). In ensembles, shared performance cues remind co-performers of shared performance goals and link individual performance plans into a common scheme that can be used to regulate the interplay between musicians (Keller 2014).

Once shared goal representations, performance plans, and cues are established, they interact with online sensorimotor and cognitive processes that facilitate precise yet flexible interpersonal coordination by allowing co-performers to anticipate, attend, and adapt to each other's actions in real time. The following sections of this chapter deal with how shared representations are formed during preparation for joint musical performance, and how these representations interact with sensorimotor and cognitive processes during actual performance. Our treatment of these topics is organized around three central claims about shared musical representations. First, shared representations involve the integration of information related to one's own part, others' parts, and the joint action outcome while maintaining a distinction between self and other. Second, self, other, and joint action outcomes are represented in predictive internal models. Third, internal models recruit the motor system to simulate self- and other-produced actions. Studies that employ behavioral and brain methods provide converging evidence for these three claims.

2. Self-Other Integration and Segregation

While the collective aim of much ensemble performance is to produce a cohesive musical Gestalt, the primary responsibility of each individual performer is to produce his or her own part accurately. In other words, the coherence of the whole depends on the integrity of its parts. Therefore, although shared goals are represented and used to guide performance, a distinction between representations of parts produced by the self and others must be maintained in order to allow each performer to retain autonomous control of their own movements (cf. De Jaegher and Di Paolo, 2007; Pacherie, 2012). Ensemble musicians thus integrate information related to their own part and others' parts to monitor the joint action outcome while maintaining a distinction between self and other. This balance between self-other merging and self-other distinction entails the simultaneous integration and segregation of information from separate sources (Keller, Novembre, and Hove, in press).

Generally speaking, the human capacity for segregation relies on the ability to isolate parts that constitute a whole object or event, while the capacity for integration relies on the ability to construct a whole by grouping together a collection of parts. Integration and segregation have been investigated extensively in the domains of visual and auditory perception. In vision, segregation is exemplified by the perception of figure-ground relations in a visual scene, where one object is perceived as a distinct entity against a background, while integration is exemplified by countless demonstrations by Gestalt psychologists that the whole is greater the sum of its parts (Schacter, Gilbert, and Wegner 2011). In audition, integration and segregation have been studied most thoroughly in the field of AUDITORY SCENE ANALYSIS. In particular, research on the phenomenon of auditory streaming has shown how the relationship between concurrent sound sequences in terms of pitch and timing determines the degree to which they are likely to be perceived as separate streams versus an integrated whole (see Snyder and Alain, 2007).

In traditional auditory streaming demonstrations (e.g., Bregman and Campbell, 1971), a sequence of alternating high- and low-pitch tones is perceived by listeners to segregate into a sequence of high tones and a sequence of low tones when the pitch difference between the tones is large and the tempo is fast. Streaming is also influenced by the relationship between tones in terms of their timing, timbre, and intensity (see Bregman, 1990). While these features can automatically lead to the segregated or integrated percepts (Müller, Widmann, and Schröger 2005), the ability to hear sequences as segregated or integrated is nevertheless subject to some degree of control through the allocation of attention (van Noorden 1975). A classic example of this is the cocktail party effect, which refers to the ability to attend selectively to one stream of information while ignoring others (Cherry 1953). When listening to ensemble music, it is likewise possible to focus attention locally on a particular instrumental part, or to spread attention across parts and focus more globally on harmonic and rhythmic relationships between them (Bigand, McAdams, and Forêt 2000; Janata, Tillmann, and Bharucha 2002).

Furthermore, it has been argued that a mode of attention that is a hybrid of these two extremes may be recruited when listening to, and performing, ensemble music (Keller 1999). Specifically, in the case of listening, an individual may focus attention on a particular part (e.g., the melody) while simultaneously attending to the interrelationship between parts (e.g., the melody and accompaniment). Similarly, ensemble performance involves concurrently paying attention to one's own actions (high priority) and those of others (lower priority) while monitoring the overall ensemble sound. This form of divided attention has been termed 'prioritized integrative attending' (Keller 1999).

Prioritized integrative attending assists ensemble musicians to integrate their own actions with others' actions while maintaining autonomous control of their own movements (Keller, 2014). This mode of attention facilitates ensemble cohesion by allowing co-performers to adjust their actions based on the online comparison of mental representations of the ideal ensemble sound and incoming perceptual information about the actual sound (Keller 2008). Performers are thus able to deal with changes in the momentary demands of their own parts and the relationship between their own and others' parts in terms of timing, intensity, intonation, articulation, and timbre (Keller, 2014). To the extent that prioritized integrative attending entails simultaneous self-other segregation and integration, it is cognitively demanding and can be seen as an advanced ensemble skill (Keller, 2001).

Keller and Burnham (2005) studied the dynamics of prioritized integrative attending using dual-task paradigms designed to capture a subset of the cognitive and motor demands of ensemble performance. In a listening task, musicians were required simultaneously to memorize a target (high priority) part and the overall aggregate structure (resulting from the combination of two complementary parts) of short percussion duets. Results indicated that recognition memory for both aspects of each duet was influenced by how well the target part and the aggregate structure could be accommodated within the same metric framework. Analogous results were obtained in a second 'rhythmic canon' study, which required professional percussionists first to listen to a

rhythm pattern, and then to reproduce it on a drum while listening to a concurrently presented pattern that also had to be subsequently reproduced. Reproducing the first pattern in time with the second one is essentially a form of sensorimotor synchronization, and as such requires the integration of sensory information associated with the pattern being listened to with motor information related to the pattern being produced (c.f., Lakens et al., this volume). Taken together, Keller and Burnham's (2005) results demonstrate that musicians are able, first, to prioritize one part while monitoring the relationship between parts when listening to or producing multipart patterns and, second, to form memory representations for different levels (part and whole) of the multipart structure. However, the ability for such processing and representation is affected by the temporal compatibility between parts.

Subsequent research has sought to identify the neural correlates of prioritized integrative attending. Recent studies employed functional Magnetic Resonance Imaging (fMRI) to investigate the simultaneous segregation and integration of melody and accompaniment parts during listening to piano duos (Ragert, Fairhurst, and Keller 2014; Uhlig et al. 2013). The melody and accompaniment parts were differentiated in terms of both pitch and rhythm, and participants were required to attend to one part while judging its temporal relationship to the other part (leading or following). The results of these studies suggest that the planum temporale (posterior to the primary auditory cortex) plays a role in segregation, the intraparietal sulcus supports integration, and frontal regions (including dorsolateral prefrontal cortex and frontal gyrus) regulate attentional modulations of the balance between these two processes. By recruiting this fronto-parieto-temporal network, prioritized integrative attending calls upon brain regions that subserve basic forms of auditory attention, including selective, divided, and nonprioritized integrative attending (see Janata, Tillmann, and Bharucha, 2002b; Satoh, Takeda, Nagata, Hatazawa, and Kuzuhara, 2001).

In ensemble performance, simultaneous self-other integration and segregation is especially important for the task of monitoring an ongoing performance to determine whether shared performance goals are being met. In a recent study of

this process, Loehr et al. (2013) investigated whether pianists are able to monitor their own and their partner's part of a duet in parallel. Pairs of pianists performed duets together while their brain activity was recorded using electroencephalography (EEG). During their performances, the pitches elicited by each performer's keystrokes were occasionally altered (by a computer that controlled the keyboard output) so that an unexpected pitch was produced. Half of the altered pitches occurred in the upper part of the duet (*own part* for the pianist performing the upper part; *partner's part* for the pianist performing the lower part) and half occurred in the lower part of the duet (vice versa). Each unexpected pitch changed either the auditory outcome of one pianist's action (i.e., a single pitch in one pianist's part) or the joint outcome of the pianists' combined actions (i.e., the harmony of the chord produced by the two pianists' combined pitches; see Figure 1).

The altered pitches elicited two brain responses that are commonly associated with monitoring action outcomes. First, altered pitches elicited a feedback-related negativity (FRN), a negative-going potential that signals a perceived mismatch between expected and actual action outcomes and peaks approximately 250 ms after the unexpected action outcome (Oliveira, MacDonald, and Goodman 2007). Equivalent FRNs were elicited whether the altered pitch occurred in the pianist's own part or the partner's part, indicating that pianists monitored their own actions and their partner's actions in parallel. Second, altered pitches elicited a P300 response, a positive-going potential that peaks 300-600 ms after the action outcome. The P300 occurs relatively late in the processing stream and its amplitude is thought to reflect the perceived significance of the unexpected outcome (Nieuwenhuis, Aston-Jones, and Cohen 2005). As Figure 1 shows, the amplitude of the P300 was larger in response to altered pitches that occurred in the pianist's own part compared to the partner's part and in response to altered pitches that changed the joint outcome compared to an individual outcome. Thus, whereas the FRN findings indicate integration of own and others' parts at an early stage of action monitoring, the P300 findings indicate that pianists differentiate between their own and others' action

outcomes, and between individual and joint action outcomes, at later stages of processing.
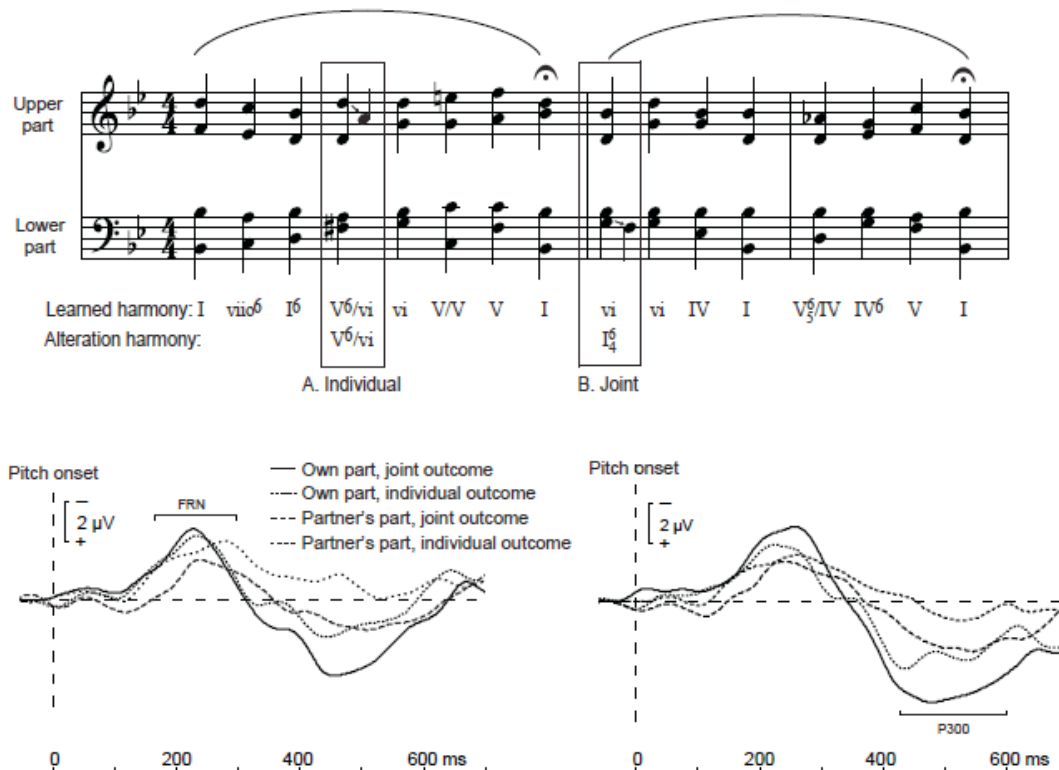

Figure 1. Brain responses to unexpected pitches indicate integration and segregation of self and other during action monitoring. Upper panel: The first half of a duet, showing two altered pitches. One pianist performed the upper part of the duet and the other performed the lower part. Symbols immediately below chords (labeled "learned harmony") indicate the harmony given in the score. Symbols labeled "alteration harmony" indicate the harmony introduced by the altered pitch. A) *Individual outcome* altered without changing the harmony of the chord. (B) *Joint outcome* altered by changing the harmony of the chord. Lower panel: Brain responses to altered pitches. Left side: The feedback-related negativity. The difference between brain responses to expected and unexpected pitches, averaged over five frontocentral electrodes, is shown for each type of altered pitch. Right side: The P300. The difference between brain responses to expected and unexpected pitches averaged over three parietocentral electrodes, is shown for each type of altered pitch. Reprinted and modified, with permission,

from Loehr et al. (2013).

In addition to monitoring joint musical outcomes, the balance between self-other integration and segregation influences the process of maintaining autonomous control of one's own actions. Such autonomous control presumably requires agent-specific representations at the level of the motor system. Novembre et al. (2012) explored the representation of self- and other-related actions in the human motor system in a single-pulse Transcranial Magnetic Stimulation (TMS) study that employed a virtual piano duo paradigm. Skilled pianists were asked to learn several piano pieces bimanually before coming to the laboratory. The right-hand part contained a melody line and the left-hand part contained a complementary bassline. When the pianists were invited to the lab a few days later, they were required to perform the right-hand part of each piece while the left-hand part was either not performed or believed to be played by another pianist hidden behind a screen (this hidden pianist feigned playing while the participant actually heard a recording).

The experiment ran across two sessions, one in which pianists could hear feedback of their actions as well as the recording, and a subsequent session in which the pianists received no auditory feedback (i.e., the piano was muted) but were still aware of the presence of the co-performer behind the screen. In both sessions, single-pulse TMS was applied over the right primary motor cortex to elicit Motor Evoked Potentials (MEPs), which were measured (with electromyography) from a left forearm muscle that would normally be used to perform the complementary part.

It was assumed that bimanual learning of the piece would lead to a *co*-representation of the left-hand part, which would then be associated either with the self (when the part had been learned but was not performed) or with the other player (behind the screen). Consistent with this, differences in MEP amplitude suggested that distinct patterns of cortico-spinal excitability—inhibition and excitation—were associated with the representation of self and other, respectively (cf. Loehr, 2013; Schütz-Bosbach, Avenanti, Aglioti, and

Haggard, 2009; Schutz-Bosbach, Mancini, Aglioti, and Haggard, 2006; Weiss, Tsakiris, Haggard, and Schütz-Bosbach, 2014). Crucially, the results did not change as a function of whether or not the pianists received auditory feedback about their own performance or the 'hidden partner'.

Novembre et al.'s (2012) findings support the hypothesis that musicians form agent-specific forms of motor representations in the context of joint musical tasks. Inhibition and excitation of the motor system might therefore constitute markers of the functional segregation of parts performed by self versus other during musical ensemble performance. The finding that this segregation occurred in the mute session suggests that these agent-specific representations arise in response to the potential for interaction with another, and may therefore be intrinsically social in nature. This 'social' interpretation was buttressed by the additional finding that the degree of excitation in the condition where pianists believed they were performing with another was positively correlated with scores on a subscale of an empathy questionnaire assessing the tendency to adopt others' perspectives in everyday life.

Social factors have also been found to affect the balance of self-other integration and segregation during sensorimotor synchronization with virtual partners that vary in dynamic cooperativity. One relevant study (Fairhurst, Janata, and Keller 2014) addressed the relationship between leader-follower tendencies, temporal adaptation, and locus of control—a dimension of personality related to the degree to which life events are perceived to be a consequence of one's own actions. The study aimed to identify behavioural strategies and patterns of brain activity that distinguish between individuals with different leader-follower dispositions when they interact with synchronization partners with high or low levels of competence. This was examined in an fMRI experiment that required individuals to synchronize finger taps with sounds produced by virtual partners who varied in terms of competence at keeping a steady tempo. For performance to be successful, the human participant must take responsibility for keeping the tempo when the virtual partner cannot.

Results indicated that 'leaders' (individuals who attribute the cause of events to their own actions) generally engaged in less adaptive timing than 'followers' (who attribute events to external factors). In other words, leaders were less likely than followers to adapt the timing of their taps to the virtual partner's timing. This may stem from a difference in the balance of self-other integration and segregation: While followers prioritized the task of synchronizing with their partner (i.e., self-other integration), leaders focussed on stabilizing the tempo of their own performance (self-other segregation). This difference was reflected at the level of the brain. Specifically, brain regions implicated in self-initiated action (e.g., pre-supplementary motor area) and the evaluation of agency (e.g., precuneus) were activated more strongly in leaders than followers. More generally, the activation of right lateralized areas (including the inferior frontal gyrus and the inferior parietal lobule) varied as a function of the competence of the virtual partner, suggesting that these areas may be involved in the regulation of degree of self-other integration and segregation based on the skill of an interaction partner.

3. Internal Models for Self, Other, and Joint Action Outcomes

Shared representations of musical goals facilitate ensemble coordination, first, by ensuring that co-performers plan to produce their parts in a manner that is mutually compatible and, second, by assisting co-performers to anticipate each other's action timing via the generation of online predictions during performance. It has been claimed that both of these functions are enabled by 'internal models' instantiated in the central nervous system (see Keller, 2014). Internal models represent sensorimotor associations between motor commands that issue from the brain and the sensory experience of bodily states and events in the immediate environment (Kawato 1999; Wolpert, Miall, and Kawato 1998). In the case of music performance, these associations link musical sounds with instrumental and ancillary body movements.

Research in the field of computational movement neuroscience has identified two types of internal model: forward and inverse (Kawato 1999; Wolpert et al.

1998). Forward models represent the causal relationship between motor commands (e.g., to lower a finger) and their effects on the body and the environment (the tactile sensation of striking a piano key and the auditory sensation of hearing a tone). Inverse models represent transformations from intended action outcomes (sounds, in the case of music) to the motor commands that produce them. It has been argued that multiple hierarchically nested internal models represent events at multiple timescales in the context of complex action sequences (Pacherie 2008). Accordingly, music performance recruits models linked to different levels in the music's hierarchical structure, including long-range performance goals and plans (representing musical phrases and ancillary body sway, for example) and models of short-range goals and plans (representing instrumental movements and individual sounds or brief sequences) (Pacherie 2012; Ragert, Schroeder, and Keller 2013). Internal models thus represent dynamic processes to the extent that they contain information about movement kinematics and sequential event transitions (Pezzulo et al. 2013).

It has been proposed that internal models arise from the cerebellum, from where they communicate with other brain regions (see Ito, 2008). Internal models can thus be used to drive simulations of goal-directed actions by recruiting the brain areas that would normally be involved in action execution and action observation, but without causing overt movement and in the absence of corresponding sensory input (Pezzulo et al. 2013). ACTION SIMULATION plays a role in planning one's own actions (Jeannerod 2001), as well as in predicting the future course of others' actions and understanding their intentions (Schubotz 2007; Wilson and Knoblich 2005). Two classes of internal model therefore operate in tandem during ensemble performance, one for simulating one's own actions ('self' models) and the other for simulating co-performers' actions ('other' models) (Keller, 2008; Keller and Appel, 2010; Sänger, Lindenberger, and Müller, 2011).

'Self' models are used to guide the production of one's own part: They facilitate efficient action planning and execution by running slightly ahead of movement,

thereby allowing potential errors to be anticipated and corrected before they occur (Wolpert et al. 1998). 'Other' models are used to simulate the observed actions of co-performers: They allow one musician to predict what another will do, how they will do it, and when they will do it (Keller 2008, 2012; Wolpert, Doya, and Kawato 2003). In the context of joint action, the coupling of 'self' and 'other' models in a 'joint' model facilitates fluent coordination between co-performers by allowing potential interpersonal timing errors (as well as errors affecting other musical dimensions such as pitch and intensity) to be simulated and corrected before they occur (see Box 1) (van der Steen and Keller, 2013).

Insert Box 1

 'Self', 'other', and 'joint' internal models for complex skills such a music performance require training. Specifically, the sensorimotor transformations represented in internal models must be acquired, strengthened, and refined through active experience and observational learning (Cross et al. 2009; Schubotz 2007; Wolpert et al. 2003). Representations of these transformations may develop in tandem with the strengthening of links between sensory and motor cortical regions, notably, the auditory-motor coupling that develops with musical experience (Herholz and Zatorre 2012; Zatorre, Chen, and Penhune 2007). Practicing instrumental technique thus leads to the development of internal models that assist in producing the desired sounds, while observing and listening to co-performers allows one individual to learn to simulate another's idiosyncratic playing style via the calibration of internal models to the other's action system (Repp and Keller 2010). Reliable and efficient 'self', 'other', and 'joint' internal models can be viewed as a hallmark of expertise as an ensemble musician.

In music performance, action simulation is experienced (in phenomenological terms) as anticipatory auditory and motor imagery of musical sounds and related movements (Keller and Appel 2010; Keller 2012). It is through such

mental imagery that ensemble musicians activate internal representations of shared goals, plans, and cues during performance (Keller 2014). Anticipatory imagery thus steers action simulation while internal models provide the motor that drives it. The importance of imagery in ensemble performance is highlighted by self-reports of elite musicians. A member of the renowned brass section of the Chicago Symphony Orchestra states: "If I don't hear it [the ideal sound] or conceptualize it in my brain, there's no way I'm going to get it" (Trusheim, 1991, p. 146). The performer is referring to the use of anticipatory auditory imagery to recruit 'self' inverse models that assist in achieving the level of motor control required to produce the ideal sound. Another Chicago brass player alludes to the use of auditory imagery of co-performers' parts during private practice for ensemble performance: "The sound of what is going on in the rest of the orchestra is always in my imagination… you're training yourself to think of what else is happening. You're hearing the whole picture…" (Trusheim, 1991, pp. 145-146). Here the performer refers to the use of 'other' and 'joint' models even when playing in the absence of co-performers. Clearly, the effectiveness of such a strategy would depend upon knowledge of the structure of co-performers' parts and their playing style.

Evidence that self, other, and joint action outcomes are represented in predictive internal models comes from behavioral, neuroimaging, and brain stimulation studies addressing the effects of familiarity with a co-performer's part on the performance of an individual's own part, as well as on overall ensemble coordination.

A specific piece of evidence supporting the claim that musicians form internal models of their partner's part of a duet is the finding that knowledge of the partner's part influences how the pianist's own part is performed. Loehr and Palmer (2011) and Palmer and Loehr (2013) compared pianists' performances of a right-hand melody when paired with a left-hand accompaniment produced by themselves or by a partner. The left-hand accompaniment was either simple (repetitive, arpeggiated pitch changes and repeating harmonies) or complex (scalar pitch changes with less repetitive harmony). When the pianists

performed both parts themselves, the right-hand melody was produced differently (e.g., more slowly and with a more pronounced temporal grouping structure) when paired with a simple compared to complex left-hand accompaniment. The same pattern of differences occurred when the left-hand accompaniment was produced by a partner. Thus, pianists' internal models of the partner's part modified the production of their own part of a joint performance.

In another study (Ragert et al. 2013), pairs of unacquainted pianists came to the lab after practicing either one part or both parts of several piano duets at home. The complementary parts of the duets were therefore familiar in one condition and unfamiliar in the other. Pianists' keystroke timing was recorded on digital pianos and their body movements were tracked with a motion capture system as they played repeat performances across six takes in each condition. It was assumed that, in the unfamiliar condition, each pianist would develop performance goals, plans, and cues for their own part during private practice, whereas shared goals, plans, and cues that take both parts into account would not be consolidated. Internal models for simulating the co-performer's part would therefore not be initially available when the part was unfamiliar. However, increasing exposure to the co-performer's part and playing style across takes was expected to lead to the formation of shared performance goals, plans, and cues, and to the acquisition of internal models that generate temporal predictions based on simulations that are consistent with the co-performer's expressive style.

Ragert et al.'s (2013) results pointed to a partial dissociation between interpersonal coordination at the level of keystrokes and body sway. Variability in keystroke asynchronies decreased across the takes, and was generally lower in the unfamiliar condition than the familiar condition. This indicates that coordination started out better, and remained so, when pianists had *not* rehearsed their co-performer's part. By contrast, body sway coordination was high throughout the takes in the familiar condition, while it started out low and improved across takes in the unfamiliar condition. These findings suggest that

knowledge affects interpersonal coordination by influencing predictions at different timescales. Familiarity with a co-performer's part, but not their playing style, engenders predictions about expressive micro-timing variations that are based instead upon one's own personal playing style, leading to a mismatch between predictions and actual events at short timescales. As knowledge about a co-performer's stylistic idiosyncrasies is acquired, however, the individual learns—through the calibration of internal models—to simulate the other's action style. Familiarity with the structure of a co-performer's part, on the other hand, facilitates predictions at longer timescales related to high-level metric units and musical phrases, and reflected in ancillary body sway movements.

Another study (Novembre et al. 2014) examined how disrupting (via double-pulse TMS) the cortical brain network underlying action simulation affects the ability of pianists to adapt to tempo changes in familiar and unfamiliar parts during virtual duet performance. The task (see Figure 3A) required participants to play the right-hand part of piano pieces in synchrony with a recording of the complementary left-hand part, which had (Trained) or had not (Untrained) been practiced beforehand. The recordings of the left-hand part contained occasional tempo changes, to which the pianists had to adapt in order to maintain synchrony. In critical conditions, these tempo changes were preceded by double-pulse TMS delivered over the right primary motor cortex (to interfere with simulation of the left hand part). It was hypothesized that practicing the left-hand part would lead to the development of internal models for performing the part, thereby enhancing the ability to simulate it and assisting with adaptation to the tempo changes. To test this hypothesis, the accuracy of tempo adaptation following TMS or sham stimulations was compared across Trained and Untrained conditions (Figure 3B).

It was found (Figure 3C) that TMS impaired tempo adaptation when the left-hand part had been previously trained, but not when the part was untrained (suggesting that tempo adaptation may have been underpinned by a different, possibly subcortical, brain network in this case). These results extend previous research on the role of training in developing the capacity for (cortical) motor

simulation (see section 4 of this chapter; cf. D'Ausilio, 2007; Haueisen and Knösche, 2001; Lahav, Saltzman, and Schlaug, 2007) by demonstrating that motor representations of other's actions support interpersonal coordination. Consistent with the results of Novembre et al. (2012), the social implications of such co-representation at the level of the motor system were borne out by the additional finding that the pianists who were particularly susceptible to TMS-induced interference to tempo adaptation scored highly on the perspective-taking subscale of an empathy questionnaire (Figure 3D).
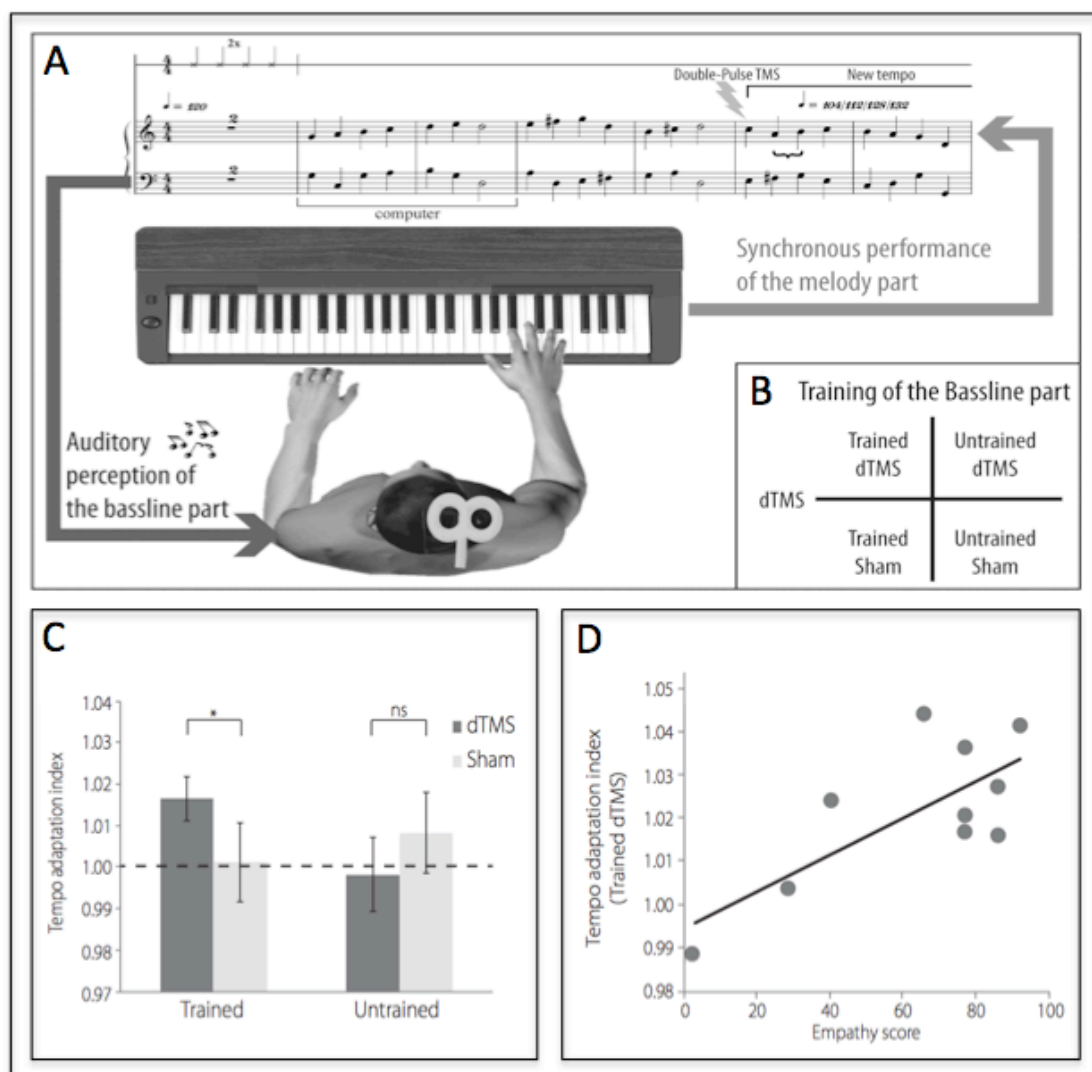

Figure 3. Schematic summary of the study by Novembre et al. (2014). A: Experimental task. B: Experimental design. C: Tempo adaptation index across conditions (the dashed horizontal line indicates perfect adaptation, values above or below indicate deceleration or acceleration, respectively, of the produced

melody with respect to the bassline part presented by the computer). D: Correlation between TMS-interference to motor simulation and the perspective taking (empathy) score of each participant. Reprinted and modified, with permission, from Novembre et al. (2014).

4. Motor Simulation of Self and Other

The proposal that internal models recruit an ensemble musician's motor system to simulate co-performers' actions is consistent with embodied accounts of social cognition more generally (e.g., Hurley, 2008). A corollary of such motor involvement is that representations of co-performers' actions may be influenced by one's own action repertoire and action style. ACTION REPERTOIRE refers to the set of musical structures that an individual performer is potentially able to produce given his or her technical mastery of their instrument. ACTION STYLE refers to idiosyncratic ways of producing these structures (in terms of fluctuations in event micro-timing and intensity). Action style may vary due to a mixture of factors including learning history, aesthetic preferences (Repp 1997, 1998), level of expertise (e.g., expert pianists play with more idiosyncratic expressive timing profiles than novices [Repp, 1995]) and biomechanical properties related to individuals' physical characteristics (see Keller, 2014). Here we consider how the effects of action simulation on interpersonal coordination in ensembles are moderated by the degree of overlap in co-performers' action repertoires and the similarity of their preferred action styles.

Synchronizing with a recording of one's own performance presents a special case of perfect overlap in action repertoire and action style, because the sensorimotor system engaged in action simulation is the same system that produced the action in the first place. In a study of such self-synchronization (Keller, Knoblich, and Repp 2007), pianists were asked to record one part from several duets and then, several months later, to play the complementary part in synchrony with either their own or others' recordings. As expected, synchronization was best when the pianists played with their own recordings. This finding was taken as support for the hypothesis that pianists predicted the timing of sounds in the recordings by

engaging in online simulation of the performances. On this account, such simulation led to a self-synchronization advantage because the match between simulated event timing and actual timing in a complementary part was best when both were products of the same sensorimotor system. Additional analyses (examining correlations between timing profiles of duet parts recorded separately by the same pianist) indicated that the self-synchronization advantage was not merely due to *a priori* self-similarity in performance technique. This reinforces the claim that overlap in action repertoire and action style facilitates interpersonal coordination by enabling the accurate simulation of other co-performers' actions.

The self-synchronization advantage found by Keller et al. (2007) invites the hypothesis that ensemble musicians with similar action styles (when they perform alone) should be better able to simulate each other's actions and therefore better able to coordinate with each other when they perform together. In a study on this topic, Loehr and Palmer (2011) investigated whether performers who are more similar to each other in terms of their preferred solo performance tempi are better able to coordinate with each other during duet performance. Each pianist in a randomly assigned pair was first asked to perform a simple melody alone, from which his or her preferred performance tempo was calculated. The pairs then performed duets together, and the degree to which the pianists were able to synchronize with each other and mutually adapt to fluctuations in each other's timing was measured. Pairs who were better matched in solo performance tempi were better able to synchronize with each other and displayed mutual adaptation, whereas pairs who were less well-matched produced larger asynchronies and displayed a tendency for one person to track the other's timing but not vice-versa. Importantly, coordination between partners was predicted by the degree of similarity between their preferred solo tempi, but not by either partner's solo tempo considered alone. These findings suggest that performers who are better matched are better able to generate predictions about each other's timing, resulting in improved coordination.

Compatibility in action style may therefore occur at multiple time scales, ranging from local micro-timing to global tempo. The way in which similarity in action style influences motor simulation and the process of generating predictions at these different timescales depends to some degree on the degree of overlap in action repertoire. Movements that produce sounds on a particular musical instrument (such as a pianist's keystrokes) can be simulated accurately only when these actions are in the observer's behavioral repertoire (e.g., when a pianist sees or hears another pianist). Indeed, neurophysiological studies of music listening have revealed that the strength and anatomical specificity of brain activations associated with motor simulation is modulated by the degree to which an individual is experienced at producing the movements required to produce the heard sounds (D'Ausilio, 2007; Haueisen and Knösche, 2001; Lahav, Saltzman, and Schlaug, 2007). For example, regions of the primary motor cortex that represent specific fingers (thumb and little finger) become especially active when pianists listen to sounds that would be played by those particular fingers in the context of a specific musical piece (Haueisen and Knösche 2001). Without such specific knowledge, simulation is limited to more general, instrument-independent movements (body sway, rocking, and expressive gesturing with the head and hands), as well as vocal and articulatory activity that could potentially approximate others' sounds (Keller 2008; Schubotz 2007). Overlap in action repertoire thus affects the specificity of the movements that are simulated, ranging from instrumental movements at short timescales to ancillary movements that evolve at longer timescales.

5. Conclusions

Ensemble performance is a refined form of joint action that entails the nonverbal communication of information about musical structure and expressive intentions via sounds and body movements produced collectively by co-performers. For such communication to be successful, precise yet flexible interpersonal coordination is required across multiple musical dimensions (including pitch and rhythm), timescales (expressive micro-timing vs. large-scale tempo changes), sensory modalities (auditory and visual), and modes of

interaction (unison *vs.* complementary action). Furthermore, the real-time demands and aesthetic goals of ensemble coordination necessitate interpersonal alignment at the level of sensorimotor, cognitive, emotional, and social processes.

In the current chapter, it was claimed that such alignment is facilitated by representations of performance goals that are shared across ensemble members. These shared musical representations facilitate ensemble cohesion by interacting with sensorimotor and cognitive processes during performance, thereby allowing ensemble musicians to anticipate, attend, and adapt to each other's actions in real time.

We presented evidence that shared musical representations consist of integrated information related to an ensemble performer's own part, other performers' parts, and the joint ensemble sound, while maintaining a distinction between self and other. Such simultaneous integration and segregation of self and other allows each performer to retain autonomous control of their own actions, while the ensemble itself attains a form of autonomy that signals cohesive social interaction (Keller et al., in press; cf. De Jaegher and Di Paolo, 2007). The balance between group integration and individual segregation may be especially critical in small ensembles. For instance, a member of the renowned *Trio Wanderer* describes the ensemble as follows: "It's like a holy trinity. It's three individuals in a group. Both things [individuality and group] are equal and very important." [Interviewed by Peter Keller on 9 September 2011 in Leipzig].

Finally, we argued that self, other, and joint action outcomes are represented in internal models that recruit a performer's motor system to simulate actions at multiple hierarchical levels, ranging from movements that produce sounds on an instrument to ancillary body movements (e.g., sway) that are linked to higher levels of musical structure. Shared musical representations are thus dynamic in the way in which they embody action outcomes related to the self, others, and the ensemble as a whole. Investigating open questions on shared musical representations (Box 2) will potentially further our understanding of how

humans achieve exquisite real-time interpersonal coordination in complex forms of communicative joint action.

Insert Box 2

Box 1: Internal Models
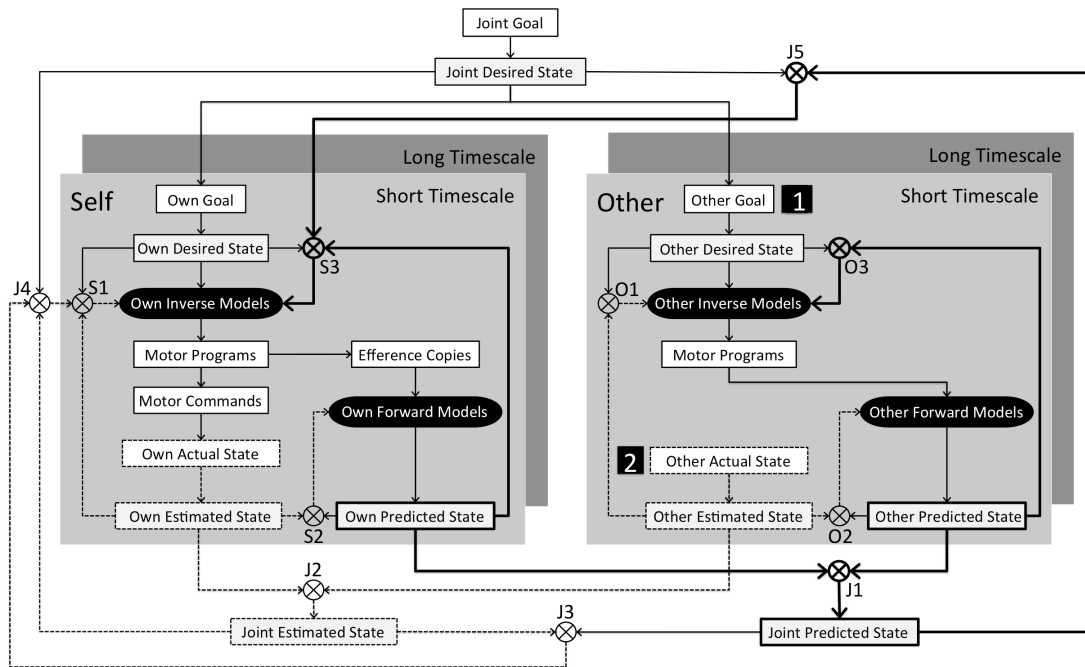
Although a number of authors have postulated the existence of internal models that represent 'others' in addition to the 'self', the precise way in which these models are linked is typically not specified. Here we present a conceptual framework of linked internal models of self, other, and joint action that extends a basic framework formulated by van der Steen and Keller (2013) to musical ensemble performance. In this conceptualization, self and other internal models operate at multiple timescales, allowing the simultaneous simulation of instrumental movements at short timescales and ancillary movements at longer timescales. In the schematic diagram, the operations carried out by internal models are illustrated for the short timescale only, but it is assumed at similar operations are performed at long timescales. It is furthermore assumed that hierarchically arranged internal models permit the representation of sequential and temporal relationships between the constituent elements of complex actions, as well as different levels of action specification (see Pacherie, 2008, 2012; Wolpert et al. 2003). The dotted lines in the diagram indicate processes that rely on sensory feedback while unbroken lines indicate feedforward processes.

Self Internal Models

Internal models that represent sensorimotor transformations related to an individual's own actions (Self) facilitate action planning and online control (Ito, 2008; Kawato, 1999; Wolpert et al., 1998). These 'self' internal models may be acquired and refined through musical experience via mechanisms such as Bayesian probabilistic learning (Haruno, Wolpert, and Kawato 2001; Körding and Wolpert 2004). During this process, 'own' inverse models, which provide motor programs for achieving action goals, are developed through a process that entails minimizing discrepancies (S1) between the desired state associated with an action goal and estimates of the actual state brought about by executing a motor command. 'Own' forward models receive efference copies of motor programs provided by own inverse models and, based on this information, generate predictions about state changes that would result from the execution of these programs. Own forward models are calibrated during learning by minimizing discrepancies (S2) between predicted and estimated actual states. Once calibrated, own forward models can be used to correct potential errors before they occur by comparing (S3) predicted and desired state during action execution.

Other Internal Models

'Other' internal models, which represent sensorimotor transformations related to others' actions, allow one individual to predict the actions of co-performers. These predictions may evolve via two routes (cf. Phillips-Silver and Keller, 2012). If an individual has pre-existing knowledge of another's goal (1), then a top-down form of simulation takes place where 'other' inverse models activate motor programs that would be appropriate for achieving the other's (inferred) desired state. 'Other' forward models can generate predictions about the other's likely future state by simulating the execution of these programs. The second 'bottom-up' route (2) proceeds via an automatic process of motor resonance. Incoming perceptual information is used to estimate the other's current state, which is used by an 'other' inverse model to provide a motor program that would be appropriate for bringing about this state. To the extent that the program is linked to higher-level programs representing sequential relations between action elements, an 'other' forward model can be used predict the future state that would arise if these programs were to be executed.

'Other' inverse models develop with increasing familiarity with particular co-performers through a process involving the minimization discrepancies (O1) between the inferred desired states and estimated actual states. Other forward models are calibrated to co-performers' action styles by minimizing discrepancies (O2) between predicted and estimated states. Following such calibration, other forward models can lead to modifications of other inverse models based on comparisons (O3) between predicted and desired states. In situations where an individual is familiar with neither the structure of co-performer's parts nor their playing style, 'other' internal models may be restricted to representing sensorimotor transformations at long timescales associated with ancillary body movements (e.g., sway) yoked to higher levels in the music's structural hierarchy.

Joint Internal Models

In the current conceptualization, internal models of self and other interact in a joint internal model. The joint model provides a dynamic representation of the shared performance goal (see section 1). Joint internal models integrate the outputs of self and other internal models, and then modify 'own' inverse models to compensate for any discrepancies between these outputs. The predicted states for own and other are combined to yield a joint predicted state (J1). Similarly, state estimates based on perceptual information about one's own and another's actions are combined to yield a joint estimated state (J2). Predicted and estimate joint states are compared (J3) and compensatory adaptations are made to own internal models to account for discrepancies (J4). Furthermore, inverse models may be modified due to discrepancies arising from comparisons between the joint estimated state and the joint desired state (J4). Finally, interpersonal errors can be corrected before they occur based on comparisons between the joint predicted state and the joint desired state (J5). This is a key component of van der Steen and Keller's (2013) framework.

Box 2. Questions for Future Research

- What form do shared representations take when performance goals cannot be fully specified in advance (e.g., during improvisation) or distributed equally among all ensemble members (e.g., in a symphony orchestra)?

- What factors determine the quality of interpersonal coordination at short timescales where instrumental movements occur vs. longer timescales associated with co-performers' ancillary movements?

- How do joint internal models develop over the course of training or rehearsal? Are joint internal models of higher hierarchical levels (e.g., tempo changes at the phrase level) developed sequentially or simultaneously with models at lower levels (e.g., micro-timing deviations)?

- What factors determine the balance between self-other integration and segregation, and how does this balance change dynamically over the course of a musical joint action?

- How is the balance between self-other integration and segregation regulated in the brain?

- How do shared representations influence performers' sense of agency or control over a performance?

- To what degree does the accuracy of joint internal models contribute to feelings of 'flow' or positive affect that arise during musical interactions?

KEY TERMS

AESTHETIC GOALS
The artistic ideals of ensemble performance. These ideals may vary as a function of musical piece, genre, socio-cultural context, and performers' predilections. Nevertheless, ensemble musicians commonly aim to interact during performance in a manner that is conducive to producing a cohesive sound in which the whole is perceived to be greater than the sum of its parts. This general goal is expressed in different forms of behavior. Multiple performers may seek to sound as one voice, to establish leader-follower relations, or to engage in turn-taking analogous to conversation. These forms of interaction require shared artistic goals to be agreed upon (explicitly or implicitly) by the group.

MUSICAL STRUCTURE
The patterning of musical sounds in pitch and time to produce melody, rhythm, harmony, and higher-order forms of organization. Melodic structure is determined by the way in which the sequential ordering of tones encourages perceptual grouping into motives and phrases that constitute a melody. Rhythmic structure is influenced by temporal relations between sounds within and between instrumental parts. Harmonic structure refers to sequential progressions of chords (simultaneously sounding tones) that are governed by genre specific syntactic rules. Formal structure stems from the organization of melodic, rhythmic, and harmonic structural units into sections (e.g., verse and chorus in songs) that combine to form the narrative of a musical piece.

EXPRESSIVE INTENTIONS
The impression that a performer wishes to convey to a listener about musical structure, meaning, mood, and emotion. Ensemble musicians express their intentions to co-performers and audience members through musical sounds and body movements. Musical expression thus entails nonverbal communication via auditory and visual cues.

INSTRUMENTAL MOVEMENTS
Movements that a performer is required to execute in order to produce sounds on a particular musical instrument (e.g., keystrokes of pianists; bowing actions of violinists; articulation and fingering in wind players).

ANCILLARY MOVEMENTS
Movements that are not technically necessary for sound production but nevertheless accompany music performance. Examples include head nods, body sway, and limb gestures (e.g., shoulder, elbow, and hand motion). Ancillary movements function to regulate performance tempo and to provide visual cues that assist basic interpersonal coordination and the communication of expressive intentions.

EXPRESSIVE VARIATIONS
Variations in musical sound parameters that are introduced deliberately by the performer to convey his or her expressive intentions. These variations may affect the timing, intensity (loudness), articulation (length), intonation (tuning), and

timbre (tone color) of musical sounds. A common expressive device is deceleration of performance tempo at the end of musical phrases, especially those ending major sections in the formal structure of a piece. In ensemble performance, such expressive devices need to be aligned across individuals.

TEMPO
Musical speed or pace. In music where rhythms are structured relative to a regular underlying beat, tempo can be specified in terms of beats per minute, as produced by a metronome. Musical tempi typically fall within a range that corresponds to rates at which human locomotion is possible. Performance tempo (unless electronically controlled) is not strictly regular but contains unintentional fluctuations due to perceptual and motor limitations as well as intentional variations introduced for expressive purposes.

MUSICAL SCORES
Systems of notation that specify elements of musical structure (pitch and rhythm) and expression (tempo, articulation, and intensity changes) as intended by a composer. Scores provide ensemble musicians and orchestral conductors with an overview of all instrumental parts and how they fit together, thus forming a potential basis for shared musical representations.

AUDITORY SCENE ANALYSIS
Ensemble music presents a complex auditory scene characterized by streams of sound emanating from multiple instruments, each representing a separate sound source. The human auditory system recovers individual sounds from the mixtures of sounds that arrive at the ear based on auditory cues related to pitch, timbre, intensity, timing, and spatial localization, as well as perceptual grouping cues that operate according to Gestalt principles of organization. Auditory scene analysis facilitates the perception and production of ensemble music by allowing sounds from different instruments to be simultaneously segregated and integrated by listeners and performers.

ACTION SIMULATION
The activation of sensory and movement-related brain areas in a manner that does not necessarily follow from exogenous stimulation or lead to overt movement. Such covert simulation, which may be experienced phenomenologically as mental imagery, can assist in action planning and online motor control, as well as in understanding the goals and predicting the outcomes of observed actions performed by others.

ACTION REPERTOIRE
The set of goal-directed actions that an individual is potentially able to execute. These sets are developed through the implicit learning and deliberate practice of motor skills. In music, a performer's action repertoire includes movements that are necessary to meet the technical requirements of producing sound on an instrument, as well as specific movement sequences required to play a particular musical piece.

ACTION STYLE

An individual's idiosyncratic way of doing things. Action style is determined by a mixture of factors including anatomical constraints, learning history, level of expertise, personality, and aesthetic preferences. While individuality in action style is valued in music performance, ensemble co-performers may seek to transcend their individual musical identities to achieve a group identity.

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