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Empathy and groove in musical movement

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The role that empathy plays in the way that we learn, perform and listen to music has recently become a significant focus in the field of music cognition. This research includes investigations of how being more empathetic changes musical action and perception (Eerola, Vuoskoski & Kautiainen, 2016; Kawase, 2015; Pecenka & Keller, 2011), how taking part in musical performance can affect empathy (Greenberg, Rentfrow, & Baron-cohen, 2015; Novembre et al., 2015; Parsons et al., 2014; Rabinowitch & Knafo-Noam, 2015; Saarikallio, Vuoskoski, & Luck, 2014), the role it plays in the development of social behavior (Clark & Giacomantonio, 2015; Kirschner, Sebastian & Tomasello, 2010; Phillips-Silver & Keller, 2012; Rabinowitch, Cross, & Burnard, 2012; Rabinowitch & Knafo-Noam, 2015), how it relates to brain stimulation (Novembre et al., 2012; Novembre et al., 2013), and how musical listening can be a vehicle for increasing cultural understanding and openness (Clarke, DeNora, & Vuoskoski, 2015).

Concepts employed to define empathy range from perspective-taking, the capacity to experience others' feelings as their own, seeing the world through someone else's eyes, and having compassion for another's pain (Clarke, DeNora, & Vuoskoski, 2015). Definitions differ according to whether empathy is considered a static trait or achieved skill, where it is cognitive or affective in nature, and whether expressing it is voluntary or involuntary. The empirical methods employed to measure the different dimensions of empathy are often psychometric scales or questionnaires, including the Interpersonal Reactivity Index (Davis, 1983), the Basic Empathy Scale (Jolliffe, D., & Farrington, 2006) the Empathy Quotient (Lawrence, E. J., Shaw, P., Baker, D., Baron-Cohen, S., & David, 2004), and the Empathy Components Questionnaire (Batchelder, Brosnan, & Ashwin, 2017).

Clark, DeNora & Vuoskoski (2015) question if empathy is a coherent enough term to be useful in understanding musical experience, the empirical evidence for the relationship between the two being "scattered" and "disciplinarily disconnected" (p. 63). They attempt to synthesize the empirical evidence from the different disciplines into one comprehensive "model of musical empathetic engagement" that focuses primarily on describing the different factors that affect the way listeners interact with the components of a musical performance or piece. The focus of this paper will on just a small part of their complex model, in particular what is happening between musicians during the act of performance. The real-time interpersonal coordination necessary to perform music as a group requires multiple individuals to anticipate and adapt to each other's actions (D'Ausilio et al., 2015). Musicians' experience of the temporal dimensions of this anticipation and adaptation are key to how music performance relates to empathy, and how it helps us understand the processes of creative musical expression.

Sensorimotor empathy

Synchronization as well as the "call and response" dynamics of music improvisation both require that musicians are able to anticipate the actions of their co-performers and continuously adapt their musical movements. The dynamics of the self-organized bodily coordination that emerges is key to musical behavior (Borgo, 2005; Linson & Clarke, in press; Walton et al., 2015), and while there is ongoing debate about the primacy of movement in understanding musical knowledge (Geeves & Sutton, 2014; Maes, 2016) it is at least uncontroversial to say that musicians need to move their bodies when they play music. Just as the embodied approach to music performance isn't novel, neither is the suggestion that one would need to look "beyond the head" to understand the relationship between music and empathy (Krueger, 2015).

Given these theoretical motivations, the appropriate concept for understanding the embodiment of empathy and musical expression is *sensorimotor empathy* (Chemero, 2016). Sensorimotor empathy emerges from the way that we coordinate with objects and people in our environments. As we engage with the world we form "synergies" where our movements and actions are constrained such that the environment and ourselves exist as a cohesive unit. Much of our experience of the world can be understood through the spatiotemporal patterns of this engagement, where "doing things takes time, after all, and we are always moving" (Chemero, 2016, p. 5). This kind of bodily extension and skillful engagement has been applied to the understanding of tool use, but sensorimotor empathy is the way that the boundaries of our body expand as the temporal aspects of our experience become coordinated with the bodies of others. Other bodies in the world that we experience as connected and responsive to the time and space of our own movements also temporarily become part of our existence. Empathy in music can be understood through this mutual, two-way sensorimotor engagement, as opposed to decomposition into different levels where the actual physical interaction is one process, and the representation and simulation of another's mental state is another (Coplan, 2011). Embodied approaches to social interaction have long refuted the necessity of simulation in anticipating and understanding the emotional experience of others (Gallagher, 2008). And so in the case of music performance, empathy *just is* the experience of moving together in time– and luckily, making music takes time and musicians are always moving.

Importantly these human-to-human synergies can be scientifically investigated, and the dynamics of the spatial-temporal properties of these synergies can be quantified. In demonstrating how our movements allow us to perceive the properties of a tomato, Chemero (2016) explains that even after mere seconds of being in the same room as a tomato, saccadic movements have occurred in our eyes, and our posture has swayed such that our gaze is affected and all of this immediately provides knowledge of the tomato's three-dimensional properties. Just as these brief, subtle fluctuations of action in time tell us about the world, they also tell us about the sensorimotor empathy experienced by musicians as they engage in the social task of co-constructing musical meaning.

Understanding Groove

The temporal connection between musicians has been extensively studied in the field of music cognition, in particular research that focuses on how improvising musicians experience groove (Iyer, 2002; Janata, Tomic & Haberman, 2012). Most relevant to the current discussion is the work of Mark Doffman, whose approach to understanding groove involves the triangulation of qualitative accounts of subjective experience with quantitative analyses of the temporal aspects of musical coordination (Doffman, 2009, 2013). Doffman (2009) claims that in order to understand groove, the concept of musical meaning needs to be shifted away from the formal musical structure and focus on the dynamics of the interactions between players. Groove is the "feeling of shared coherence and rhythmic flow" (Doffman, 2009, p.131). Doffman experimentally investigates groove through the analysis of entrainment between members of a group of performing jazz musicians and the verbal reports of their experiences. He concludes that groove cannot be understood as the sum of deviations from an idealized metronomic beat, but a complex set of interactions that involve negotiations between players that have social and communicative significance.

Doffman's approach to the quantitative assessment of temporality is motivated by entrainment theory, providing a theoretical framework and measures for understanding sensorimotor synchronization between musicians. He investigates this entrainment by using the raw timing data to extract note onsets for each player and calculate relative phase angles. He compares the relative phase angles between the pianist and the drummer, and the drummer and the bassist, and so on. Values of relative phase allow for the identification of what he calls “shared timing points”, where relative phase angles are small, as well as “asynchronies” where the difference in relative phase angles is larger (Doffman, 2013, p. 137). This is then compared to the musicians’ experiences of entrainment, for example how they reported feeling that they were ahead or behind, pushing forward or pulling back, relative to the others in the group (Doffman, 2013).

In order to account for the musician’s affective experiences of groove, Doffman employs a separate theoretical framework called the theory of participatory discrepancies (Keil, 1995). This theory suggests that the feeling of groove depends on the “out-of-timeness” between players, and that these disparities in timing constitute “micro-interactions” that are crucial to what it means to “feel” music (Doffman, 2009, p. 135). He explains that the subtle deviations at these faster time scales have just as much significance as the negotiations that occur between musicians at the larger time scale of musical form. These deviations at fast timescales result in the positive affective experiences of groove that emerge from the “inherent messiness or creative tension at work within the musical fabric”(Doffman, 2009, p. 132). So according to his analysis, the structure of temporal relationships between players contributes not only to the musicians’ affective experiences performing but also has implications with respect to the creativity of the music produced.

Doffman concludes that there are two separate elements of the experience of groove: one that is about the coordination of movement in time between musicians, and one that corresponds to the social and communicative significance that musicians articulate in their post-session interviews. Doffman explains that entrainment theory and the application of its quantitative methods complement the ability of participatory discrepancy theory to account for his qualitative findings. Similar to how sensorimotor empathy *just is* the way that musicians move their bodies in time, we propose that the dynamics of temporal variation when musicians experience groove itself constitute the social and affective meaning musicians articulate. And there are analytic tools available to further understand and investigate the relationship between these dynamics and musicians' experiences.

Relative phase versus long-range correlations

Because these temporal deviations are crucial to the affective experience of groove Doffman (2009) rightly questions how much temporal deviation is needed for musicians to have these experiences, specifically: "what are the boundaries of this variability in groove?" (p. 133). However, the key to capturing both the temporal and social aspects of groove is not asking *how much* variability (magnitudes of relative phase angles) but what is *the structure* of variability (correlations of the variability in relative phase angles across time scales). While phase angles are a relational measure, it necessitates the "pairing off" of musicians in order to look at the behavior of isolated component parts of these temporal relationships. This misses the fact that musicians are not performing as a set of pairs but as one group, and the timing relationships between individual players will be constrained and governed by their perception of the temporal aspects of the music performance as a whole. While there are promising new methods that can evaluate group synchrony by analyzing phase relationships between multiple time series simultaneously (Richardson, Garcia, Frank, Gergor, & Marsh, 2012), it is self-similarity, or long-range correlations in musicians' movements that can reveal the dynamics of groove as well as the social conditions that support the processes of creative musical production.

Detrended fluctuation analysis (DFA) provides an index of the long-range correlations (LRC) in a time series, namely how the variability in the time series is related to the time scale over which it is measured (Riley & Van Orden, 2005). LRC have been demonstrated in high-hat drumming (Räsänen et al., 2015), hand movements while playing piano (Ruiz et al., 2014) and a range of different cognitive and motor tasks (Chen, Ding, & Kelso, 1997; Hausdorff et al., 1995;1997; Repp, 2013; Van Orden, Holden, & Turvey, 2005). Because DFA has been successfully applied to understanding human-tool synergies (Dotov, D. G., Nie, L., & Chemero, 2010), there is reason to believe it can tell us about the human-human synergies of sensorimotor empathy. The application of LRC as an indicator of both the temporal and social dimensions of groove eliminates the problem of discrepancies between relative phase analysis and the musicians' verbal reports, because the feelings of "push and pull" and the "emotional weight" of the connection and responsiveness between co-performers is characterized by the dynamics of the system as a whole. Additionally, experimental manipulations can be used to observe how these dynamics are affected according to how the musical context constrains the interaction between performers.

Long-range correlations in improvised musical movement

In Walton et al. (2016) pairs of pianists improvised music over different backing tracks while their body movements were recorded. One backing track was the chord progression of the jazz standard *There's no greater love,* the second was a drone consisting of the pitches D and A played together for the duration of the performance. Musicians performed eight two-minute improvised sessions with each backing track, half in a no-vision condition where a curtain obstructed their view of their co-performer, and half without a curtain for the vision condition. The first analysis, cross-wavelet spectral analysis, examined the relative phase relationships between the musicians' left arms, right arms, and head movements at the frequency interval corresponding to the pulse of the swing backing track. The second analysis, DFA was used to capture self-similarity or long-range correlations in the musicians' movements, as discussed above.

Cross-wavelet spectral analysis assesses coordination by examining the patterning of relative phase relationships that occurs between two time series across multiple frequencies (see Grinsted et al., 2004; Issartel et al., 2006, for a more detailed introduction). The relative phase angle between two time series can be assessed for shorter, ½ second and second-to-second frequencies, as well as at longer 4, 8, 12 and 16 second frequencies. This analysis was used to capture how bodily movement coordination relates to the faster time scales of the musical context, in particular the frequency that corresponds to one beat of the backing track. The measure used to evaluate coordination was the *inverse of circular variance*, which represents the overall variability of relative phase relationships visited between two time series. More variability in relative phase relationships can be understood as indicating *less,* and *less* variability in relative phase relationships can be understood as corresponding to *more* coordination between time series. An inverse of circular variance of zero means that two time series never visited the same relative phase relationship more than once. Higher values of the inverse of circular variance indicate that two time series visited a smaller set of relative phase relationships; a value of one would mean that the two time series maintained the same relative phase relationship for the entire duration of a trial, see *Figure 1*. This measure is comparable to the analysis of relative phase in Doffman (2009), except it examines the continuous movements of the left arms, right arms, and the musicians' heads instead of note onset intervals.

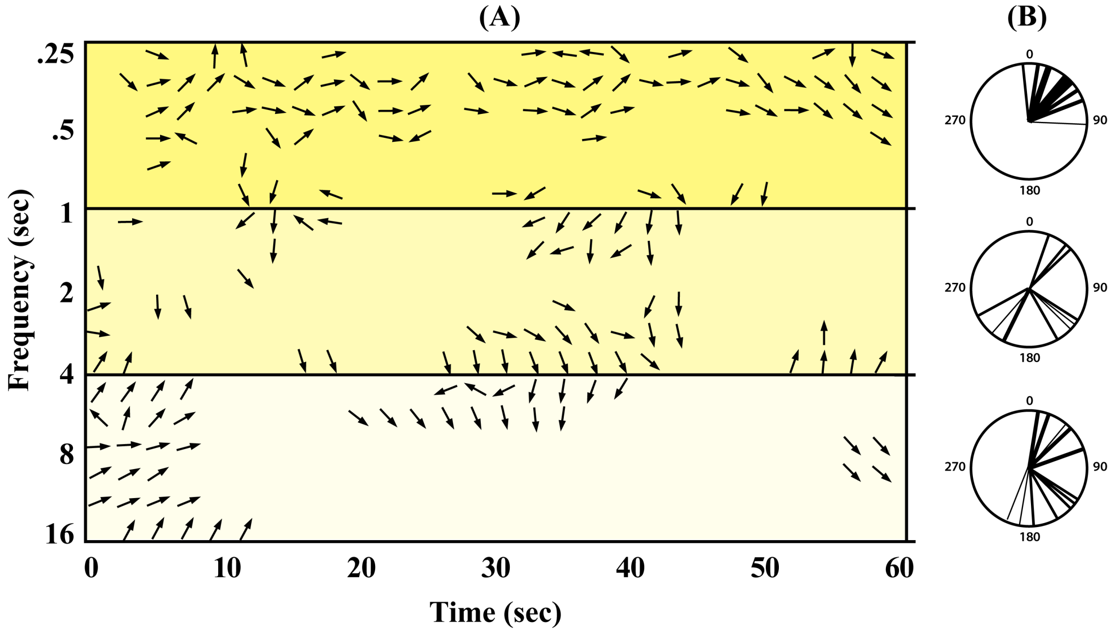

Figure 1. Illustration of how the inverse of circular variance is obtained from a cross wavelet plot. (A) The relative phase relationships are calculated between the movement time series of two musician's heads, and plotted across time, for different frequencies. A right-facing arrow indicated an in phase relationship, a left-facing arrow an anti-phase relationship. The cross wavelet plot allows for the observation of how the relative phase relationships change throughout the performance, as well as how they coordination at different frequencies. (B) The phase relationships for different frequency bands can be calculated separately (indicated by different shades of yellow). In this illustration, there was less variability, or more coordination in the relative phase relationships for the faster time scale (.25 – 1 seconds).

DFA measures the LRC in a time series by providing a scaling exponent (alpha) that relates the measure of variability to the time scale over which it is measured. A time series with an alpha value that is approximately .5 is considered uncorrelated (no LRC), and an alpha value between .60 and 1.10 indicates LRC, or fractal *self-similarity* (Peng et al., 1995). In the latter case the log-log plot of temporal changes and increasing window size (time scale) demonstrates power-law scaling behavior, thus the variability is correlated across time scales (i.e. long range correlations). Alpha was calculated for the side-to-side, up-and-down, and forward-back dimensions of each musician's head, left arm, and right arm movements for each backing track in the current study.

The results of the cross-wavelet analysis on the musicians' head movements for the frequency band corresponding to the beat of the swing backing track, as well as the DFA results are displayed in *Figure 2* (for full results see Walton, 2016). For the cross wavelet analysis, coordination in the musicians' head movements was significantly greater when they improvised with the swing backing track compared to the drone backing track, $F(1,11) = 8.73$, $p = .013$, $\eta_p^2 = .422$. For the DFA, the alpha values for the musicians' head movements were significantly higher, indicated higher levels of LRC, when improvising with the drone backing track as compared to the swing track $F(1,5) = 55.21$, $p = .001$, $\eta_p^2 = .917$. There were no significant effects of condition (vision/no-vision) for the head, left arm, or right arm movements for the cross wavelet or DFA analysis.

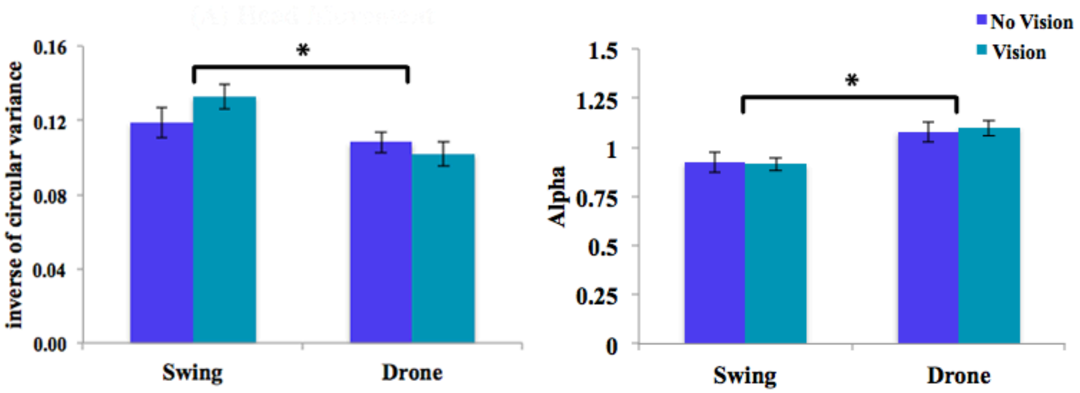

Figure 2. Comparision of the results of cross wavelet spectral analysis (left) and DFA (right) on the head movements of improvising muscians. For the swing back there was less variability in relative phase relationships, indicated by higher values of the inverse of circular variance. Conversely, the alpha value indicated higher levels of LRC in the head movements of the musicians when they were performing with the drone backing track. Importantly, the musicians experienced more freedom in the performance for the drone track as well.

To summarize, cross-wavelet analysis evaluating the movement coordination between two improvising musicians demonstrated a decrease in the variability of relative phase at the frequency of the beat of the backing track for the head movements when performing with a swing (rhythmic structure) backing track as compared to a drone (no rhythmic structure) backing track. DFA of the same head movement, however, revealed higher levels of LRC when playing with the drone backing track, compared to the swing backing track. If the structure of the backing tracks is understood to contain different levels of constraint on the dynamics of the system, an analysis focused on the *amount of variability* in movement coordination (cross-wavelet analysis) when compared to the *structure of variability* (DFA) resulted in opposite effects. More variability, or higher asynchrony in relative phase relationships, does not necessarily mean that these behavioral fluctuations are the result of random noise or error. Variability can possess both random noise as well as deterministic structure (Riley & Turvey, 2002). LRC demonstrates this deterministic structure in a system's variability, where the future states and prior states of a system are not independent of one another. The importance of LRC in combination with random variability in music performance, is related to how this variability makes functional contribution to the dynamics of a system. The influence of both random and deterministic processes can create a state of adaptive flexibility, where a system is both able to adjust to changes and in the musical context but lacks rigidity such that it can be pushed into new stable patterns of musical coordination. In considering flexibility in musical movement and expression, it's important to understand how these patterns of LRC related the musicians' performance experiences.

Freedom in groove

In post-session interviews musicians described having more “freedom” when performing with the drone as compared to the swing, the trials for which there were higher levels of LRC in their movements. They claimed they could to work together to “create time” and felt the opportunity to truly interact with one another (Walton, 2016). This is echoed in Doffman’s (2009) findings where intimacy and the sense of participation was enhanced not by higher levels of synchronization, but by the ability to actively distort the musical structure (Doffman 2009, p.144). Thus the LRC demonstrated in the musician’s behavior when performing with the drone back tracking, and the way the musicians experienced more creative freedom, provide an example of how constraints on the system allow for dynamics that provide the right kind tension, the right kind of and the pushes and pulls between components. In a description of participatory discrepancies, Doffman explains:

> *“The tension, in our social communications, between self and other, between seeking closeness and maintaining distance, between group and individual, all seems to be captured within an idea that stems from the study of musical sounds and their inherently organized chaos.”* (Doffman, 2009, p.146)

Thus the interpersonal synergies of sensorimotor empathy are themselves the experience of groove, and provide an understanding of its temporal and social dimension. The freedom musicians experienced when they were able to “create time” together demonstrates how the constraints on the temporal dimensions of musical interaction are also constraints on the social dimensions of interaction. Performance contexts that allow musicians to mutually constrain each other’s musical production in ways that create a balance between individual expression and group cohesion, open up new communicative possibilities and the realization of new musical states (Walton, Richardson & Chemero, 2014). LRC in musical movements indicates the engagement of sensorimotor empathy, as well as reflects a system that is organized in a manner that is adaptive and flexible, where fluctuations can be capitalized on in order to discover new creative musical states. The creative freedom in groove is not only perceptible by musicians; listeners have been found to prefer musical beats whose temporal fluctuations demonstrate LRC (Hennig, Fleischmann & Geisel, 2012). Thus the structure of variability in the dynamics of human systems can help us understand the ways that sensorimotor engagement couples and constrains us together– and how can we organize ourselves, how we can organize our bodies, to communicate and generate new meaning (Walton, Richardson & Chemero, 2014).

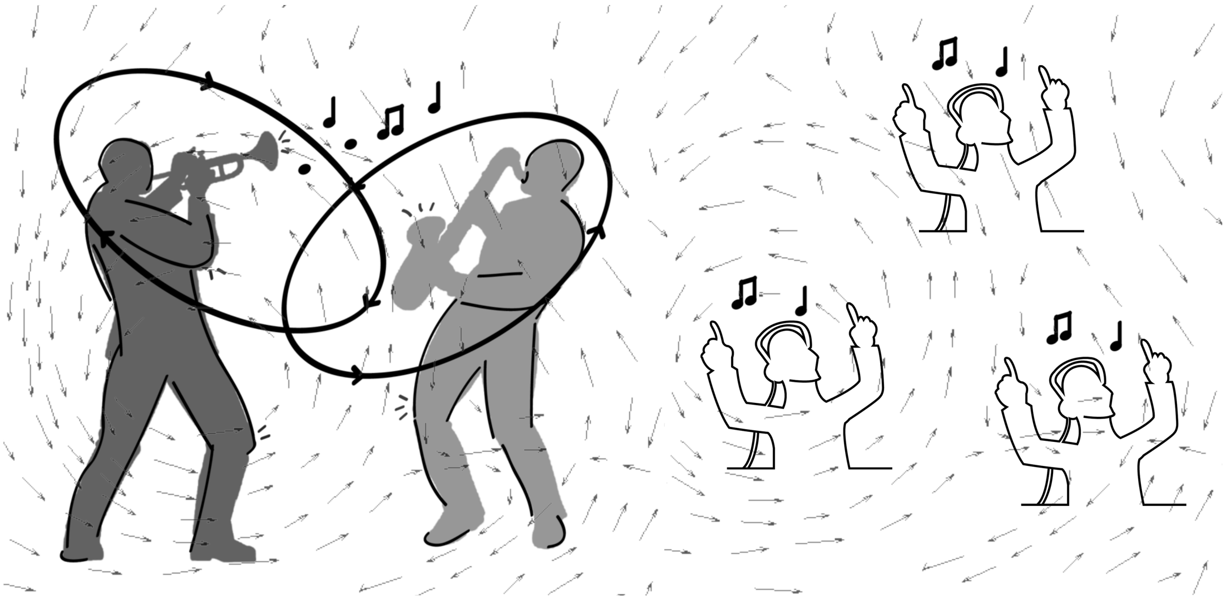

Figure 3. Long-range correlations in musical movements capture the effects of constraints on performance, and the experience of constraints on social interaction between performers and their ability to create together, as well as constrain the experience of listeners (adapted from Walton et al., 2014).

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