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MINDS, MUSIC, AND MOTION: ECOLOGIES OF ENSEMBLE PERFORMANCE

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Abstract: Minds, music, and motion: ecologies of ensemble performance

According to recent neuroscientific literature, expert musical performance is one of the most complex and challenging tasks humans undertake and constitutes an important potential area of inquiry into neurocognitive aspects of motor knowledge and brain plasticity, among other concerns (Schlaug 2015; Brown, Zatorre, and Penhune 2015). While there exist a large number of research projects focussing on individual performance, ensemble performance has not altogether garnered the same degree of attention, notwithstanding significant contributions from perspectives such as ecological psychology, incorporating notions of affordances under

the aegis of what has become loosely known as 4E cognition (Clarke 2005; Windsor 2011; Windsor and de Bezenac 2012; Walton et al. 2015).

This article explores some opportunities and challenges that arise from a broadly ecological perspective as applied to ensemble performance, arguing that there is a fundamental difference between individuals as soloists and individuals as part of performing ensembles: in short, that the ensuing dynamics within performing groups cannot be straightforwardly understood as additive processes (in which individual contributions result in a group outcome in linear fashion). An additive approach, it is argued, cannot do justice to the emergent character of music in performance, when considered as an activity (Small 1998) rather than an object of analysis.

Studies of emergent relationships within ensemble performance (Borgo 2005; Sawyer 2006; Sawyer and DeZutter 2009; Barrett 2014) seem to exhibit a natural kinship with improvisation, whether in theatre or music. However, the question remains as to the applicability of these various approaches—which incorporate concepts from systems theory as models to account for unpredictable dynamic outcomes of group processes—to performances where the outcomes are pre-constrained by the composer's authoritative directions. The article aims to offer a snapshot of current research in this emerging field of analysis in discussing the opportunities and challenges at play when aspects of ecological psychology and systems theory are applied to ensemble performance.

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Minds, music, and motion: ecologies of ensemble performance

‘Movement is our mother tongue.’[1]

According to the neuroscientific literature, group musical performance is one of the most complex and challenging tasks humans undertake[2] and constitutes a promising area of inquiry into neurocognitive aspects of motor knowledge and brain plasticity, among other concerns.[3] While there exists a relatively large number of research projects focussing on individual performance in controlled settings, live ensemble performance has apparently not garnered the same degree of attention with respect to its cognitive and developmental aspects. This article aims to explore some opportunities and challenges that arise from applying a systems perspective to performing ensembles, considered as a special case of groups.[4]

From systems theory, the argument emerges that the dynamics which function within performing groups cannot be straightforwardly understood as arising from additive processes, in which individual contributions result in a group outcome in a linear fashion. This concept depends on the notion of emergence, insofar as the totality of the ensemble members’ combined contributions is held to be greater than, or at least different from, their individual contributions. As Margaret Barrett puts it:

> This suggests that models of creativity that characterize the creative process as individual problem-solving activity ignore the social dimension of all activity, unless that problem solving [sic] is seen to occur in a community of practice and interaction.[5]

A systems-theoretical approach, it is suggested by advocates such as Barrett, does greater justice to the emergent character of music in performance, when considered as an activity rather than an object of analysis.[6] Using it, the emphasis moves from the aesthetic aspects of musical performance (the purported value or significance of the music) to music as it is executed in real time. The dynamic aspect of music as it moves and unfolds over time (as process, *tout court*) then becomes the focus of research as opposed to aesthetic considerations regarding a given musical outcome.

Systems-theoretical approaches, as applied to musical performance, are further informed by the fundamental difference between the roles and actions of individuals as soloists and individuals as members of ensembles. While it remains clear that a soloist interacts with an audience, there is no such thing as a team with one member (this is not to ignore the hidden network of agents, promoters, and technical staff whose collective efforts enable such solo performances).

Notions of *collective* interactivity (and associated ideas regarding creativity, intelligence and knowledge within groups) animate the heart of this line of argument regarding ensembles. Studies of emergent relationships within predetermined ensemble performance seem to exhibit a natural kinship with those which explore improvisation, whether in theatre, dance, or music.[7] The question remains as to the applicability of these various approaches, which incorporate concepts from systems theory as models to account for the dynamic outcomes of group processes, to performances where the outcomes are constrained. Such constraints may take on many forms - from the composer’s authoritative directions (as in the score of a Beethoven symphony, for argument’s sake) to less specific cultural concerns as to performance etiquette (as in ‘traditional’ jazz improvisation, drawing from the canon of the Great American Songbook). While systems theory brings the undoubted advantages of taking into account music’s mutable nature and sometimes unpredictable outcomes, it is less certain to what extent its tenets of non-linearity, emergence, and changeability are applicable beyond the field of free improvisation. This article will examine aspects of this emerging field of analysis through a discussion of the opportunities and challenges at play when aspects of ecological psychology and systems theory are applied to ensemble performance.

The leafcutter's world: a thought experiment

> The doctrine that I am maintaining is that neither physical nature nor life can be understood unless we fuse them together as essential factors in the composition of "really real" things whose interconnections and individual characters constitute the universe.[8]

To begin, a thought experiment. You awake one morning mysteriously transformed into a leafcutter ant. Let us assume for argument's sake that this transformation is entire, unlike Gregor Samsa in Kafka's *The Metamorphosis* (1915) who wakes up as 'a monstrous verminous bug' while retaining full human consciousness.[9] A consequence of your complete transformation is that you possess a leafcutter's consciousness, in short, that you are a minute but purposeful member of an ant colony. Three immediate speculative questions spring from this experiment: What would your leafcutter ant's world consist of? How might it look and sound? How would you occupy yourself on a given leafcutter day?

A tentative response to the first question is simply that your world might be a somewhat limited one: limited not in the conventional sense that the leafcutter's brain is less sophisticated than those of humans, but rather in its bandwidth - the window of signals to which it can tune, if you will – in order to extract the most useful information from its immediate environment, its *Umwelt*.[10] Eagleman points out that the idea of limited bandwidth applies equally to human consciousness, insofar as there exists information unavailable to humankind because of the limitations of the human sensorium as well as the fact that much human experience operates unbeknownst to ourselves (for instance, the functioning of the autonomic nervous system).[11] Humankind possesses no bodily armour and has a rudimentary sense of smell as compared to other mammals, for whom evolution has honed this sense to a far more refined degree. Other creatures such as bats and orcas employ echolocation to navigate their particular *Umwelten* during their expeditions.[12] Humans need to resort to radar and other extrinsic technologies to achieve similar purposes.

Again, the second question posed above suggests that this might be a world of similar limits, but one abounding with signals which you, as a leafcutter, can receive and respond to. One assumes that, similarly to humankind, leafcutters might experience such signals selectively, only receiving and responding to those appropriate for their daily tasks.

Finally, in response to the third question, it is noteworthy that even a creature as apparently unsophisticated as the leafcutter demonstrates clearly defined occupational roles within the colony. Leafcutters' tasks variously consist of foraging, defence, harvesting fungi, and reproduction, according to their caste and physical attributes. On the basis of these clearly defined roles, Eagleman characterises the leafcutter colony as an emergent superorganism.[13]

In some musical ensembles, musicians' roles tend to be based on the hidden assumptions and demands of the genre and may be defined as such. In a typical jazz quintet (Miles Davis' classic 1960s groups, for argument's sake), the rhythm section of drums and bass provide rhythmic and harmonic impetus (with bass providing the roots of harmonic progressions) and tend to solo less frequently than the frontline (melodic instruments such as trumpets and saxophones). The piano outlines both chords and melody and may solo more frequently than bass or drums. Taking these conventional roles into account, and recognising that musical and gestural signals also abound within specific musical environments, might it then be useful to consider an ensemble similarly as a superorganism?

In music, ensembles often have identities which overshadow those of their constituent members and the most famous of such groups become canonised as 'classic' or 'supergroups,' a popular term in 1970s pop and rock discourse. To develop the superorganism metaphor, one needs to consider which aspects of systems theory can fruitfully apply to ensemble situations, with a view to understanding 'how individuals and social groups bring forth worlds of meaning through shared and embodied processes of dynamic interactivity'.[14]

Theoretical underpinnings

This article draws from aspects of ecological psychology,[15] bio-musicology,[16] systems theory,[17] and postphenomenology.[18] Fundamental to ecological psychology is the idea that every animate creature inhabits a specific *Umwelt* or ecological niche with a specific information bandwidth. Such creatures acquire and respond to information (in short, learn) through their embodied and goal-directed action-in-the-world. Obviously, understanding cognition as taking place within isolated brains, as a set of largely computational (or representational) processes, misses this point.[19]

The learning processes ensuing from such embodied and goal-directed interactions are grounded in what Fuster has referred to as action-perception cycles.[20] Since these cycles form the basis of learning and development for all living organisms, we might assume that the leafcutter's world differs from that of humans in degree rather than in kind. On this view, cognition and learning are understood as dynamic processes, which depend on a given creature's taking up relevant signals within a dynamic and changing environment and acting thereon.

Turning to bio-musicology, Fitch writes:

> A core tenet of bio-musicology is that musicality is deeply rooted in human biology, in a form that is typical of our species and broadly shared by members of all human cultures. While music, the product of human musicality, is extremely diverse, musicality itself is a stable aspect of our biology and thus can be productively studied from comparative, neural, developmental and cognitive perspectives.[21]

If musicality is grounded in human biology, as Fitch asserts, so equally is the very nature of perception for ecological psychologists such as Gibson. There exists something reassuringly pragmatic about Gibson's conception of the world as perceived:

> The world we perceive, according to Gibson, is a connected, public world that we share. It is, again, *the* world, the logical individual world and not an abstraction. This is not an account of the experience of abstract shapes, distances, and motions. It is a system in which travelers can visit *the* pyramids and in which I can trip over your garbage.[22]

At the heart of Gibson's eco-psychological insights lies the notion of affordances as 'action-possibilities'.[23] For Heft, affordances are:

> […] the essential stuff of experience of the world; they are "*what* is there" most immediately, and it is with affordances that an ecological analysis of perception must begin, because most fundamentally an ecological analysis is an account of perceiving the world.[24]

For musicians, instruments and voices play the role of '"*what* is there" most immediately,' so that musical affordances are located at hand, under the fingers as it were, brought into being through the actions of singing and playing within a dynamic and emergent environment, be it a jazz club, a concert hall or a group informally musicking around a campfire.[25] These different locales suggest, following Fitch, that humans share the universal characteristic of musicality while its particular instantiations may differ widely in purpose, intention, and social context. That said, acts of musicking originate from concerted goal-directed movements by individuals which, for Small, depend on the establishment of musical and social relationships.[26]

At expert level, the cognitive requirements of musicking are very demanding, entailing not only the coordination of fine motor responses and a high degree of responsiveness to environmental signals, but also resilience and adaptability.[27] Obviously, such motor responses are not deployed anew on each occasion but draw from a storehouse of memory acquired over time through practice, such that the execution of musical tasks becomes 'second nature.' Musicians develop executant skills over long periods of seclusion with, and immersion in, the idiosyncrasies of their chosen instrument, to whose nuances responsive individuals become attuned over time. Musicking with conspecifics requires integrating individual skills with those of others and interpreting responsively a wealth of musical and extra-musical cues, such as gestures ('Continue in the same vein,' 'Fade out,' 'Next soloist,' and so on).

The understanding that musical processes emerge and transform over time (in short, that these are *dynamic* processes) so as to arrive at a particular outcome in the form of a performance, a recording, or a rendition of a specific set of instructions ('a score') opens the way to applying aspects of systems theory to such processes. Granted that systems are abstractions, thinking in these terms places the emphasis on interactions and interrelationships that emerge in and through time.

An arbitrary heap of stones by the roadside cannot by definition constitute a system; rather its lack of connections defines it as a 'nonsystem'. As Turvey defines it, 'Certainly lacking in the image of a nonsystem is the sense of shared influences or mutual dependencies; intuitively, a nonsystem exhibits no coherence or functional unity.'[28] Perhaps the prime example of a system (at least, for purposes of this argument) is an animate creature. What makes life possible for any creature is the vastly complex network of interlocking systems that maintain its equilibrium, regulate its metabolism and allow for the intake and excretion of nutrition and waste products, in short, those systems that make life possible. For Skyttner, 'Systems are wholes which cannot be understood through analysis inasmuch as their primary properties derive from the interactions of their parts'.[29]

The human body understood systemically, then, consists of a highly complex set of interrelated 'modules' (the brain, the nervous system, the senses, hands and feet, for instance) which operate in concert to allow for embodied cognition to unfold in and over time. In the case of a performing ensemble, the actions of embodied agents can be understood in similar fashion, with individual perceptual systems working in concert to enable collective musicking.[30] Musicians draw from these perceptual systems (in this case, mainly those of hearing, sight, and touch) both to bring individual musicality into being (the soloist's province) and to navigate the cognitive demands of such coordinated actions. In an ensemble setting, the same perceptual systems drive the ways in which individuals interact within, and as, groups. The crucial argument from systems theory maintains that these are different facets of a systemic perspective and that an ensemble represents a different phenomenon from a collection of individuals. How so? This line of argument does not make its appeal to some transcendental notion of a group mind but draws from the following definition of a complex system:

> A complex system is defined as any system comprising a large number of interacting components (agents, processes, etc.), whose aggregate activity is nonlinear (not derivable from the summations of the activity of individual components) and which is characterised by self-organisation.[31]

This aspect of self-organisation is most obviously reflected in musical ensembles that operate without a *de facto* leader, who does not herself perform (such as a conductor).[32] Large-scale jazz settings (most notably, big bands and groups that integrate orchestral and jazz musicians) often do require a conductor to coordinate proceedings. The focus of this article, however, is placed squarely on ensembles as complex, self-organising groups, in which every participant is a player of equal standing without an external governor. Hutchins' classic study of shipboard navigation, in which many of the participants in this complex cooperative task are separated by distance— the commander on the bridge who needs to communicate with crew in the engine room, for example—argues that accomplishing such a task depends on what he describes as distributed cognition.[33]

While placing the emphasis on synchronised perceptual systems within and across individuals as points of origin for the embodied collective actions which constitute a given performance, present-day communication networks allow for virtually instantaneous real-time performances to take place in cyberspace. Although the origins of such performances still lie in embodied individual knowledge, the nature of such cognitive processes as are brought to bear suggests that networked performances might be candidates for distributed cognition. In venues where the performers are within touching distance of one another, Hutchins' notion also holds true but is enriched by a wide range of infra-ensemble gestures and facial expressions that ease the negotiation of the musical terrain and allow for distributed creativity to emerge.[34]

Moving and touching: worlds in (and of) motion

Crucial to the application of Gibsonian eco-psychological thinking to ensemble performance is the notion of movement. Through questing movements, the creatures inhabiting specific ecological niches learn their properties, their size and shape, if you will. Exploration is key. Consider the repetitive actions of a toddler learning to walk, which have to be learned over time and acquired through trial and error. Even with the support of adult caregivers, she will fall more than once in the process of mastering the coordination dynamics of walking, of learning how to deploy and coordinate different muscle groups to balance her own upright body, so as to account for the challenges of different terrains.[35]

Over time, the coordination of such actions becomes an unconscious process below the radar (as it were) of conscious deliberate cognition. Thelen provides an apt definition of embodied cognition that can be extended to all animate creatures and which does not attribute a misplaced privilege to human experience as the presumed summit of all experience:

> To say that cognition is embodied means that it arises from bodily interactions with the world and is continually meshed with them. From this point of view, therefore, cognition depends on the kinds of experiences that come from having a body with particular perceptual and motor capabilities that are inseparably linked and that together form the matrix within which reasoning, memory, emotion, language, and all other aspects of mental life are embedded.[36]

This passage perhaps represents the moral of the story with regard to the leafcutter thought experiment. As simple as such creatures may well be, the crux of their learning depends on their bodily makeup, which, in turn, determines the characteristic bandwidth of possible leafcutter experience. Their capabilities to perceive and move are far more restricted than those of the great apes or humankind, for instance, and one can only speculate (following Nagel) as to the kind and content of mental experiences they possess. Nonetheless, they share with all creatures the abilities to perceive, move, and respond to environmental cues *en masse*.

Such environmental cues are dynamic in two senses: first, they depend on the movement of molecules (changing patterns of air circulation which constitute sound and other percepts) and second, they exist in a state of flux, since they depend on changes in the broader ecological niche such as temperature variations brought about by the weather.

Where humankind might seem to have the environmental advantage, again not simply in terms of relatively greater cognitive sophistication, lies in our prehensile capabilities.[37] McGinn characterises humans as 'a species of talking toolmakers' who use cutlery to eat, cars to move, and musical instruments and singing voices to communicate.[38] Amplifying the distinction between this line of thought and the earlier computational model, Gallagher draws upon notions of enactive cognition to argue that:

> [T]he brain is not composed of computational machinery locked away inside the head, representing the external world to provide knowledge upon which we can act. Rather, in action—whether reaching and grasping, pointing, or gesturing—the brain partners with a hand and forms a functional unit that properly engages with the agent's environment.[39]

For both these writers, the hand-brain partnership, together with its enabling conditions (the specific anatomy of the human hand involving opposable thumbs, more sophisticated muscular development that makes fine-grained repetitive actions feasible, and so on) constitutes a cognitive system in itself. In a less well-known article than his later works on visual perception and affordances, Gibson maintains that 'the solid geometry of things is best got by feeling them'.[40]

So, too, with musicians. The inertia of strings, membranes, and static air columns resists the player's initial attempts to control them. This relationship, through which the player gradually negotiates and learns to manage her instrument's inherent resistance, requires time. As a result, even the most virtuosic musician must begin at the beginning, acquiring notions of heft, inertia, weight and other physical qualities (in short, instrumental affordances) through active touch, learned and mastered through action-perception cycles that encompass both feedback and feedforward networks.

'At the edge of chaos': free improvisation, the tradition, and the study of groups

> Put another way, transferring the properties of complex systems to living music agents allows us to think of them as being able to function at the edge of chaos—a term that refers to their ability to initiate episodes of entropy and to self-organize new relationships through adaptive goal-directed activity, resulting in coherent "outcomes" that are not completely predictable.[41]

We have seen that a theory of complex systems allows for the deployment of concepts of non-linearity, self-organisation, and emergence within the context of a musical ensemble. A further important idea within the field of systems theory is that of bifurcation ('sudden transitions between configurations of equilibrium states'), in which the system's operations take an unpredictable turn.[42]

Free improvisation, in which interactions between participants are generally not scripted in advance, tends to operate in a state that is far from equilibrium, allowing, almost by definition, for successive bifurcations, creating sudden and unexpected changes in the musical texture and direction. These bifurcations involve decisions at individual and collective levels by the protagonists, which may or may not be associated with divergent thinking, defined by Guilford as 'the ability to generate multiple alternative problem solutions',[43] and as 'a key capacity underlying creative thought'.[44] The problem, in this case, may simply be what to do next - how and whether to respond to an apparent cue from a conspecific, whether to imitate the contours of a phrase (almost a 'conversational' response) or simply to ignore this cue and carry on with one's own line of invention; in short, how to interact in a given situation.

Within the field of free improvisation, the outcome tends to be unpredictable because of the wide range of possibilities at hand. Within notated music, what to do next is largely a function of the score, by means of which the composer has already and purposefully mapped out in advance the performers' collective journey, and is therefore more circumscribed. What these different voyages of discovery share, though, is that, whether free or substantially preordained, they are constituted by the individual actions of performers. At first, the drivers for these actions are 'merely musical' ones, such as sounding their chosen instrument (changing the nature of the audible waves which move the air) by way of the dynamic affordances offered by the instrument-performer relationship (feedback, and so on). Immediately, however, these individual actions become interactive, as each performer's actions prompts responses from her co-performers, setting in train a cascade of further affordances.

For the purposes of this argument, the notion of affordances is here understood in a fairly restricted way: its focus is at their point of origin and, by analogy, is dependent upon what a particular environment offers to a particular agent (the 'climbability' of a staircase, while an invariant property according to Gibson, varies according to stature and age). It seems plausible to argue that free improvisation offers the most fruitful context for the application of systems theory, precisely because of its conditions of operation, which, as already indicated, are far from a state of equilibrium.

However, such a characterisation needs careful thought to head off a potentially damaging objection. For systems theory to be applicable to all types and contexts of collective musicking, cases of more traditional approaches must also be considered. Here, I have in mind the same range of possibilities as those cited above, from a Beethoven symphony to cases of 'mainstream' jazz improvisation that draw from the canon of the Great American Songbook. These cases cannot be understood as operating in far-from-equilibrium conditions, since a Beethoven symphony tends to be identifiable as such, regardless of variations in tempo and dynamics between performances of it (which are matters of interpretation on the conductor's part). The same is true of a mainstream jazz standard, even where there is a greater latitude as to interpretation of the received melody.

Degrees of stability or otherwise provide the solution to this particular problem. Large points out how '*Stability* is a fundamental property of a dynamical system, which means that the qualitative behavior of its time evolution is not affected by small perturbations of the trajectory'.[45] This stability factor allows the performer a degree of latitude (freedom of movement) within the constraints of a particular piece, while maintaining the piece's integrity as part of the established repertoire and its recognisability as such. This process is also reflected in the identity of particular ensembles whose membership changes over time, such as the very long-lived ensembles led by Duke Ellington. While participants came and went, Ellington's sound remained recognisably 'Ellingtonian', so contributing to the group's success and longevity regardless of personnel changes.

I conclude this section with a short meditation on the nature of groups, beginning with a quotation from Arrow and colleagues:

> We treat groups as adaptive, dynamic systems that are driven by interactions both among group members and between the group and its embedding contexts. We do not believe that groups can be adequately understood as collections of independently acting individuals. Instead, we focus our attention on relationships among people, tools, and

> tasks, activated by a combination of individual and collective purposes and goals that change and evolve as the group interacts over time.[46]

Applied to a musical context, the emphasis is placed on the nested relationships between participants ('people'), musical instruments ('tools'), and the 'task' at hand (the realisation of a given musical performance). So far, so good, you might say. Unless wilful sabotage plays a part, under normal circumstances, the ensemble's task might be construed as the realisation of a successful musical outcome. This musical realisation surely necessitates collective co-operation, but this is not always as straightforward as it may appear. The supergroup phenomenon of the late 1960s and early 1970s has a bearing in this regard, and to conclude I examine the case of Blind Faith, a British supergroup which promised much but, in the final analysis, delivered less than expected.

Fifty years or so ago, men walked on the moon, and the so-called supergroup Blind Faith was formed out of three successful rock groups of the time: two parts Cream (Eric Clapton and Ginger Baker on guitar and drums respectively), one part Traffic (Steve Winwood: keyboards, guitar, and lead vocals), and one part Family (Ric Grech, bass). In an era when hype tended to dominate the market, Blind Faith had to live up to impossibly high expectations from critics and the public alike. Predictably perhaps, they failed and released only one album before breaking up.[47] The breakup was ascribed to personality differences and disagreements about musical direction.

The lesson of Blind Faith's 'crash and burn' is that musical ensembles tend to survive *in spite of* musical and personal disagreements, until such conflicts overwhelm their collective identity. This case exemplifies how conflict may trump the co-operative impulse, perhaps a warning not to ignore the tensions that may destroy hitherto functional relationships. In the light of what Arrow and colleagues have stated above, the group's breakup may be seen as a natural evolution toward entropy or simply as a case of unrealistic expectations on the part of the band, critics, and the public alike. As Forsyth notes, 'A group, in a very real sense, is alive. It acquires energy and resources from its environment, maintains its structure, and grows over time.'[48]

Conclusion: Ensembles as living systems

> Professional jazz musicians who are used to performing together in public clearly share a great deal of common ground, derived both from knowledge of the history of the jazz traditions they identify with and around which they have built their musical relationship and from knowledge derived from their own history of playing together in a culturally, socially and historically situated context.[49]

For systems theory to apply to all forms of musicking, its fieldwork must surely begin by examining a wide range of actual musical performances *in situ*. In other words, it must take account of cases where the interaction parameters are relatively fixed (by convention or on the basis of a variety of the 'common ground' of which Gratier speaks above). Conventions of notation, which fix the composer's instructions, leave the performers and conductor (in the case of large-scale orchestral works) with fewer options for 'improvising' apart from basic concepts such as tempo and relative volume within the ensemble (notions of balance and form). These cases might be regarded as tending to operate within relatively stable-state spaces in contrast to examples of free improvisation, where performers are free(r) to choose how to respond to the demands of a particular situation.

The application of this article's theoretical framework to ensemble performance may provide alternatives to an outcomes-oriented perspective. What is of interest here may be summarised as a focus less on aesthetics and more on the individual and collective actions at the heart of a musical performance. That such actions may be theorised according to principles of systems theory (such as emergence, bifurcation, self-organisation, among others) may be useful in placing the emphasis on the underlying cognitive processes that facilitate musical performance. I recall attending a performance by George Lewis where he used a computer-generated pianist to respond to his trombone gestures. Such interactions remind us that our co-musicians may be silicon-based organisms, such as computers and modular synthesisers, as well as flesh-and-blood collaborators.

There is a growing body of literature that considers in some detail the micro-interactions between performers,[50] and mechanisms now exist for capturing the underlying motoric-gestural components of musical interactions for further research. The advantage of a systems approach is that it regards such individual contributions as related to a broader system of organisation. This opens the way for amassing information on the behaviour of groups, which systems theory regards as qualitatively different from that of the individuals who constitute them.

Adopting a systems-theoretical approach may satisfy demands for ecological validity, insofar as ensemble interactions are examined in real-time and in place. Further to this point, such a framework makes it possible to address the cognitive complexities of expert performance without placing undue emphasis on the individual's contributions or disregarding the learning processes of so-called amateur musicians. The major challenge is collecting data 'from the outside in.' While there exist mechanisms for carrying out such investigations, data gathered by these means need to be balanced with individual narratives of learning and development. These individual perspectives may be only partial and subjective, but they are an important complement to the insights gained by observing the operations of the group as a real-time interactive system.

Gratier's comments at the head of this section raise pertinent questions as to the nature of the common ground of which she speaks. For Loaiza:

> [W]hat most new-ethno-socio-musicologists emphasise, in one way or another, are the complex ways in which heterogeneous parts (persons, technologies, institutions, etc.) co-determine one another and form larger networks that may exhibit tendencies and global behaviours of their own.[51]

Professional groups who get to know each other's musical personalities over time may represent a paradigm case of such complexities, but this approach also needs to take account of zero-history groups whose success depends on predictive assumptions as to how their colleagues will respond in the heat of the moment.[52]

While it is tempting to conclude that musical ensembles constitute superorganisms, some reservations are in order. Performances need to be considered on a case-by-case basis, on the understanding that successive performances contribute to a particular group's history and development over time. Such a two-tiered approach remains anchored in the moment of collective musicking. The key ideas of systems theory suggest that the efficacy of groups may not necessarily develop (or improve) over time in straightforwardly linear fashion. They are subject to the same false starts, happy accidents, and unexpected vistas that tend to characterise all voyages of discovery.

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[12] ‘... bat sonar, though clearly a form of perception, is not similar in its operation to any sense that we possess, and there is no reason to suppose that it is subjectively like anything we can experience or imagine.’ Thomas Nagel, ‘WHAT IS IT LIKE TO BE A BAT ?’, *The Philosophical Review,* 83.4 (1974), 435–50 (p. 438).

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[14] Dylan Van der Schyff and others, ‘Musical Creativity and the Embodied Mind’, *Music & Science*, 1 (2018), 205920431879231 (p. 2) <https://doi.org/10.1177/2059204318792319>.

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[20] ‘A flow of environmental signals gathered by sensory systems shapes the actions of the organism upon the environment; these actions produce environmental changes, which in turn generate new sensory input, which informs new action, and so on. This circular flow of information operates in the interactions of all animal organisms with their environment.’ Fuster, *The Neuroscience of Freedom and Creativity: Our Predictive Brain* (Cambridge: Cambridge University Press, 2013). p. 90.

[21] W. Tecumseh Fitch, ‘Four Principles of Bio-Musicology’, *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences*, 10 (2015), 197–202, p. 1.

[22] William M. Mace, ‘James J. Gibson’s Ecological Approach: Perceiving What Exists’, *Ethics and the Environment*, 10.2 (2005), 195–216 (p. 196), original emphases.

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24 Heft, p. 156, original emphasis.

25 Alfred Schutz, 'Making Music Together: A Study in Social Relationship', in *Collected Papers II: Studies in Social Theory*, ed. by Arvid Brodersen (The Hague, Netherlands: Martinus Nijhoff, 1964), MCMLXXVI, 159–78 (p. 177).

26 Small, *Musicking: The Meanings of Performing and Listening*, pp. 12-30.

27 'Performing music requires experts to retrieve musical information from long-term memory and continuously plan their ongoing performance in their working memory system. Performing music also requires experts to initiate and control complex movements and to monitor outcomes or feedback from those movements to make adjustments if needed.' Brown, Zatorre, and Penhune, CCXVII, p. 59.

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32 ''Self-organisation' is used to refer to behavioural patterns that emerge from the interactions that bind the components of the system into a collective system, without a centralised controller.' Michael J. Richardson and Anthony Chemero, 'Complex Dynamical Systems and Embodiment', in *The Routledge Handbook of Embodied Cognition*, ed. by Lawrence A Shapiro (London; New York: Routledge, 2014), pp. 39–50 (p. 40).

33 Edwin Hutchins, *Cognition in the Wild* (Cambridge, MA: The MIT Press, 1995), pp. 1-381.

34 R Keith Sawyer, *Group Creativity: Music, Theater, Collaboration* (Mahwah, NJ: Lawrence Erlbaum Associates Inc, 2003); Sawyer and DeZutter; Walton and others; Van der Schyff and others.

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38 Colin McGinn, *Prehension: The Hand and the Emergence of Humanity* (Cambridge, MA: MIT Press, 2015), pp. 65–66.

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40 James J. Gibson, 'Observations on Active Touch', p. 484.

[41] Van der Schyff and others, p. 12.

[42] P. J. Beek, B. Hopkins, and P. C. M. Molenaar, 'COMPLEX SYSTEMS APPROACHES TO THE DEVELOPMENT OF ACTION', in *The Development of Coordination in Infancy* (Elsevier Science Publishers B.V., 1993), pp. 497–515 (p. 502).

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[46] Arrow, McGrath, and Berdahl, p. 34.

[47] Curiously enough, the bass riff which underpins 'Had to cry today' has had a surprising longevity, cropping up in different contexts as part of Jaco Pastorius' solo bass concerts and on a recording by the jazz composer Don Grolnick.

[48] *Group Dynamics*, 5th ed. (Belmont, Calif.: Wadsworth Cengage Learning, 2010), p. 19.

[49] Maya Gratier, 'Grounding in Musical Interaction: Evidence from Jazz Performances', *Musicae Scientiae*, 12.1 Suppl (2008), 71–110 (p. 74) <https://doi.org/10.1177/1029864908012001041>.

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[52] David T. Bastien and Todd J. Hostager, 'Jazz as a Process of Organizational Innovation', *Communication Research*, 15.5 (1988), 582–602.