Exploring Attention through Technologically-Mediated Musical Improvisation: an Enactive-Ecological Perspective

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Abstract

In this chapter we consider attention from an enactive-ecological perspective in which the organism-with-environment interdependencies that emerge in the process of living are fundamental and necessary for understanding cognition (Thompson 2010). While technological advances have often provided an impetus for empirical studies of attention, we propose, moreover, that such developments have enabled the facilitation of new highly participatory forms of musicking. In these types of technologically-mediated musical interactions, there is fertile ground for exploring attention within the types of organizational dynamics that emerge over time between group members within musical situations, especially those related to improvisation.

We propose three enactive-ecological themes that we develop in terms of three ranges of timescales of attention modulation. The purpose of the three themes and associated timescales is to provide a way of making distinctions and disentangling processes while doing justice to the complex interdependencies of organizational dynamics (Gahrn-Andersen et al. 2019). Firstly, we consider the notion of habit which affirms the interdependencies between organism and environment as a fundamentally embodied process of identity generation (James and Loaiza 2020). Secondly, we consider the role of attention within social interactivity, whereby attention can be said to emerge within the processes of participatory sense-making (De Jaegher and Di Paolo 2007). Finally, we propose that while attention has often been articulated through ocularcentric metaphors of focus or illumination, a more fruitful approach might involve articulating the speed, strength, or amplification of such dynamics as a processual, non-static

paradigm. Technologically-mediated musical practices, particularly ones which involve improvisational modes of playing, offer not only an environment in which these ideas can be studied, but also provide participatory and experiential platforms for interdisciplinary research (Hayes 2019).

Introduction

Over the last couple of decades, there has been a significant growth in the study of musical performance and improvisation within cognitive science research. Yet, when Pressing offered one of the first formal attempts to theorize improvisation in 1988, the research was scant (Pressing 1988). While his formulation was indeed generalizing in its attempt to blend studies from psychology that were concerned with attention and skill within performance practice with literature that he identified as relevant from musicological research, he had pointedly noted four years earlier that it would be within the very practices of improvising artists that psychologists would unquestionably find "the single largest source of information" (Pressing 1984, 345) on which to base their studies. Pressing suggested that not only could analyses be drawn from the large corpuses of recorded media, comprising video and audio recordings, but moreover, that the phenomenological and experiential knowledge of the improvisers themselves could provide information on "proprioception and self-observation… issues as learning, training, the usefulness of imagery, muscular coordination, and cognitive processing" (Pressing 1984, 345). At around the same time, the proposal of the enactive framework was put forth as an alternative way of understanding cognition, compared to traditionally cognitivist or "computational" approaches (Varela et al. 1991). Specifically, the enactive view proposes that cognition arises out of active participation and engagement between organisms and their environments, stressing the embodied nature of cognition, and the mutually affecting nature of such relationships. While not explicitly linked at the time, Pressing highlights the importance of the relationships between cognitive processes and both auditory and proprioceptive feedback loops within the ongoing activity of improvisation. Furthermore, in Pressing's writing we see some of the first discussion that connects musical improvisation to studies of attention in the field of psychology (Pressing 1998). Crucially, he suggests that it is within the "long-standing question of multiple attention" (Pressing 1984, 356) – namely whether and how it is possible to attend to two or more things simultaneously – that key work for understanding improvisation will need to be undertaken.

What can be understood about the processes of attention through an enactive-ecological account of musical improvisation? Research within the cognitive sciences has started to acknowledge and reflect on the importance of action within a model of musical improvisation (Linson and Clarke 2017). In addition to studies focusing on motor control, perception and cognition, some empirical work has begun to explore themes such as, for example, the coordination of joint action (Walton et al. 2015) and even the processes of creativity itself (Loui 2018). Concurrently, neuroscientific research that is now several decades old has hinted at the importance of attention in connecting these various areas (Posner and Petersen 1990) and its ability to demonstrate that creativity and cognition are by no means skull-bound activities. In this chapter, we consider attention from an enactive-ecological perspective in which the interdependencies of the dynamical processes that emerge between organism and environment in the process of living are fundamental and necessary for understanding cognition (Chemero 2009; Thompson 2010).

We refer to the idea of attention modulation not from the cognitivist standpoint of "neural activation" in relation to localized or isolated functional modules within the brain, but rather as part of the sensorimotor action-perception loops that cognition comprises. In what follows, we propose the notion of three ranges of timescales – or temporal ranges – of attention modulation which draw on three distinct yet related areas of discourse from within enactivist research. At the longest timescale, we consider the habitual and embodied processes of how identities are formed; at the mid timescale, we discuss issues of joint attention via collective participation in, for example, communities of practice; and at the fastest timescales, we consider how attention changes on the fly. While technological advances have often provided an impetus for empirical studies of attention at various key points historically, we propose that moreover, such developments have concurrently enabled the facilitation of new highly social forms of musicking. We argue that it is within these types of technologically-mediated musical interactions that fruitful opportunities for exploring attention amidst the organizational dynamics that emerge over time between group members will be found.

Technology and Improvisation

While all musical instruments can be thought of as "technologies", we wish to focus this discussion around the changes that occurred with the development of electro-mechanical, electro-acoustic, electronic, and latterly digital technologies

and how the affordances of these technical musical objects have impacted the practices of musical improvisation. Firstly, the process of transduction of kinesthetic information or gestural energy into electrical signals which appeared with some of the earliest electrical instruments around the late nineteenth century, meant that distinct acoustic parameters were no longer bound up with the sound-producing mechanisms of the instrument. For example, with the Theremin – which was patented in 1928 – moving one's hand within the vertical electro-magnetic field would produce changes in pitch, while moving the other hand near the horizontal electrode would change the amplitude. While acoustic instruments certainly afford changes in, for example, dynamics to the performer, these are generally not specifically related to a particular section or physical part of the instrument. Secondly – and in particular concerning digital musical instruments (DMIs) – the mechanisms that produce sound are no longer necessarily coupled to the mechanisms which transduce gesture. The action of striking a key on a piano results in a hammer being deployed onto a string, which produces an acoustic sound. However, there now exists a large variety of "controllers" which can be mapped onto digital signal processing (DSP) within computer software in order to affect various parameters within a signal chain. For example, the x-y joystick of a game controller could be mapped both to a filter frequency on the x-axis, and a low-frequency oscillator on the y-axis. This would allow for extensive real-time timbral transformations to be produced and explored. Perhaps the most crucial paradigm shift – which of course had a profound impact on how music is shared and consumed – is the ability to record and playback sound. In terms of improvisation[1], recording technologies have been utilized in order to not only remix external material from other performers, but also to capture, transform, and reproduce material within the course of the improvisation itself. In this way, the performer may have to attend to material which has not been created "in real time", or indeed be aware of ongoing processes – such as recording or analysis – which are not yet audible.

In the domain of "freely" improvised music involving technology, instruments are often highly personalized, may exist as singularities, and may comprise assemblages of acoustic, analogue, and digital elements. Moreover, a

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[1] Much has been written about the musical activity of improvisation, including discussions that aim to situate improvising on various – often unhelpful – axes including improvisation-composition, or freedom-restraint (see, for example, Andean 2014). While it is beyond the scope of this chapter to discuss such trends, we will use the term "improvisation" simply to refer to musical activity that involves some form of real-time decision making where the timeliness of such choice making and action is crucial. Writing on improvisation from both embodied and ecological perspectives, Iyer summarizes that "we might take improvisation to denote that semi-transparent, multi-stage process through which we sense, perceive, think, decide, and act in real time" (Iyer 2016, 74).

performer may have to navigate several different interfaces within a single instrument. In the case of digitally augmented acoustic instruments, for example, in addition to navigating the existing acoustic form, a performer may have to work with foot pedals, tabletop MIDI controllers, and a variety of other devices and interfaces. As previously noted, "this may expend the amount of time available to watch out for cues from the other players" (Hayes and Michalakos 2012). Technologically-mediated musical practices, particularly ones which involve improvisational modes of playing, can also be multimodal in that they combine sonic, visual, and movement elements. For example, using sensors attached to the hands of a dancer, both musical and projected visual changes can be produced as derived from the analysis data of the sensors (see Hayes 2019, for further examples). Furthermore, sensor technologies can be employed to derive control data from bio-signals using devices such as portable electroencephalogram (EEG) headsets or pulse sensors (Ortiz et al. 2011). The feedback loop can subsequently be closed as the near real-time analyses of such processes can be sent back to the performer as sonic output. Another corollary of human-machine improvisation is the ability for agency to be imbued within computer systems, to the extent that an improviser may feel as if they are improvising with another performer (Lewis 2000).

It is important to highlight the ways in which these technical developments have allowed for new forms of musical activity to take place given the increasing attention to musical improvisation within cognitive science research. Not only do such practices offer an environment in which issues of action, motor control, perception, and cognition can be studied, but they also provide participatory and experiential platforms for interdisciplinary research into the role of attention within these areas. Attention can be distinguished as perceptually-guided actions that alter the agent's openness to a multitude of further possibilities for action in relation to a task in a situation (van den Herik 2018). In the case of technologically-mediated musical improvisation, the performer's situation and environment comprises not only what may be hybrid or augmented acoustic-electronic-digital instruments and other musicians, but also the space in which the music is being created. This is important not only in terms of its acoustic properties but also the cultural history, norms, and possibly behaviors that have suffused within the site. An example of this might be the ways in which a particular venue will dictate whether the audience must sit in silence, or is "permitted" to move around or make sound during musical play.

Attention from an Enactive-Ecological Perspective

We adopt an approach to understanding the modulation of attention which brings together insights from enactivism and contemporary versions of ecological psychology (Chemero 2009; Rietveld and Kiverstein 2014). This mixed enactive-ecological approach – or E approach – presents the idea that cognition is constituted by the skillful bodily engagement of an agent with a rich socio-material ecology (environment). Accordingly, attention is seen not so much as a particular cognitive faculty but as an aspect of the embodied engagement of the agent; it is an aspect of enaction or the bringing forth of a sensorimotor loop of perceptually-guided action (Varela et al. 1991). In this view the agent's skillful engagement manifests as the responsiveness, sensitivity, and selective openness to the opportunities for action afforded by the environment and the unfolding coupling between the agent and their niche (Bruineberg and Rietveld 2014). It is the skillfulness of such interactions that requires selectiveness. For an E approach, the point is not to show how attention works as a distinctive intracranial process of selection of focus or awareness. Rather, it is about embedding attention within the ongoing skillful activity and showing how ecologically-spread processes shape, control, amplify, and select the unfolding of the engagement as a whole.

The E approach, in a very general sense, consists of two complementary philosophical insights. On the one hand, it offers the idea that the agent's history of interactions – with materials, tools, particular settings in a situation, sounds, words, other agents' bodies, and so on – determines the agent's particular sensitivity to the possibilities for action in a given situation (Bruineberg et al. 2018). The agent's particular coupling of body and environment becomes a main source of significance and experience. This idea is a consequence of the emphasis on autonomy of the enactive approach (Di Paolo and Thompson 2014). On the other, the E approach proposes the idea of the direct perception of the kind of information in the environment that stands out in relation to the agent's bodily capacities. In other words, this entails the coming together of physical regularities or law-like properties of the environment and the features of the body (Chemero 2009). This idea – which is essentially relational – is captured by the term "affordance" in ecological psychology (Gibson 1977). Building on this, Rietveld and Kiverstein propose to see affordances not as individual aspects of the environment to which the agent attends one by one, but as constituting what the authors call "landscapes of affordances" (Rietveld and Kiverstein 2014, 326). With this move, they aim at the problem of so-called "higher-cognition", addressing it in terms of "skillful activities in sociocultural practices and the

material resources exploited in those practices. Skilled 'higher' cognition can be understood in terms of selective engagement – in concrete situations – with the rich landscape of affordances" (Rietveld and Kiverstein 2014, 326). Ultimately what Rietveld and Kiverstein achieve is the elimination of a hard distinction between "lower-cognition" (e.g. motor control in a task) and "higher-cognition" (e.g. planning). What changes along the continuum between "lower" and "higher" cognition is the observational focus on larger, more spatially and temporally distal relationships – that is, a social landscape of affordances – that enable the regularity of behavior.

The two ideas come together to account for a particular form of experience and intentionality. From an experiential perspective, the sensitivity to relations between body and environment is manifested as a felt concern or tension that solicits attention, recalibration of perception, and tension-reducing actions. In the phenomenological literature the experience of tensions – as the drive to adjust or act – is usually phrased in terms of what Merleau-Ponty called a process of finding an "optimal grip" (Merleau-Ponty 1962 [1945], 51). The classical example is the visitor in a gallery who adjusts their position in front of a painting as a means to maximize their aesthetic experience. Confronted with the painting as it is immersed in the light conditions of the art gallery, the visitor feels a need to reduce the tension with respect to the situation and is thus prompted to find the right angle of vision and distance of their body with respect to the painting. In the E approach vocabulary, the visitor enacts an optimal grip in the situation (Bruineberg et al. 2018). The key point of the E approach is that this particular sensitivity is not the result of a general inbuilt cognitive capacity for picking up and filtering stimuli but the effect of the active exercise of bodily habits that are acquired and stabilized through recurring interactions throughout the agent's life.

This view highlights bodily aspects in interaction, habitual ways of doing things, and the immersion of the agent in rich socio-material contexts. Agents develop forms of selective openness – attentional actions – in a way that is always engaged with a multiplicity of ongoing activities. This amounts to one of the principles of the E approach: perception and action are not separate processes linearly connected by cognitive modules. Rather, perception and action constitute a continuous dynamical loop (Chemero 2009). Thus, to perceive possibilities for action and to act is to generate the flows of information that can be sensed by means of, for example, moving in a gallery room. As agents are continuously immersed in ongoing activities the dynamic nature of their sensitivity and selectivity is constantly modulated by the parameters of interaction and

engagement in those activities. Turning back to the example of the gallery visitor: each of their movements is equivalent to changes in the relation between body and environment – changes in the flow of energy array available in the gallery ecology – that alter simultaneously the perception of possibilities for further actions. Moreover, the history of interactions of the gallery visitor determines how certain features of the environment become salient as the visitor moves in the room. Such sedimented processes and background histories reveal themselves only when disrupted by, for example, artworks which aim to frame such interactions, or expose institutional confinements such as is the case in Daniel Buren's works which exceed "the physical boundaries of the gallery by having the art work literally go out the window" (Kwon 2004, 18). Here we notice that what might be described as "cultural factors" are indeed part of Rietveld and Kiverstein's notion of affordance topographies which encompass not only affordances in the Gibsonian sense – opportunities for action – but also affordances with more distal relationships, such as those that may be encountered within, for example, cultural institutions, social conventions, and so on.

Spanning a diverse set of fields from human-computer interaction, systematic musicology, and music psychology, these key ideas from enactivist theory and ecological psychology that comprise the E approach have been hugely valuable in spearheading musical research that moves away from conceiving music as a purely cerebral, or skull bound activity. These themes have been discussed with respect to a variety of "non-representational" musical practices; that is, musical activities that are not concerned with representing aspects of an "original" reality – standing in for things – and that, moreover, favor and foster participation rather than detached observation (see Hogg 2013 for further discussion). Some pertinent examples include the design of new DMIs which focus specifically on embodied and tacit knowledge of everyday materials (O'Modhrain and Essl 2004); interdisciplinary improvisation using novel technologies involving musicians, visual artists, and dancers (Hayes 2019); research into musical emotion (van der Schyff and Schiavio 2017); music pedagogy focusing on embodied approaches (van der Schyff et al. 2016; Hayes 2017); and group improvisation through the lens of distributed cognition (Linson and Clarke 2017). This shift in focus not only sidesteps issues of cultural dominance – where Euro-American musicological research has privileged, for example, twelve-tone equal tempered scales – but also opens up interdisciplinary realms that challenge which forms of musical activity might be useful to study. Thus, music can be expanded to include all forms of organized sound, moving beyond focusing only on what can be represented within the Western notation

system, which quickly demonstrates its limitations when timbral or spectral content is considered, for example.

Three Ranges of Timescales of Attention Modulation

E approaches, in brief, radically reframe the notion of attention as selective openness in the continuous coordination between agents and a richly structured environment. They highlight how attentional actions are interwoven within the mutually shaping dynamics of patterns and regularities of the landscape of affordances (i.e. physical, but also socio-cultural regularities) and bodily features of the agent (including the self-organization of the central nervous system). They also bring to the fore the history of environments (particular socio-material relations that bear on the presence of affordances), history of bodies (idiosyncratic tendencies and habitual actions), and the emergent histories of interaction between agents and the world.

To understand modulation of attention in E approach terms thus requires a different strategy compared to conventional cognitivist approaches. Rather than privileging a description of modulation of attention based on a single process, often occurring on a single timescale, we propose to characterize at least three ranges of timescales (see Figure 1), each of which pick up a particular angle on the rich coordination between agents and environments. Following multiscalar frameworks of human interactivity and coordination (Gahrn-Andersen et al. 2019; Loaiza et al. 2020) we propose three temporal ranges associated with slow, mid, and fast modulation[2]. We outline these temporal ranges in relation to three enactive-ecological flavored themes as follows:

1. Firstly, we consider the notion of habit which affirms the interdependencies between organism and environment as a fundamentally embodied process of identity generation: this refers to the slowest or longest timescales of development and enculturation. The person, as a matter of development of personal and sensorimotor identity, becomes sensitive, or attentive to certain forms of interaction, expression, use of tools, and so on.

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[2] Loaiza, Trasmudi, and Steffensen (2020) define a temporal range as an observer-dependent set of timescales that can sufficiently capture the interdependencies and feedback loops of processes that take place across multiple scales. This can be understood in the usual terms of longer / slower timescales determining the boundary conditions of faster / shorter processes, but also in terms of reciprocating constraints on slower timescales reproduced on faster timescales.

2. Secondly, we consider the role of attention within social interactivity, whereby attention can be said to emerge within the processes of participatory sense-making (De Jaegher and Di Paolo 2007). This refers to mid timescales of participation in communities of practice and sociality. Here selectivity is modulated through joint attention[3]. In particular, this occurs through joint attention to and with mediating technologies, including not only musical interfaces but also environmental aspects such as venues.

3. Finally, we propose that while attention has often been articulated through ocularcentric metaphors of focus or illumination, a more fruitful approach might involve articulating the speed, strength, or amplification of such dynamics as a processual, non-static paradigm. This refers to the fast timescales of changing attention on the fly.
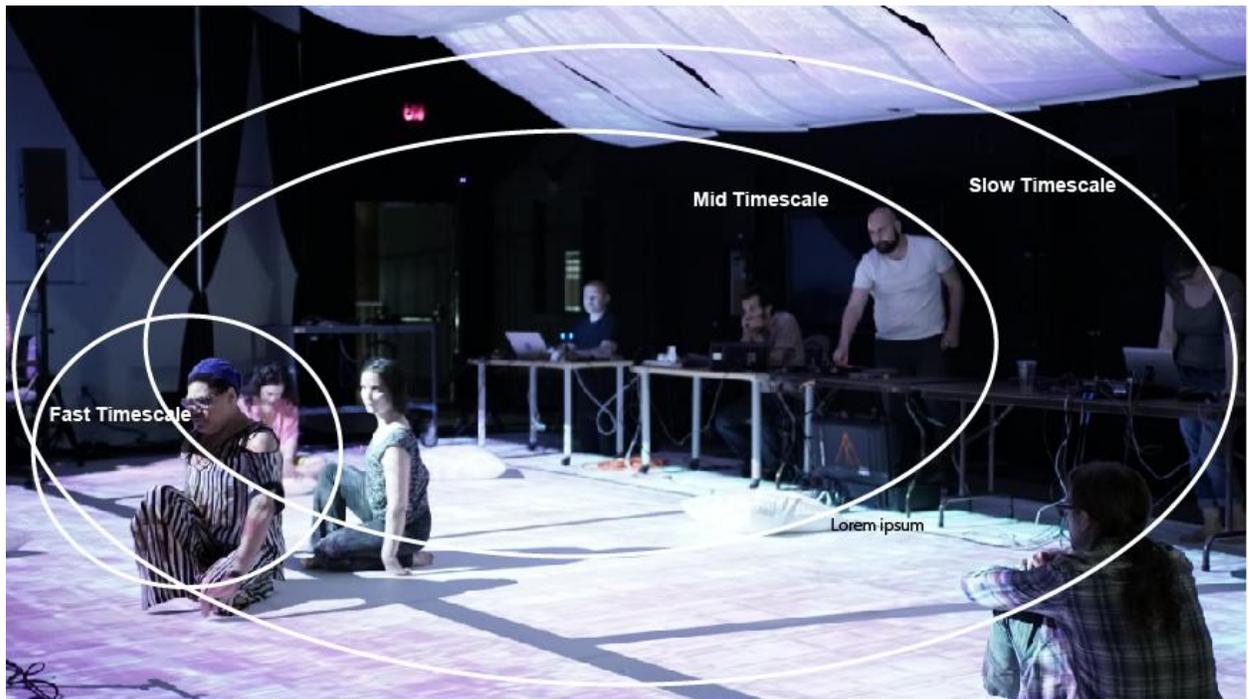

Figure 1: Example of multiscalar frameworks of human-environment / human-human coordination within interdisciplinary improvisation involving sound, movement, and visuals during LLEAPP 2018, Tempe, AZ. The slowest timescale includes the regularities and conventions of the performance space, the audience and performer etiquette, the material factors that enable this performance; the mid timescale concerns the community of practice (in this case, the various performers); the fastest timescale indicates how the individual performer changes attention on the fly, perhaps weakening the focus on physical movement while strengthening awareness of co-performers or visual changes that appear within the space.

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[3] Here joint attention refers to the kind of social triangulation most commonly present in dyadic interactions with a shared task. For example, the dyad of child and caregiver in which interpersonal coordination comprises the engagement with a "third" party: an object of the child and caregiver's joint attention. Joint attention is an important developmental step in what ecological psychologists have described as "education of attention", in which adults guide the child's discovery of affordances in the environment (van den Herik 2018).

The long timescales of modulation of attention along a person's development can be explored with the notion of habit. This term has been recently reincorporated into the literature on cognition from an enactivist perspective (Barandiaran and Di Paolo 2014). After the eclipse of behaviorism on account of the early forms of cognitivism in the 1950s and 60s, the notion of habit became associated only with the kinds of automatic and repetitive behavior or putative forms of "lower" cognition. However, outside of the cognitive science discipline, the term remained in wider use. For example, echoing Bourdieu's use of *habitus*, ethnomusicologist Thomas Turino refers to habits when accounting for the acquisition of musical tastes and embodied styles of performative behavior (Turino 2008; Bourdieu 1977). For Turino, dispositions and habits

"are products of relations to the conditions around [the person] and her concrete experiences in and of the environment. Habits and dispositions guide what we think, do, and make (practices). Our practices and the things we produce affect, to greater or lesser degrees, our environment, which in turn affects our dispositions, which in turn affect our practices, which in turn affect external conditions, and so on" (Turino 2008, 120).

Turino uses this circularity in order to formulate both a definition of the personal "self", and of "cultural formations" and "cultural cohorts" (Turino 2008, 120). Ethnomusicologist Judith Becker similarly points to a "habitus of listening" (Becker 2004, 69) that accounts also for a totality of predispositions and tendencies of "communities of listeners" whereby "every hearer occupies a position in a cultural field not of his or her own making: every hearing is situated" (Becker 2004, 69). In short, for Becker musical perceptual attitudes are socially constituted.

Recent developments on habit have incorporated some of the core concepts of the enactive approach (Barandiaran 2008; Barandiaran and Di Paolo 2014; Ramírez-Vizcaya and Froese 2019; James and Loaiza 2020), in particular the organizational notion of autonomy that characterizes structures "between the biological and the psychological" (Egbert and Barandiaran 2014, 2). In the enactive view, habits are "self-sustaining patterns of sensorimotor coordination formed when the stability of a particular mode of sensorimotor engagement is dynamically coupled with the stability of the mechanisms that generate it" (Barandiaran 2008, 281). In this way, habit is not simply a kind of automatic or solidified behavioral program but a process that acquires a "life of its own" and thus is the cause and effect of itself (Barandiaran 2017). This circularity of self-production is precisely what characterizes the notion of autonomy in the enactive

literature, the outcome of which is the complementary idea of self-distinction or identity[4]. Habits, thus, are self-producing and self-distinguishing patterns with lasting structuring effects on behavior.

We argue that in terms of long/slow timescales, attention is modulated by habits of listening, playing, and gesturing, amongst others. Following the enactive notion of emergent self-production, these habits are not simply copied from the sociocultural milieu as memes, nor do they otherwise express the implementation of a pre-established program. Instead, habits – on an individual level – emerge gradually and in an unprescribed way along the myriad of concrete encounters between persons in interaction and engaging with materials. Habits, once they have life of their own, strongly regularize behavior. But the way, quality, and intensity in which habits emerge in the first place are thoroughly contingent and idiosyncratic. Beyond single individual patterns, habits can form networks of mutually reinforcing activity (James 2020). Once they act as a network taking a significant part of the individual person's behavior, habits generate what James and Loaiza call a form of "enhabiting" (2020, 6)[5]. Persons "enhabit" as they acquire habits and also are themselves the effect of enhabiting. In this view, the individuality of our personalities and unique musical experiences, tastes, and imagination, as well as the personal autonomy we can self-designate and claim credit for, all rest on a network of mutually self-sustaining habits in a form of an enhabiting process. Crucially, enhabiting – that is, the activity of a network of habits – has an identity, yet there is no central "self" behind the network to which we can point to as the source or ultimate bearer of such identity. In other words, identity is precisely the overall effect of the self-sustaining and self-constraining activity of the whole network (Loaiza 2016).

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[4] The notion of identity that we use here is a technical term of enactivism. It corresponds to the persistent patterns of organization of behavior that emerge from the operational closure occurring at distinct levels (Thompson 2010, 60). In this way, there's an identity for each cell at the level of closure of cell metabolism; there's an identity of the central nervous system at the level of closure of self-organized neurodynamics; and similarly, it is suggested that there are other forms of identities at the levels of the whole organism and beyond the individual: sensorimotor coordination, habitual patterns, personal linguistic use, participatory coordination (Cuffari et al. 2018).

[5] The enactive approach to habit is a development of ideas found in – amongst others – Husserl, Piaget, and Merleau-Ponty. Merleau-Ponty sees habits "as incorporated styles of being-in-the-world… [which reveal] corporeal intentionality in contrast to notions of habits as blind automatisms" (Barandiaran and Di Paolo 2014, 6). What the enactive approach adds to the phenomenology of habit is a dynamical and operative account of the type of operational closure of processes that needs to be in place for habits to self-maintain and simultaneously be adaptive (James and Loaiza 2020). See previous footnote on the relation of operational closure and identity in enactivist terms.

What does this idea of enhabiting have to do with modulation of attention? Each individual habit implies a way of modulating attention as part of the circular reciprocity between action and perception. As a network of habits matures, it is thus also implied that such particular forms of modulating attention will mutually reinforce, with the effect of the emergence of a more general identity of the attentional activity. In this way, a person may have a network of associated habits of listening to particular melodic structures, habits of handling instruments and controllers, habits of use of vocalizations in performance. The network, given the particulars of an environment and the tasks at hand, may yield a more general pattern of attentional actions. For example, this may include patterns of marking points of interest in the production of sonic material by timing and integrating a certain detail in the way of handling the instrument, a particular idiosyncratic vocalization, or a certain way of anticipating a melodic structure. In our view, attention – as a global organization of awareness and selectiveness in a task – emerges in part as a self-organized network of mutually self-sustaining habits of listening, moving, seeing, touching, vocalizing, and so on. In this way, following Ganeri (2017), there is no need to think of a centralized entity (a self) or process that is the bearer of the attentional "spotlight" or the fundamental source of attention[6]. Attention, at slower timescales, is modulated by the history and entrenchment of constellations of habits. What follows is to show how, although generally stable in slow timescales, habits, and thus attention, can also manifest plasticity in faster timescales. They come to be modulated by constraints brought forth in social participation. In this way, habits can also become part of skillful engagements with other persons within communities of (skillful) practice.

In their efforts to provide an enactive account of social interaction, Hanne De Jaegher and Ezequiel Di Paolo develop the notion of "participatory sense-making" (De Jaegher and Di Paolo 2007, 485). Their approach focuses on a move away from individualistic interactions between agents and environments, and instead deals with the crucial micro-interactions that comprise social

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[6] Ganeri (2017) presents a non-orthodox view of the relation between attention and self that in part reverses and overcomes the more classical European view in which attention implies a minimal form of authorship and self (cf. Zahavi 2014). Ganeri's position explores the Buddhist doctrine of "no-self" (Anātman) in light of contemporary philosophy of mind to argue against a conception of authorship in attention. In parallel to Ganeri, the enactive approach is rooted in the Buddhist Madhyamika tradition in which "emptiness" (Sunyata) and "(co-)dependent arising" (Pratītyasamutpāda) play an important part in the rejection of self/nonself essentialist distinctions. Enactivism reworks "codependent arising" in its notion of emergent identity of self-organized systems. To our knowledge, the connection between Ganeri's work on attention and the enactive approach to emergence of identity and self has not been worked out more fully in the literature (Ganeri 2017, 306, 309). The discussion reaches considerably beyond our present proposal. It is however necessary to mention the resonances and possible cross-pollination between the enactive approach and Ganeri's views. Thanks to one of the reviewers for pressing the question of the relation between attention and self (minimal or otherwise).

interaction. Moreover, this is not limited to linguistic or even anthropocentric patterns. Specifically, they define social interaction as "the regulated coupling between at least two autonomous agents, where the regulation is aimed at aspects of the coupling itself so that it constitutes an emergent autonomous organization in the domain of relational dynamics" (De Jaegher and Di Paolo 2007, 493). Importantly, the autonomy of the agents involved – while it may grow or diminish – remains intact. Here, attention emerges within the mutually-affecting relationship between coordination and interaction. Echoing their example of dancers taking on the role of leader or follower, so too can we illustrate this idea within musical practices. In freely improvised music, for example, there is a common approach where performers may take on these roles, either through direct assignment prior to starting to play, through a number of "conducted" approaches, or through other ad hoc means. Yet despite the typical etiquettes determined by such roles, it becomes evident that each musician turns their attention to the other which affects how the other plays, how they themselves play, and how both, together, create, sustain, and modulate the ongoing stream of musical activity. This participatory framing can be contrasted with what has been described as a "spectatorial stance" (Schiavio and De Jaegher 2017, 32).

We define this mid-scale temporality of attention as referring to an agent's participation in communities of practice – that is, their participation with their various milieux. Crucially here, attention is modulated not only through the specific histories and experiences of the individual, but rather through collective processes of joint attention that occur among and between agents. Moreover, this occurs through jointly being attentive to various technologies of mediation, which may include not only musical instruments or sounding objects, but also the spaces in which the activity is taking place. Here, "musicians (and audience), as a coupled system, participate in, *and thus can form and transform* each other's sense-making, enacting unique shared worlds of meaning" (Schiavio and De Jaegher 2017, 33). Through engaging with mediating technologies, groups of improvisers develop habitual patterns of behavior[7] through informal or formalized attentive strategies. Group musical vocabularies are established and developed through playing together and listening practices, as well as through reflection and discussion. Individual musical practices and techniques are shared and subsumed within the group's evolution. For example, as part of the creative music practice research group Laboratory for Live Electronic Audio/Art

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[7] See our earlier explanation (Footnote 4) of identity as a technical term within enactivism. This allows for a definition that encompasses, on one hand, the cellular level to issues of group identity via participatory coordination, on the other.

Performance Practice (LLEAPP), musicians and movement practitioners engaged in various collectively defined attentive strategies (see Figure 1) using techniques drawn from both the performing and the visual arts (Hayes 2019). Here, a sound-reactive projected visual – an instrument developed by one of the musicians in the group – was repurposed in order to create rule-based movement strategies for the entire group (see Hayes 2019 for more details). Working together over several days led to the emergence of a group identity which was formed out of not only the unique histories and skillsets of the individual members – slow timescales – but also through mutually affecting relationships of participatory sense-making. The sociality of such "habitual identity" (Wehrle 2020, 1) is evident within such practices. As Wehrle notes, "As human bodily subjects we are situated, which is to say that we are embedded in and shaped by already existing ecological, historical, cultural and socio-economic environments, reflecting in turn specific social norms and power relations" (Wehrle 2020, 14).

Perhaps most prevalent within discussions of attention is what we define as the third time-scale: that of the fast, often near-instantaneous on the fly changes of attention. Typically, the sorts of metaphors that are commonly used to describe attentive processes are almost exclusively derived from ocularcentric notions of "illumination", even within studies of attention in musical contexts. These can be found in studies that use the typical "spotlight" metaphor, where participants are asked to shift their focus – in the same way that a spotlight can jump between different targets – from, for example, the movement of their body to the sounds that their movements produce (Duke et al. 2011); or where attention might be diverted by a secondary task (Norgaard et al. 2016). Another example is a comprehensive study dealing with auditory attention from both spatial and feature processing perspectives which similarly uses an "auditory searchlight" (Fritz et al. 2007, 441) metaphor. While such studies do important work from an interdisciplinary perspective, we suggest that this framing is limiting in its ability to describe more nuanced dynamics of the processes of attention. With this strategy, the focus – or location – of attention can be described but not how intensive or prominent this may be, nor how it may vary over time. Rather, we invoke metaphors of speed, strength, and amplification of such dynamics in their ability to help convey the richer possibilities that can be exemplified in attentional mediation within various forms of musical activity. Furthermore, this approach avoids the prevalent issues of how to account for divided attention or task switching (see, for example, Monsell 2003 for a neuroscientific discussion of such issues).

Numerous empirical studies point to the importance of multimodal feedback in the joint coordination of musicians (Schroeder et al. 2007; Eerola et al. 2018). Rietveld and Kiverstein's (2014) extended notion of landscapes of affordances – as more than opportunities for motor action alone – is particularly helpful in understanding the richly dynamic ways in which attention is mediated in the often highly complex situations of musical activity. As mentioned above, when performing with technologically-augmented instruments, musicians have the ability to work with non-real time aspects of what has transpired, or even with audio samples recorded in advance. Here, attention to memory extends beyond the current performance and involves not only the emergence of new musical material based on joint articulation, but also the ability to re-trigger musical events that have been heard in the past. Moreover, computer technologies mean that sounds can be performed beyond the physicality that is humanly possible: algorithmic automation can produce repeated percussion "hits" every millisecond. Musicians must assess whether to respond to gestures that may not even produce sound, such as triggering a DSP analysis process on a laptop. Furthermore, ensembles can often be extremely large, and may not even be in the same location, such as in the field of telematic musical performance. While De Jaegher and Di Paolo's thesis is based on the joint articulation between two people – although they state that it can be extended to three or more – a musician may have to attend to what is transpiring between dozens of other improvisers, or more. When the world of music making opens itself to unconventional instruments, novel technologies, spontaneous configurations of performers, unusual spatial – often dislocated – arrangements, and so on, it becomes clear that "openness to affordances consists of a readiness to act in ways appropriate to a particular concrete situation" (Rietveld and Kiverstein 2014, 347).

Rather than, then, the skillfulness of a musical improviser being determined by their ability to focus on a locus of activity, and shift the "searchlight" of their attention to something else – or indeed divide this into several searchlights – we suggest that a dynamic network of attentive bonds that become strengthened, amplified, or diminished better describes this skillfulness. Moreover, these bonds may form and dissipate at varying speeds: a sharp interjection from another musician may command rapid attention, but more subtle development within textural sonic material, for example, may become noticed and responded to more gradually. Attention here is multimodal and embodied, as the musician attunes to a variety of physical gestures and sounds, or perhaps a more general rhythm, pulse, or vibe, and so on. The musician's skillful engagement is found within their ability to be sensitive and responsive to these

changes in their environment. That is, it resides within their selective openness to the opportunities for action that constantly appear and disappear within the ephemerality of improvisation. Amplification of a particular musical motif – which literally gets louder – may trigger attentive amplification, but the skilled improviser may also strengthen their attentive bond to a quieter, subtler, perhaps almost inaudible sound that transpires simultaneously, or entrain their bodily movements to an irregular but palpable pulse. Similarly, when improvising with DMIs, rather than focusing on a particular parameter of an instrument or system, the skillful musician remains open to the affordances offered by what may be a highly complex musical software agent or instrument. This is done not by forming mental representations of, for example, interface to DSP mappings on the fly, but rather, by being able to respond by strengthening and weakening particular attentive bonds within this constantly evolving dynamic activity.

Conclusion

In this paper we have argued that technologically-mediated musical practices, particularly ones which involve improvisational modes of playing, offer a site in which attention can be explored as an embodied and dynamic process, rather than conceiving of it as a specific cognitive faculty. Through the enactive-ecological framework we have defined three ranges of scales which demonstrate the different ways in which the selective openness or responsiveness of a musician within their niche can be said to modulate attention. Within her writing concerning the modes of attention, composer and founder of Deep Listening, Pauline Oliveros (2010) has pointed to two contrasting types of attention: "focal" and "global". While her notion of focal attention aligns very much with the ocularcentric metaphorical paradigm – "attention to one point and nothing else" (Oliveros 2010, 29) – her concept of global attention very much aligns with our notion of attention as selective openness, as an "open receptive state… attention [is] expanded to a field" (Oliveros 2010, 29). We hope that this framework not only provides new avenues for the study of attention across all three ranges of timescales – as habitual maturation, joint sociality, and dynamic engagement – but also that it opens up collaborative possibilities that build upon the expertise found within the skillful and deeply social practices of techno-fluent improvising musicians. In this, we hope to see the emergence of interdisciplinary research that – by moving away from taking "spectatorial stances" – is itself simultaneously enriched.

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