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Using Electroencephalography to Explore Cognitive-Cultural Networks and Ecosystemic Performance Environments for Improvisation

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INTRODUCTION

The aim of this chapter is to bring together three areas of enquiry with the purpose of exploring their potential application within the realm of musical improvisation and in so doing providing a rationale for future creative developments in the area of human-computer interface design within the context of improvised music performance systems. The areas under investigation can be broadly categorized as cognitive-cultural networks, ecosystemic design and brain-computer interfaces. These three elements form a tripartite approach to the contextualization of human agency within the realm of improvised music-making and suggest a three-tier approach to the investigation of causation, in the chain of influence which affects musical behavior in this context. Much research has been undertaken, which concentrates on particular segments of the creative process, focusing primarily either on the behavior of the performer, the relationship of the performer to the means of production or the social context in which the activity exists. The motivation for taking a more holistic approach is to provide technological interventions that facilitate the development of performance environments that support improvising musicians, striving to explicate their art in a manner that satisfies a desire to create a unique musical performance—one that minimizes mechanical forms of musical behavior and utilizes pre-programmed units of musical material. This form of creative endeavor, often referred to as non-idiomatic or free music (Bailey and National Sound Archive, 1992), is rich with anecdotal evidence to support an enquiry of this nature. As a starting point, various subjective views from this field of improvisation will be presented to define the problem space and shed light on the dilemmas and frustrations experienced by practitioners. These concerns will then be subjected to brief analysis in terms of their relationship to art in the wider context of cognition, looking at cognitive evolution with specific reference to Donald's work on cognitive-cultural networks (Donald, 2008). These ideas will then be recontextualized, drawing on themes from Di Scipio's ecosystemic design principles (Di Scipio, 2003) and also passive brain-computer interaction

(BCI), to suggest a novel approach to the design of performance contexts within this field of enquiry. The theoretical themes of the chapter will be represented as a model for the development of performance architectures and performance environments. By way of an exemplar, the recently created piece *Mondrisonic* will be described as an implementation of that model.

IMPROVISATION IS NOT UNCONTENTIOUS

This investigation is very much informed by the experience of improvising musicians, and as such anecdotal evidence has been an important source of information. Given that this is such an important starting point, I think it's worth clarifying that I do not regard the content of an anecdote to represent empirical evidence of anything other than as an indication of perception. That is to say, its factual accuracy may be called into question, but unless there is a deliberate attempt to deceive, it can be regarded as a reasonable reflection of what was perceived in a given situation. Anecdotes, personal as they are, cannot escape the crudity of language as a tool to represent a domain, such as music, that could be considered in some sense meta-lingual. Anecdotes are interesting because they can often reveal a mismatch between perceived (internal) reality and the objective (external) reality. In this context, they present an opportunity for an observer to reconcile the improviser's duality in their performance, that of producer and consumer. For the musician it is a chance to offer a personal perception of a situation, which may defy an objective, logically causal explanation—things that just happen. The following quotation from Steve Lacy offers his perception of the relationship between learning and improvising and conveys what could be interpreted as an ethical stance on what can legitimately be called improvisation.

> Why should I want to learn all those trite patterns? You know, when Bud Powell made them, fifteen years earlier, they weren't patterns. But when somebody analysed them and put them into a system it became a school and many players joined it. But by the time I came to it, I saw through it—the thrill was gone. Jazz got so that it wasn't improvised anymore.
>
> (Bailey, 1993, p. 54)

What is interesting about Lacy's observation is the assertion that the pioneers of Jazz didn't play patterns and begs the question: what constitutes a pattern? Lacy seems to be suggesting that the formulation of patterns is the mechanism by which acts, that he regards as spontaneous, can be replicated. They are perhaps the product of a mimetic process for which the primary motive is 'learning' and 'copying'. What this opinion fails to address is the possibility that the 'learned' has to exist on some level in all musical improvisation, particularly improvisation at speed (Gaser and Schlaug, 2003). Borrowing from others or from an idiom certainly raises questions of authenticity, but it seems implausible to contemplate the notion that an improviser can develop their practice in a vacuum, without influence. In fact, as John Cage famously articulated, this aspect of improvised music-making can result in some artists rejecting it altogether.

> Improvisation . . . is something that I want to avoid. Most people who improvise slip back into their likes and dislikes and their memory, and . . . they don't arrive at any revelation that they are unaware of.
>
> (Cage and Turner, 1990, p. 472)

Lee Konitz's observation places more responsibility on the performer to circumvent these tendencies with an awareness of how focused attention functions, to reduce auto-responsive musical behavior. This alludes to the issues of memory, to which Cage and Lacy refer, but pulls focus on procedural (motor skills) rather than declarative memory (facts and events).

> Playing mechanically suggests a lack of real connection to what you are doing at the moment. We learn to play through things that feel good at the time of discovery. They go into the "muscular memory" and are recalled as a matter of habit.
>
> (Hamilton and Konitz, 2007, p. 109)

Konitz acknowledges here the tension within the master-slave relationship between declarative memory and procedural when engaging in an activity that is perceived to be under conscious control, suggesting that playing becomes more habitual when the executive function of declarative memory is weakened by non-attentiveness.

If we analyze the experiences of those who seem to have developed a practice that has, at least from their own perception, partially resolved the aforementioned issues, we can see an interesting subversion of episodic and semantic memory, via a reactive response to an unpredictable sequence of events. Physical reactions, when stimulated by external stimuli, can be executed with minimal need for conscious attention (Libet, 1985). The following quotations, first from Derek Bailey and then from Evan Parker, suggest that the environment is key to unlocking the creative freedom in their practice, not their learned repertoire, at any level of their memory system.

> A lot of improvisers find improvisation worthwhile. I think, because of the possibilities. Things that can happen but perhaps rarely do. One of those things is that you are 'taken out of yourself'. Something happens which so disorientates you that for a time, which might only last for a second or two, your reactions and responses are not what they normally would be. You can do something you didn't realise you were capable of or you don't appear to be fully responsible for what you are doing.
>
> (Bailey, 1993, p. 115)

> It can make a useful change to be dropped into a slightly shocking situation that you've never been in before. It can produce a different kind of response, a different kind of reaction.
>
> (Bailey, 1993, p. 128)

These statements, from two of the most influential exponents of improvisation in the post-war UK experimental music scene, echo sentiments expressed in biographies, documentaries, articles and interviews by performers in this genre, the world over. They are bringing to the debate the role of external context, and in so doing adding another dimension to the path of causation that governs the musical behavior of improvising performers. This brief excursion into the frustrations and elations expressed by improvising musicians has shown the influence of context and environment on the subjective experience of their continuous battle to generate original material—to evolve the music beyond that which has been played before.

CULTURAL COGNITIVE EVOLUTION

The experiences highlighted here allude to a strata of cognitive processing which is rich in its potential to reveal points of intervention in the chain of causation from sensory input, through perception, to manifest musical behavior. They suggest the existence of entry points, which map to human responses but may not necessarily feature in attentive awareness. We could conceptualize this as a series of layers of habitual and planned action, sometimes referred to as goal-states (Cushman and Morris, 2015). In describing the evolutionary development of cognition, Donald defines four periods of development that map how culture and the brain interact in decision-making. He describes this as a "cascading model", which has resonance with this notion of layers. He suggests a process whereby hominid cognitive development retains and builds upon each earlier adaption and is a useful lens through which to examine improvised musical behavior, probably the earliest form of human music-making (Cox and Warner, 2017). The first period, episodic, which existed over 4 million years ago (MYA), he describes as pure event perception, when humans existed much like other species in the way their behavior was stimulated directly by their environment. The second period spanning 4–0.4 MYA, which he calls mimetic, is characterized by action modeling. During this period the ability to manifest behavior based on imitation, ritual and shared attention is developed. The mimetic period was the first point at which human experience, and consequently behavior, was augmented by the experiences of others, purely through observation. It was not until the third period, the mythic, some 0.5 MYA, that shared attention between individuals led to symbolic/linguistic forms of representation and communication. These approximate periods were mediated by neurobiological change, while the transition to the final period, the theoretic, was stimulated over the last 2000 years, largely by environmental and technological influences on cognition. This period is characterized by human augmentation, both conceptual and physical. The rate of change over this period has been unprecedented, fueled by extensive developments in the cognitive-cultural networks that move this evolution beyond the domain of the individual into the social, supported by an extraordinary rate of technological development.

> This is a "cascade" model inasmuch as it assumes (as Darwin did) a basically conservative process that retains previous gains. As hominids

> moved through this sequence of cognitive adaptations they retained each previous adaptation, which continued to perform its cognitive work perfectly well. . . . The first two hominid transitions-from episodic to mimetic, and from mimetic to mythic-were mediated largely by neurobiological change, while the third transition to the theoretic mode was heavily dependent on changes in external, nonbiological, or artificial, memory technology. The fully modern mind retains all of these structures, both in the individual brain as well as in the distributed networks that govern cognitive activity in cultural networks.
>
> (Donald, 2008, p. 199)

In addition to the generic influence of cognitive-cultural networks (CCN) on the evolution of cognition, Donald applies this theory to trace the cognitive origins of art. He suggests seven main defining factors that constitute an arts practice, which can help understand its function within the evolution of cognition. In summary, these factors relate to (1) the intent to influence the mind of an audience through the reciprocal control of attention, (2) its link to a larger distributed cognitive network, (3) its ability to construct mental models and worldviews by integrating multiple sources of experience, (4) the utilization of metacognition as a form of self-reflection, (5) being technology-driven, (6) the unfixed artist's role within the distributed cognitive network, and lastly (7) aiming for a cognitive outcome by engineering a state of mind in an audience.

So, what relevance does this long view have to an exploration of improvised music-making in the 21st century. When Steve Lacy disparagingly describes the rote learning of patterns as having an undermining influence in improvisation, he is touching on a remarkably persistent mimetic facility, one that provides the basis for human self-awareness. There is a strong argument that proposes the mimetic core of hominid behavior, which Donald suggests is the basis of the evolutionary split leading to modern humans' higher cognitive abilities, has a neural correlate in the mirror neuron (Wohlschläger and Bekkering, 2002). The discovery of this physical phenomenon some 20 years ago in the brains of monkeys (Gallese et al., 1996), and now evidenced in the human brain (Decety and Grèzes, 1999), shows the basic mechanism by which the observable experiences of others can be registered partially, on a neural level, as our own. The area in which this phenomenon is observed is the premotor cortex, and it is worth noting that as these neurons are responding to audio-visual stimuli, the effect is resultant on action-related sound as well as that which is visually observable. It has been suggested that the function of the mirror neuron is strongly associated with sensorimotor associative learning, and that mirror neurons can be changed in radical ways by sensorimotor training (Lotem et al., 2017). The relevance, to the field of improvised music-making, of this layered model of cognition and the facility of mirror neurons to respond to action-related sound, is that it suggests the possibility of a cognitive-cultural network, which disrupts the regular causal flow from stimulus to behavioral response or action. Technology has the potential to initiate that disruption in a controlled and potentially creative way, via the entry points that exit within the multitude of cognitive layers that are operational when a musician is engaged in improvisation. The argument for a sensorimotor associative learning basis for mirror neurons, as opposed to a genetic adaptation designed by evolution to undertake a specific socio-cognitive function, supports the idea that this intriguing human capacity has the potential to be harnessed for creative/artistic purposes (Cook et al., 2014). Experimentation to shed light on the "action-listening" capabilities of mirror neurons has been undertaken, involving the teaching of untrained musicians to play a simple piano piece by ear. When learned pieces were listened to by the participants without any movement, the mirror neuron system became much more active than when they were exposed to an equally familiar but unpracticed piece of music. This research supports "the hypothesis of a 'hearing—doing' system that is highly dependent on the individual's motor repertoire" (Lahav et al., 2007). This suggests that emancipation from mechanistic improvisation will inevitably require an intervention, which subverts the neural infrastructure that supports "action-listening" in humans, but this subversion might come from the performance environment, as an external stimulus rather than a fully attentive action.

> Individual decisions are made in the brain. Human brains, however, are closely interconnected with, and embedded in, the distributed networks of culture from infancy. These networks may not only define the decision-space, but also create, install, and constrain many of the cognitive processes that mediate decisions.
>
> (Donald, 2008, p. 191)

ECOSYSTEMIC DESIGN

The potential to introduce computer technology into improvised performance has enabled the possibility of building interfaces that are active, not just reactive. In this sense they can respond to but also initiate interaction between a performer and their performance environment in accordance with a predetermined parameter map, in ways that the performer may or may not be consciously aware. Many computer-based interfaces continue to evolve tightly coupled gestural mapping using a variety of peripheral devices such as data gloves, motion detectors, velocity sensors, etc. There are also, however, opportunities, afforded by computer-based technologies, to explore the relationship between performer and sound source with the construction of responsive environments in a manner Di Scipio refers to as ecosystemic. The second theme of this chapter relates to Di Scipio's notion of ecosystemic design. He asserts that, in this paradigm, the performer and computer system exist in a relationship of 'ambient coupling', where the computer system is responsive, not purely to the performer but to the performer in the context of the performing environment.

> Notwithstanding the sheer variety of devices and computer protocols currently available, most interactive music systems—including developments over the Internet—share a basic design, namely a linear

> communication flow: information supplied by an agent is sent to and processed by some computer algorithms, and that determines the output. This design implicitly assumes a recursive element, namely a loop between the output sound and agent-performer: the agent determines the computer's changes of internal state, and the latter, as heard by the agent, may affect his or her next action (which in turn may affect the computer internal state in some way, etc).
>
> (Di Scipio, 2003, p. 270)

In relating this paradigm to the concept of cognitive-cultural networks, I have extrapolated the "interrelationship mediated by ambience", to which Di Scipio refers beyond purely the room ambience, into a parameter space one might describe as "cognitive ambience". Expanding the concept of ecosystemic design, into the realm of the human performer's cerebral sub-systems, presents an opportunity to explore a very distinctive epistemology in the relationship between mind and machine. It suggests a relationship, which taps into the 'cascade' model that Donald suggests encompasses the four phases of cognitive evolution, as they exist in modern humans engaging in artistic practice. This model asserts that musicians undertaking an improvisatory performance are coincidentally engaged in a practice that utilizes mimetic, mythic and theoretic modes of cognitive operation. They are utilizing all the cognitive apparatus, which spans the transitions from pure event perception, action modeling, shared attention, symbolic communication and technological augmentation.

Di Scipio's piece *Texture-Multiple*, for six instruments and room-dependent signal processing, was originally composed in 1993 but has been revisited by the composer a number of times since then. In the various iterations of this piece, Di Scipio would "try ideas concerning the interactions between human performance, machinery and space, that would later become central to the 'ecosystemic' pieces"(Placidi, 2010). He says of this work, "for the good or the bad, here human relationships are profoundly mediated by the technology. (Which is what happens in our daily life, nowadays)" (Placidi, 2010). Indeed, current technologies, alongside advancements in cognitive neuroscience, have extended the effects of the mediation to which he refers, to influence the way we react and respond to our environment. The cross-modal correspondences between taste and pitch being a good example, where it has been shown that an individual's perception of sweet or sour can be manipulated by sound (Crisinel and Spence, 2010). Extending the ecosystemic paradigm to include the performers' attentive behavior during performance, presents an opportunity to bear influence on the primal mimetic facility, which defines our response to audio-visual stimuli and the resultant action-model based behavior. The following extract is from Christine Anderson's, 2002 review of a performance of *Texture-Multiple* by Ensemble Mosaik in Berlin:

> The computer intervenes in the instrumental action through a special technique of multiple granularization with different time-scale factors. This granularization is dependent on the resonant properties of the

> performance space, which is tracked by a microphone placed in the middle of the room. Mr. Di Scipio calls the resulting feedback loop an "ecological system . . . in the triangle between musician, machine, and space." In his words, the composition is not so much a piece of interactive music as an attempt to "compose interaction through which music is created." The result is a highly exciting affair, not only for the audience but also for the performers.
>
> (Anderson, 2002, p. 83)

What is illuminated by this account is how the observations cohere three perspectives of the performance, bringing together the performance environment, the materiality of the music and the inner cognitive states of the audience and the performers. However colloquially expressed, the sentiments in this review indicate an holistic account of a performance system which includes environmental stimuli, algorithmic machine-based mediation and a reflexive human cognitive system, the only element of which was not present in Di Scipio's original definition of the ecosystemic performance paradigm being the inner working of the human mind.

BRAIN-COMPUTER INTERFACE (BCI)

The final element of this systemic triptych relates to the harvesting of the performers cerebral responses to their performance environment—the augmentation to Di Scipio's ecosystemic paradigm. Electroencephalograph (EEG) headsets are now low-cost consumer products. There are many computer-based or mobile apps, which allow direct 'brain' control of some aspect of a participant's environment. This might be an aspect of a video game, a remote-controlled car, a drone or a musical instrument. Although hundreds of different applications have now been developed, the vast majority of them share a similar feature. Fundamentally, they are control systems (George and Lécuyer, no date). After a period of training, the wearer of the BCI headset focuses their attention on achieving a task, and as a consequence their brain activity is captured, interpreted and sent as a control signal to a peripheral device. The generic term for this approach is known as active BCI (Ahn et al., 2014). This paradigm has a rich seam of research potential, and many journals and conferences have drawn from it. In relation to the two previous themes (CCN and ecosystemic environments) and the contentions outlined previously around improvised music-making, it seems plausible that the interventions in the cognitive causal sequence, from stimulus to musical behavior, could be achieved by BCI, but only if conscious intent was removed from the equation. One of the alternatives to active BCI is passive BCI (Ahn et al., 2014), where the participant perceives no sense of control over any aspect of the interaction. Using this approach the system monitors and reacts automatically to changes in mental state by quantifying the level of attention or differentiating among emotional states that are exhibited by the participant. In the context of the model suggested here, passive BCI allows for a flow of data from the performer into the performance environment, which is not the result of conscious control. In the same way that Di Scipio uses audio-capture technology to mediate between the performer and the performance space, this capture technology allows a type of mediation between the performers' low-level neurological response and their attentive awareness, thus suggesting the potential to subvert declarative memory, which is significantly influential in driving the auto-responsive musical behavior discussed in the opening of this chapter. The power of passive BCI in this context is to inject into the performance system a reflection of a performer's cognitive activity, which is generated by their engagement in the musical processes which are unfolding in the performance. This injection is not a stream of control data but a by-product of brain activity generated by musical engagement, which is nonetheless reflective and responsive to the performance. Introducing this element into the model is the final triangulation point, which connects the performer to their performance environment without requiring their attentive awareness and the cognitive baggage that this entails. The mimetic facility which forms the legacy of our evolutionary development is given voice through this capture channel and has the potential to be mediated by technology in such a way that it cultivates an ability to 'surprise ourselves'.

THE MODEL

By way of an exemplar, the theoretical themes of the chapter will be represented as a model for the development of new performance architectures. The model draws together the notion of cognitive-cultural networks, which Donald suggests reflects an arts practice within the context of cognitive evolution, together with Di Scipio's ecosystemic design, which is adapted to include the performers' brain activity, mediated by passive BCI. The binding concept, which holds these elements together, I suggest, is 'cognitive ambience', a term which encapsulates the flow of cultural influence among individual performers, in a real-time performance setting, mediated by their natural environment. By natural environment I am alluding to non-technological modes of communication, relying on instinct and fueled by sensory modalities. This does not of course discount technological components but augments the parameter-space to include communication between the performance entities that do not utilize digital technologies. An example of how this model could be implemented can be seen in the piece *Mondrisonic*, created for an improvising instrumental musician, a 'brain performer' wearing an EEG headset and an animated graphic score projected into the performance space. The piece was performed in public at the 4th International Performance Studies Network Conference in July 2016, with the improvising instrumentalist playing a bass clarinet and the graphic score projected onto a seven-meter-high media wall.

The arrows in Figure 2.1 show the flow of influence around the performance environment. In this implementation of the model the graphic score, which is styled on the paintings of Piet Mondrian, is a generative animation, which is responsive to the brain activity of the brain-performer. The score is itself sonified, and its audio output has a very direct, perceivable

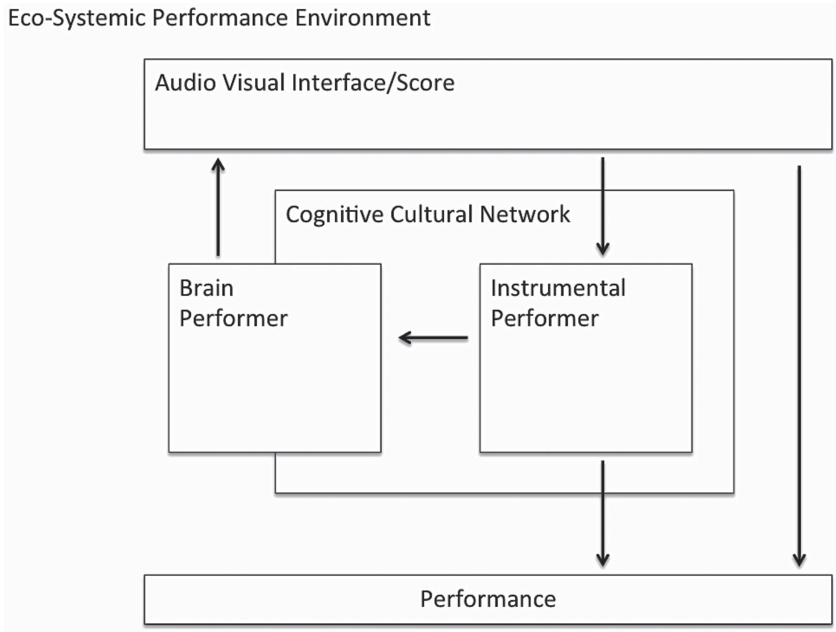

Figure 2.1 Mondrisonic Conceptual Schema

relationship to visual changes in the score. There are five tracks of audio, and each channel relates to a particular hue in the score's color pallet. The instrumental performer is therefore responding to a constantly changing mix of audio. As the piece progresses, the audio and color pallet change with each successive scene. As well as a score for the instrumentalist, the audience perceives the animation as an integral part of experiencing the piece. The particular brain activity, which is captured, is the level of attentiveness the brain performer gives to the improvisation of the instrumentalist. When this reaches a certain threshold level, a trigger is sent to the graphic score to stimulate changes in its generative output. These are perceivable by the instrumentalist, and so a curious loop is set in motion whereby the listening brain-performer is influenced by the instrumentalist, who in turn is influenced by changes in the graphic score. The causation that plays out is mediated through the 'cognitive ambience and is indicative of the type of cognitive-cultural network that Donald suggests has influenced behavior since early hominids first became self-aware. The first rendition of the piece lasted for 15 minutes and moved through five different sections, each with a different soundscape and re-mapped visual score. In each of the sections, the visual element of the score responsive to the brain performer changed. For instance, in one section, the speed of animated activity changed in response to the triggers from the brain-performer and in another the boundary between the visual elements was altered. One unforeseen characteristic of the performance was that, in embracing the principles of ecosystemic design, the brain-performer was susceptible to applying focused attention to any sonic elements in the performance space, even those not integral to the performance. This did indeed happen when ambient noise, not related to the performance, became a distraction and consequently caused a response in the audio-visual interface.

CONCLUSION

> When the individual "makes" a decision, that decision has usually been made within a wider framework of distributed cognition, and, in many instances, it is fair to ask whether the decision was really made by the distributed cognitive cultural system itself, with the individual reduced to a subsidiary role.
>
> —(Donald, 2008, p. 202)

The conceptual ideas implemented in the piece *Mondrisonic* were the first attempt to construct a simple CCN, which embraced Di Scipio's ecosystemic paradigm for the purpose of supporting improvising musicians striving to explicate their art in a manner that satisfies their desire to create music, which minimizes mechanical musical responses and maximizes originality. Of course, their perception of whether this has been achieved may fly in the face of a detailed objective analysis of their performance, but at present it is their perception that is being explored. The first experimental implementation of these ideas simultaneously violated and augmented the original ecosystemic principle, by not processing material from the acoustic environment but including brain activity generated by attentive focus on the acoustic environment. Future implementations will seek to redress this for a more holistic and faithful ecosystemic approach.

In Placidi's interview, Di Scipio makes reference to the ubiquity of technology in mediating relationships in everyday life (Placidi, 2010), a trend in which human agency is moving from one of active participation to passive involvement. Wearable devices are now available to provide feedback to the general public on general health signifiers such as sleep quality or blood pressure and suggest remedial action to avert a crisis, but it seems inevitable that in time they will detect and remedy symptoms without the need for the conscious attention of the wearer, as happens with serious medical conditions. Passive BCI has been selected for this investigation precisely to avoid the baggage of attentive awareness, primarily in this instance, conscious engagement with declarative memory. In a sense, what is proposed in this chapter is an approach that taps into two parallel epistemological traditions, the white-box approach of cognitive neuroscience and the black-box approach of experimental psychology. The first involves the monitoring, harvesting and mapping of specific neural activity onto the parameter-space of an environment designed for creative expression and the second, constructing the rules of engagement for human actors to explore during their conscious and non-conscious interactions with their environment. As Di Scipio puts it:

> The very process of "interaction" is today rarely understood and implemented for what it seems to be in living organisms (either human or

not, e.g. animal, or social), namely a by-product of lower-level interdependencies among system components.

(Di Scipio, 2003, p. 271)

The approach outlined here has many potential types of implementation, but at its conceptual core is an exploration of how technology can facilitate other modes of human agency, other than attentive focus, in improvisatory music-making and how the concept of ambience can be extended into the realm of human thought to provide a rich domain in which to build environmental relationships. This resonates with Di Scipio's desire to "shift from creating wanted sounds via interactive means, towards creating wanted interactions having audible traces" (Di Scipio, 2003, p. 271).

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