

Musical creativity and the embodied mind: Exploring the possibilities of 4E cognition and dynamical systems theory

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Abstract

The phenomenon of creativity has received a growing amount of attention from scholars working across a range of disciplines. While this research has produced many important insights, it has also traditionally tended to explore creativity in terms of the reception of products or outcomes, conceiving of it as a cognitive process that is limited to the individual domain of the creative agent. More recently, however, researchers have begun to develop perspectives on creativity that highlight the patterns of adaptive embodied interaction that occur between multiple agents, as well as the broader socio-material milieu they are situated in. This has promoted new understandings of creativity, which is now often considered as a distributed phenomenon. Because music involves such a wide range of socio-cultural, bodily, technological, and temporal dimensions it is increasingly taken as a paradigmatic example for researchers who wish to explore creativity from this more relational perspective. In this article, we aim to contribute to this project by discussing musical creativity in light of recent developments in embodied cognitive science. More specifically, we will attempt to frame an approach to musical creativity based in an 4E (embodied, embedded, enactive, and extended) understanding of cognition. We suggest that this approach may help us better understand creativity in terms of how interacting individuals and social groups bring forth worlds of meaning through shared, embodied processes of dynamic interactivity. We also explore how dynamical systems theory (DST) may offer useful tools for research and theory that align closely with the 4E perspective. To conclude, we summarize our discussion and suggest possibilities for future research.

Keywords

4E cognition, dynamical systems theory, embodied cognition, improvisation, musical creativity

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Introduction

Human creativity has traditionally been explored across a vast range of activities and domains (Kaufman & Sternberg, 2010; Shiu, 2013; Sternberg, 1988). Among these, the array of practices and experiences associated with the phenomenon of “music” may offer an especially rich area for theory, empirical research, and individual reflection (Burnard, 2012; 2013; Odena, 2012). Indeed, human musicality spans an impressive range of being, doing, and knowing—including, for example, primary interactions between infants and caregivers; emotion regulation; therapy and healing; the development of personal, social and cultural identities; collective performance; and the expression of complex aesthetic relationships (DeNora, 2000;

McPherson, Davidson, & Faulkner, 2012; Small, 1998). Because of this, developing deeper understandings of what musical creativity entails may result in finer conceptions of

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creativity more generally. This article aims to contribute to this project by exploring musical creativity in light of recent developments in embodied cognitive science. More specifically, we will attempt to frame an approach to musical creativity based in an *embodied, embedded, enactive* and *extended* (in short, “4E”) understanding of cognition (see Menary, 2010a, 2010b; Rowlands, 2010). In contrast with information-processing approaches to mind, which tend to discuss cognitive processes in terms of internal computations and representations, the 4E perspective sees cognition as distributed across the entire body of a living system and its surrounding environment, and as continuous with the fundamental adaptive biological processes required for survival and flourishing. As we will explore in more detail, this approach may help us better understand creativity not only in terms of products and outcomes, nor as a phenomenon that is confined to the inner mental domain of an agent, but rather as an essential aspect of how individuals and social groups bring forth worlds of meaning through shared and embodied processes of dynamic interactivity.

The article is structured as follows. We begin with a review of approaches to creativity. While these models all offer important insights, they tend to focus on the evaluation of creative products and/or mental processes confined to the individual. This, we suggest, may limit our understanding of creative phenomena. With this in mind, we then introduce more recent perspectives that highlight the relational (collaborative), distributed, and emergent nature of musical creativity (Burnard & Dragovic, 2014; O’Neill & Green, 2001; Sawyer, 1999, 2009; Woodman et al., 1993). Following this, we develop an approach to musical creativity based on the 4E model of cognition mentioned above, showing how this perspective may support and extend the richer view just described. Taking this further, we then explore the complex embodied–environmental interactivity associated with musical creativity through the lens of dynamical systems theory (DST). Building on previous creativity studies that discuss DST (e.g., Sawyer 1999, 2003; Schuldborg, 1999), we consider how this approach may lead to more nuanced understandings of what musical creativity entails—especially when developed in conjunction with accounts that situate specific instances of musical creativity in personal, historical, intersubjective, and cultural contexts. Here, we also consider possibilities for DST in controlled research settings by discussing results from a recent experiment (Walton, Washburn, Langland-Hassan, Chemero, Kloos, & Richardson, 2017) that measures how changes in the structure of a musical environment impacts the experience of creativity in interacting musical improvisers. We then offer some suggestions for how 4E and DST concepts might provide useful heuristics for thinking about creativity in cultural and historical contexts. To conclude, we summarize our discussion and briefly discuss its relevance for practical contexts such as music education and performance studies.

Before we begin, we would like to make it clear that this article is intended to spark dialogue and the exchange of ideas. Indeed, different approaches imply contrasting methodologies and theoretical assumptions, and the current contribution offers a new way to think about creativity and embodied music cognition that is different in its premises and scope from other perspectives.¹ We should also note that we are not aiming for some strict definition of what “creativity” entails. Like “music” we understand the term “creativity” to cover a wide range of phenomena.² It takes on different manifestations and characteristics and is recognized in different ways in different contexts—the diverse array of approaches we review in the next section all address important aspects of this multidimensional phenomenon. We suggest, however, that new insights may be found in perspectives that look beyond the traditional focus on the creative individual—and/or the reception of products and outcomes—and towards the embodied, ecological, and relational–interactive aspects of human creativity. As such, we are advocating for the inclusion of 4E/DST thinking as part of a broader, pluralistic approach to understanding the complex range of human thought, action, and experience associated with the words “music” and “creativity.” In all, then, our aim is not to overturn previous approaches to creativity, nor to offer the final word on what musical creativity entails, but simply to explore another perspective that might contribute to the field. Because of this, our discussion considers a range of areas and is often speculative in tone. Nevertheless, we hope that the ideas offered here will be interesting and provocative, inspiring further refinements as well as critical feedback.

Perspectives on creativity

As we have just begun to consider, human creativity is a complex phenomenon that takes on numerous forms and may be recognized in various ways depending on the context and criteria we impose. As a result, conceptions of creativity have changed over the centuries and vary across cultural and social contexts (Mpopu, Myambo, Mogaji, Mashego, & Khaleefa, 2006; Niu, 2006; Niu & Sternberg, 2006; Preiser, 2006; Preiss & Strasser, 2006; Sawyer, 2012). For example, in Ancient Greece the types of human activities and products we now refer to as “creative” were thought to be driven by *external* forces—the muses or some form of possession by a spirit (Dacey, 1999). During the Middle Ages, creativity came to be understood in terms of divine inspiration, or as a “gift” from a Christian God (Albert & Runco, 1999). This notion of creativity associated with “giftedness” continued into the Romantic era, but by then the locus of creativity had shifted to the *inner* domain of the artist, with the assumption being that there should be something innately and immanently “special” about creative individuals that allow them to produce the things they do (Albert & Runco, 1999). More recently, a range of scientific research has developed an understanding

of creativity not as the birth-right of select individuals, but rather as a universal human potential or disposition that may be developed in various ways. It has been suggested, therefore, that high-level creative achievements in the arts, sciences, and athletics do not emerge only because of “talent” or (some notion of) “genius,” but are largely the result of sustained practice and years of deep engagement with the domain in question (Bloom, 1985; Colvin, 2010; Csikszentmihalyi, 1996; Ericsson, 2016; Simonton, 1997, 1999). In all, current research and theory in creativity entails a rather diverse range of models and approaches, all of which offer important insights into the complex subject we are trying to understand. This said, it appears that much of this work tends to examine creativity in terms of two general assumptions (see Sawyer, 2003, 2006). The first understands creativity in terms of *products* that are categorized as creative according to various criteria. The second sees creativity in terms of *processes* associated with the personal domain of individual agents. We now turn to review these two orientations before moving on to explore other possibilities.

Products and categories

Current research explores creativity from a number of perspectives (e.g., cognitive science, developmental theories, biology, health and clinical sciences, education, business, cultural studies, computer science, and more). As such, it remains difficult to describe creativity in simple terms (see Runco, 2014; Veale, 2013). While scholars have put forward a number of contrasting possibilities, they generally agree that the generation of new and valuable outcomes (information, knowledge, procedures, artefacts, or other items) is a necessary element of creative processes (see Mumford, 2003). Because of this, much research and theory focuses on developing distinctions between a range of creative products and their reception. Here, creativity tends to be explored in terms of categories such as “big-c”³ and “little-c”—where the former refers to eminent, domain-changing outputs, and the latter to creativity in everyday problem-solving situations and creative expressions, which include the forms of wishful, imaginative, or counterfactual thinking that occur in everyday life (Byrne, 2005).

This approach has been developed in different ways (Kozbelt, Beghetto, & Runco, 2010; Runco, 2014). For example, in addition to “big-c” and “little-c,” Kaufman and Beghetto (2009) add “mini-c” and “pro-c.” The former describes the novel abilities and understandings that stem from an agent’s learning processes (e.g., a music student), while the latter concerns the types of products exhibited by professional creators (e.g., a music composer) who have not achieved eminent domain-changing (or big-c) accomplishments in society. Similarly, as Kirton (2003) argues, creativity may also be understood in terms of a spectrum between *adaptation* and *innovation*. Adapters develop and improve pre-existing methods and conditions, while

innovators initiate more radical changes that may revolutionize the way things are done in a given domain.

Another important approach is offered by Boden (1998, 2004), who posits three sub-types of creativity: *combinatorial creativity*, which entails the ability to combine pre-existing concepts and items in novel ways; *exploratory creativity*, which arises from the exploration of a given conceptual background; and *transformational creativity*, which involves a redefinition of a given theoretical or cultural framework. These forms of creativity are enhanced by another distinction put forward by Boden. This involves a *personal-psychological creativity* novel to the cognizer who generates it, and an *historical creativity* that is recognized by the cultural norms of the society in which the agent is situated.

These approaches can be applied to musical contexts in interesting ways. Consider, for example, the work of Arnold Schoenberg, who famously forged a new approach to composition. His work might be placed in the “big-c” category, be situated towards the “innovator” side of Kirton’s spectrum, and be representative of *transformational* and *historical* creativity in Boden’s model. By contrast, the output of film composer John Williams—who tends to juxtapose pre-existing styles in highly effective ways—might be situated as “adaptive,” categorized as “pro-c,” and reflect the *combinatorial creativity* discussed by Boden. However, while these approaches are indeed useful in categorizing creative agents in terms of the products they produce, they arguably tell us little about the actual experience of creativity. In other words, focusing on the individuation and description of different creative categories based on the reception and assessment of products does not offer a rich explanation of how creative thought and action comes forth, nor what it entails in phenomenological (experiential) terms.

Creativity as process

In light of the last remarks, other authors have offered a variety of models that attempt to understand creativity in more explicitly *process-based* ways. For example, the pioneering work of Wallas (1926) describes creativity in terms of both conscious (explicit) and subconscious (intuitive) mental processes. These involve stages of (a) *preparation*, the acquisition of knowledge; (b) *incubation*, the subconscious restructuring of knowledge; (c) *illumination*, the flash of insight; and (d) *verification*, the evaluation and application of the new idea. Here it is also important to mention post-World War II research in creativity, which examined what kinds of creative cognitive abilities might increase the chances of pilots and spies to survive in highly adverse conditions. Many of these studies (see Guilford, 1967) suggest that in such situations survival is dependent on the agent’s capacity to develop multiple possibilities for solving a given problem. Such thought processes are often referred to as “divergent” or “lateral” thinking (see

Gardner, 1993, p. 20), and are understood to play a central role in both everyday creativity, as well as the development of domain-changing outcomes. Again, this perspective is less concerned with the recognition of creativity vis-à-vis specific categories and products and is more interested in how people develop possibilities for action and thought; and how they become fluent at adapting such possibilities to the contingencies of a given situation through “convergent” thinking. Along these lines, Koestler (1964) introduces the term *bisociation* to highlight the combinatorial nature of creativity. According to Koestler, creativity arises from the integration (and not merely association) of two frames of thought that at first may seem completely disconnected. In his terminology, two “orthogonal matrices blend together,” giving rise to a creative outcome. While this approach does not develop the contextual aspects of creativity in detail, it might help explain in (general terms) how new musical ideas, pieces, or styles result from a process of blending between two or more different concepts, genres, or cultural traditions.

More recently, some authors have attempted to refine earlier process-based theories by introducing a range of new factors. In addition to the four processes discussed by Wallas (1926; see also Wertheimer, 1945), Hélie and Sun (2010) include creative problem-solving processes that entail the interaction of *implicit* and *explicit* forms of knowledge. In doing so they offer sub-categories that allow for more nuanced theoretical frameworks and thus greater precision in developing (connectionist) models. Likewise, Finke, Ward, and Smith (1992) describe an approach that involves a stage for *generation* and one for *exploration*. The former involves the development of representations—or “pre-inventive structures,” as they are referred to. The latter describes the process by which such structures are deployed in novel ways, resulting in creative ideas and action (see also Ward, 1995). These are further divided into additional sub-processes that describe how an agent moves back and forth between stages depending on their creative needs.

Looking ahead: Creativity as distributed and emergent

As we have seen, creativity is no longer conceived of as a divine or biological “gift,” nor is it understood only in terms of products. Increasingly, it is explored in terms of complex processes that occur in given situations. (Finke et al., 1992; Gruber, 1982; Hargreaves, Miell & MacDonald, 2012; Hennessey & Amabile, 2010). Here we should also note that the *product* and *process* orientations discussed above are not always mutually exclusive, and some approaches incorporate both to varying degrees. For example, in line with the concepts of “divergent” and “lateral” thinking we mentioned above, educational theorists have posited a process referred to as “possibility thinking” (PT) (see Craft, 1999, 2000; Cremin, Burnard & Craft, 2006). This involves encouraging students to move towards more

participatory ways of engaging with learning by developing “what if?” questions concerning a particular activity, domain, or thing. In this way, PT aims to enrich fact-based learning by having students look for possibilities (as opposed to simply focusing on technical questions such as “what is this and what does it do?”). Researchers have explored how this may facilitate moves from mini-c to little-c types of creativity in children and how such processes also provide the foundation for pro-c and big-c creativity later on (Beghetto, 2007). In short, creativity is now understood to take on manifold forms, to occur over multiple times scales, and to involve various contextually adaptive processes and outcomes.

Additionally, recent years have seen a move to understand the social dynamics of creativity, especially by researchers and theorists associated with music education who wish to foster more open and creative environments for teachers and students (e.g., Burnard & Dragovic, 2014). This aligns with a shift away from traditional “work-based” pedagogical approaches, where the focus was on developing the technical skills required for the reproduction of musical compositions, and where “creativity” was a domain (tacitly) reserved for the composer (Elliott & Silverman, 2015). Accordingly, musical creativity is now explored in conjunction with a range of activities and approaches that highlight the possibilities of collaborative music making. Among other things, research in this area explores non-formal learning processes (Green, 2001, 2008). This concerns the types of self-directed learning that occurs outside of the (formalized) school environment. Here, students develop a range of skills and understandings through engagement with creative-exploratory activities, whose processes and outcomes are not strictly defined, and where shared worlds of musical understanding are “enacted” collaboratively (Burnard, 2012; Schiavio & Cummins, 2015). In these contexts, improvisation and composition often become part of the same process (Sawyer, 2000, 2007; Swanwick & Tillman, 1986) and the body takes on a much more explicit and primary role (Bowman, 2004; Bowman & Powell, 2007). Here, participants may bring forth new ways of interacting with their instruments and each other. The cognitive relationships they develop and creatively manipulate are thus informed by the dynamic interactivity (feedback loops) that occurs between instrument, body, brain, and the environment, which includes the activity of other creative agents (more on this below; see Borgo, 2005; Walton, Richardson, Langland-Hassan & Chemero, 2015)⁴.

Importantly, we may note here that although the range of approaches discussed earlier in association with product- and process-based accounts all offer important insights into certain aspects of creativity, they do not address this last set of observations regarding the embodied and dynamically interactive (collaborative) processes that characterize musical creativity in practice. Rather, they tend to explore creativity in an individualistic context—often assuming

that it is something that necessarily occurs within the personal domain (i.e., in the head of) the individual. We suggest that this is not sufficient to meet the observations of the recent music education research just mentioned—which, again, increasingly highlights the embodied, situated, and socially interactive nature of musical activity (Barrett, 2005; Bowman, 2004; Bowman & Powell, 2007; Elliott & Silverman, 2015; Küpers, van Dijk, McPherson & van Geert, 2014; McPherson et al., 2012; van der Schyff, 2015). Such concerns have been addressed (among others) by Sawyer (2003, 2006), who draws on recent developments in social and distributed cognition (e.g., Greeno, 2006; Jordan & Henderson, 1995), and real-life experiences in musical and theatrical improvisation. In doing so, he develops a rich model for exploring creativity as a *distributed* and *emergent* phenomenon (see also Csikszentmihalyi, 1988, 1990; Gardner, 1993), where creative activity entails (at least) the following four characteristics:

1. The activity has an *unpredictable* outcome, rather than a scripted, known endpoint.
2. There is *moment-to-moment* contingency: each person's action depends on the action just before.
3. The interactional effect of any given action *can be changed* by the subsequent actions of other participants.
4. The process is *collaborative* (see Sawyer & De Zutter, 2009, p. 82).

In what follows we will attempt to support and develop this situated and socially interactive perspective on (musical) creativity through the lenses of the 4E approach to cognition and DST (see Sawyer, 1999, 2003; Schuldberg, 1999). As we go, we suggest that this approach may help us understand (musical) creativity not only in terms of products or individualistic processes, but also as a dynamically *embodied, embedded, enactive* and *extended* phenomenon that reflects the deeply adaptive relational nature of living cognitive systems more generally (Thompson, 2007; in musical contexts see Loaiza, 2016; Schiavio & Altenmüller, 2015; Schiavio, van der Schyff, Kruse-Weber, & Timmers R, 2017; Torrance & Schumann, 2018; van der Schyff, in press; van der Schyff & Schiavio, 2017).

Toward a '4E' approach to musical creativity

Humans engage in musical activities in various ways. These are continuously shaped by a range of social, biological, developmental, cultural, and historical factors (Clarke, 2005a; Cook, 2001; Cook & Everist, 1999; Cross, 2012; DeNora, 2000; Huron, 2006; Krueger, 2011, 2013; Small, 1998). Such activities may involve composing new music, improvising, dancing, reflecting on and writing about a particular piece, performing, listening, learning,

and employing music in a range of socio-cultural contexts (religious, therapeutic, etc.). And of course, the way musical experience is enacted differs with each type of activity and in relation to the context it is associated with—one can feel different emotions in each situation, or engage the body in different ways (dancing, conducting, etc.). Despite these differences, we suggest that the bio-cognitive⁵ processes at the basis of musical experience always involve an important creative engagement. We are aware that this may seem somewhat counterintuitive, particularly when considering how Western musicology has traditionally tended to treat creativity as a solitary achievement realized by great geniuses. Moreover, because psychological and philosophical approaches to musical creativity often focus on the *outcomes* of activities such as improvisation and composition it may also be difficult to see in what sense musical listening might be creative (but see Clarke, 2005b; Dunn, 1997). To deal with such issues, our approach will take a more “primordial” view of creativity than is usually entertained—one based in a 4E understanding of human cognition.

Embodied

Considering the mind as embodied means rethinking the boundaries between the neural and extra-neural (e.g., metabolic, thermodynamic, and muscular, among others) factors that drive cognitive processes. From this perspective, the brain becomes a part of a larger network that involves the nervous system and the sensorimotor capacities of the entire organism (e.g., Gallagher, 2005, 2011). In a sense, therefore, separating brain and body, perception and action, experience and behavior, may in fact be a largely artificial move that offers only limited accounts of what mental life really entails (Hurley, 1998, 2001; Thompson, 2007).

Shortly, we will develop such concerns through the lens of DST. For now, we ask the reader to consider the following example. If a bass player is given a novel instrument and is asked to improvise with it, he or she will not start only by “thinking” about what notes, phrases, dynamic and timbral configurations, and rhythmical patterns will be developed. That is, the process arguably does not first involve the generation of “mental maps” and explicit representations about the different possibilities offered by, for example, the new electric bass provided. Rather, improvising is intrinsically related to the actual ways the fingers hit the strings and how the instrument “responds” to the performer's intentions (i.e., what it “affords” in real time, as the improvisation unfolds), and how the entire body “feels”—how it facilitates and resonates with such activity, dynamically. Through this embodied form of *action-as-perception* (Nöe, 2006), new relationships emerge that span body, brain, instrument, and the emerging sonic world. In other words, the interplay between sounds and movement does not begin “in the head” but unfolds as the act of improvising reveals new creative horizons for musical

sounds and related motor possibilities to be explored. Along these lines, Merleau-Ponty (2002) describes how an organist sitting at an unfamiliar instrument generates musical possibilities by using his own body as a measurement tool (e.g., How far is this register? How distant is the seat and consequently, my body, from this pedal?). Likewise, Sudnow (2001) provides a detailed first-person account of the embodied processes involved in becoming an improvising pianist. Such phenomenological perspectives reveal that musical creativity is deeply dependent on our bodily power of action and unfolds in terms of motor possibilities (Gallagher & Zahavi, 2007).⁶ It is also important to note that several authors have discussed the “primacy of the body” even in seemingly passive listening contexts, exploring how our histories of experience as corporeal beings allow us to create meaning from such experiences (Johnson, 2007; Krueger, 2011, 2013; Schiavio & van der Schyff, 2016; see also Nagy 2017, for a focus on music composition).

Embedded

As we have begun to consider, the body does not simply provide biological support for an otherwise detached brain that “commands” behavior. Rather, it participates in driving cognitive processes (Gallagher, 2005). But this does not happen in a vacuum. Indeed, embodied minds are parts of broader physical and socio-cultural systems that shape and are shaped by the agents who inhabit them. As such, a growing number of scholars also consider cognition as *embedded* within such systems. This approach draws inspiration from the influential work of psychologist James Gibson (1966, 1979), who explored perception as an “ecological” process (see Mace, 1977). As Chemero (2009, p. 98) writes, Gibson’s standpoint has three major tenets.

1. Perception is direct (no mental representations).
2. Perception is primarily for the guidance of actions (it is not for neutral information gathering).
3. Perception is of affordances—directly perceivable, environmental opportunities for behavior.

But what does this understanding of perception as “affordances” for action reveal about how musicians negotiate meaning with their environment in creative ways? Consider, for example, a situation where an experienced trumpet performer and a beginner are both given a trumpet to look at. The expert player will be able to individuate a far richer variety of possibilities for action (affordances) than the amateur (Menin & Schiavio, 2012). Such possibilities may be understood to emerge from the dynamic relationship between an embodied agent and his or her history of action-as-perception with the instrument. This could be considered as relevant to creativity on a number of integrated situated and temporal scales—for example, how the

agent uses or (at a distance) understands the (musical) object and its possibilities in a given situation from moment-to-moment (short-term), and how such usage and understandings involve the adaptation of motor-based knowledge the agent has acquired through his or her history of development as embedded within a given milieu (long-term).⁷ All of this resonates closely with the embodied perspective just discussed, showing the deep relevance of sensorimotor activity in constituting the meaningful relationships that arise between agents and environment. Such insights are central to the enactive approach to cognition that we discuss next.

Enactive

The enactive dimension describes how organisms and their environments mutually determine each other (Varela, Thompson, & Rosch, 1991). Most centrally, this perspective highlights the active role living creatures play in developing patterns of (sensorimotor, neural, metabolic, interactive) activity that allow them to maintain a viable existence. Such sets of meaningful activities constitute what enactivists refer to as “sense-making,” which is ultimately equated with “cognition” (see Thompson & Stapleton, 2009). The enactive approach, therefore, replaces the more traditional input–output model of mind with a more relational story—where an agent’s ongoing history of interactivity (structural coupling) with the environment becomes central to his or her mental life. It should also be noted that while this perspective asserts the inseparability of organism and environment, it also seeks to provide a biological account of the autonomy we experience with ourselves and other living beings (Di Paolo, 2005; Schiavio & van der Schyff, 2018; Weber & Varela, 2002). To better understand how this is so we might consider the self-organizing social dynamics of joint music performance (e.g., a string quartet or a jazz trio). In such contexts, each performer is required to engage in circular processes of collaborative adaptive activity (Salice, Høffding, & Gallagher, 2017; Schiavio & Høffding, 2015). Here, individuality and collectivity must be continually renegotiated by each performer to sustain and develop the musical environment being enacted. This involves on-line cross-modal information coming from the individual parts being performed; an awareness of music as it unfolds “as a whole”; the shifting emotions and intentions of the musicians; their relationships to their instruments (and to their audience); as well as shared forms of visual, corporeal, and auditory signaling, and more. Broader ecological factors such as the nature of the acoustic space and the social significance of the musical event are also important to consider. In brief, musicians must individually and collectively initiate, and adapt to, a range of interacting dynamics in the larger musical system. They work within various levels of constraint to keep the musical environment coherent, maintaining their status as autonomous musical individuals whose

actions simultaneously inform and are informed by the musical environment they co-enact. Additionally, musical agents can and do push against such constraints to initiate transformations that keep the music vital or “alive.” Importantly, the way this occurs is primarily driven by the self-organizing dynamics of the system itself (more on this shortly in the context of DST).

Such processes are perhaps most evident in improvised settings, where the modes of interaction and the desired outcomes are less strictly defined (Borgo, 2005; Linson & Clarke, 2017; Schiavio, van der Schyff, Gande, & Kruse-Weber, 2018). However, even in situations where musicians are closely following a score, music-making is never simply a reproduction of that score. Rather, it always involves dynamic forms of negotiation and adaptation by and between performers, between performers and their instruments, and between performers and audience (Davidson & Good, 2002; Schiavio & De Jaegher, 2017).⁸

Extended

By now it should be evident that while each of the E’s in the 4E approach offers a certain perspective on the nature of cognition, they are not discrete. Rather, they overlap— aspects of one dimension will necessarily be reflected in the others. With this in mind, we conclude our look at the 4E approach with the “extended” aspect of cognition and creativity. This is an important dimension to consider because although many embodied approaches to cognition do, by necessity, focus on the situated aspects of cognition, it is often argued that too much focus on neural and bodily factors can obscure the dynamical processes of co-determination that occur between (musical) agents and their environments (Clark & Chalmers, 1998; Menary, 2010b; Rowlands, 2010).

The “extended” dimension of the 4E framework holds that “[biological and non-biological] features of the environment can co-constitute the mind” (Hutto & Myin 2013, p. 139; see also, Clark, 2010). Think, for example, of a percussionist improvising on an arrangement of instruments. In the process of enacting a meaningful relationship with this collection of instruments, the instruments must become part of the musician’s cognitive ecology. In other words, the performer might be seen as “offloading” his or her musical expertise to the instruments in ways that are “functionally coupled” with the broader musical environment. This is to say that, when needed, tools and objects from the environment can become integrative parts of mental life and the creative processes that go along with it (see Malafouris, 2008, 2013, 2015). The very act of engaging with musical objects and technologies—for example, composing by improvising on a specific instrument, by using music notation software (such as Finale or Sibelius), by notating by hand on a sheet of paper, and so on—can contribute greatly to how musical ideas develop. One might also consider the ways people use personal music listening

devices to regulate their emotions and to create unique “aesthetic” relationships with the everyday worlds they live through (Bull, 2000; 2007; Skånblad, 2013). In brief, non-biological components of the physical world are important parts of the realm of musical cognition and creativity. And as technology develops, they may well become ever more integrated with human bodies and brains.⁹

Finally, the extended mind is also relevant in the (social) contexts we began to discuss above. When groups of musicians enact shared musical environments, they may be understood to engage in shared or “participatory” forms of sense-making (De Jaegher & Di Paolo, 2007), which involves offloading and taking on various tasks required by the extended cognitive ecology (e.g., by entraining with a beat provided by a drummer). This could entail embodying various roles that are culturally instantiated to various degrees. Or it might involve the development of radically new extended musical ecologies through free improvisation, experimentation, novel technologies, and new approaches to composition, performance, and musical interaction more generally (Bailey, 1993; Laroche & Kadouch, 2015; Walton, Richardson, & Chemero, 2014; 2015).

A view from dynamical systems theory

From a 4E perspective, the mind may be understood as an emergent property of organism–environment interactivity, which involves biological, non-biological, cultural, social, technological, and historical dimensions. Here, cognition is not grounded first in internal representations, but rather in the ways living systems self-organize and autonomously enact dynamic patterns of behavior that are relevant to their continued survival and well-being. Such processes occur over various time scales at the level of the individual and the collective. Because of this, interacting, self-organizing agents may be understood to influence and, if the system is “functional,” help sustain each other’s behavioral dynamics. This results in what is sometimes referred to as larger-scale, multi-organism systems (Maturana & Varela, 1980, 1987; in a musical context see Walton et al., 2014). Here the cognitive agents act as “constraints” on each other to maintain the shared system they co-enact—they “work” to transform energy into *meaningful* activity (Deacon, 2012). As we have also considered, musical activity may be continuous with such self-organizing processes and the embodied, embedded, enactive and extended forms of (participatory) sense-making they entail. Listening, improvising, and coordinating musical actions more generally, all require reaching out to (social) musical environments in active ways—for example, by making (collaborative) moment-to-moment adaptations to perturbations in the musical ecology; and by initiating engagements (thought and action) that influence the state of the system, resulting in new relationships and perceptions. In brief, musical systems are functionally similar with living systems and, as such, may be

understood as dynamically self-organizing phenomena (Large, 2000; Large & Jones, 1999).

With this in mind, the theoretical and mathematical tools offered by DST may help us better understand musical creativity in terms of the 4E framework just discussed. Put simply, DST describes how self-organizing, complex, systems emerge and develop over time. In doing so it reveals aspects of the system that tend to converge and diverge as patterns of relative stability and instability. These are referred to as *attractors* and *repellers*, respectively, and are often represented on a topographical space, or a *phase portrait*. This describes how the possible states of a given system evolve—for example, areas where the system's state tends to evolve towards an attractor are shown as *basins of attraction*.¹⁰ While this approach has been used to offer useful mathematical descriptions of a range of non-organic self-organizing systems (Clark, 2001; Strogatz, 1994, 2001), it has also been explored more recently in biological contexts associated with coordinated movement, communication, problem solving, and cognition more generally. Here, important early research involves the famous “finger wagging” experiments by Kelso (Kelso, 1984; see also Haken, Kelso, & Bunz, 1985). These studies involved participants “wagging” the index fingers of both hands at various speeds in two different patterns of relative phase: (a) in-phase patterns, where the same muscles of each hand and arm were working at the same time; and (b) out-of-phase patterns, where the same muscles of each hand and arm moved in alternation. At slower tempos participants maintained coordinated (stable) wagging in both in- and out-of-phase patterns. However, at faster speeds they could only maintain stability with in-phase wagging; once a critical speed was achieved out-of-phase finger wagging exhibited a brief period of instability before falling into in-phase wagging. From the DST perspective, the possible states of the finger wagging system may be understood as tending towards two basins of attraction—a “deep” one at the in-phase state (most stable) and a “shallow” one at the out-of-phase state (less stable). However, at more rapid speeds only the in-phase pattern is stable. Here the shallow basin dissolves and the system organizes itself around the deep attractor only.

This research revealed that aspects of self-organizing behavior in living systems could be described using differential equations that express the magnitude of variability between pairs of (non-linearly) coupled components. And indeed, this approach has been enhanced in various ways, resulting in frameworks that describe a much wider range of behavioral, perceptual, and cognitive phenomena (Kelso, 1995; Schöner & Kelso, 1988a; for an overview see Chemero, 2009). Importantly, DST has been used to explore learning as a type of *phase transition*—whereby cognitive agents change the attractor layout of the system they are immersed in, creating new phase portraits and a range of new possible phase relations (Schöner & Kelso, 1988b).

A relatively simple manifestation of this can be seen in the work of Amazeen and colleagues (1996), who asked participants to learn to wag their fingers in more complex poly-rhythmic groupings (e.g., 5 left for every 4 right). Initially, the out-of-phase movements could only be maintained at slow tempi (as predicted by the studies just discussed). However, after sustained practice participants developed the ability to maintain complex out-of-phase patterns at fast tempos. In DST terms, this involves a *phase-space deformation* where, in this case, the basin at the out-of-phase attractor becomes deeper (attains greater magnitude) than the in-phase one through the sustained goal-directed activity of the participant (for a related study on musical synchronization see Large, 2000). Here it is also interesting to note that researchers (Stephen & Dixon, 2009; Stephen, Dixon, & Isenhowe, 2009) have documented distinct spikes in system entropy just before the “ah-ha!” experience associated with the moment of understanding (i.e., the enactment of a new, or “deeper,” attractor basin) involved with sustained investigation of a given problem.

The introduction of entropy to the system can be the result of the willful activity of the agent, or involve perturbations in the environment the agent must deal with—perhaps brought about by other agents, social and cultural developments, or other thermodynamic factors. Here the concept of a *strange attractor* can help us to understand such phenomena. These attractors are characterized by varying degrees of entropy and thus evolve over time within certain constraints. Under certain circumstances, however, they can also lead to *bifurcations* whereby new patterns of activity arise—that is, new attractors and attractor layouts. This is crucial for the survival of living systems, which must have the freedom to move, interact, and develop patterns of behavior in relatively stable conditions, but also be able to enact new forms of behavior in changing conditions. Because of this, we can think of a living agent's phase portrait as divided into a series of strange attractors that permit divergence in various directions within local basins (Schuldburg, 1999). This affords the bio-cognitive flexibility required to enact new attractor layouts through sustained adaptive-creative behavior. Such alterations of an agent's phase space might involve, for example, the embodied learning associated with acquiring the ability to walk, speak, and dance, or the process of learning to play an instrument (Smith & Thelen, 1994; Sudnow, 2001). Anyone who has attempted to learn a new multi-limb pattern on a drum kit will have experienced first-hand a phenomenon like the one described by the poly-metric finger wagging experiment discussed above (van der Schyff, 2016). Indeed, developing new ways of engaging bodily with an instrument (or a musical practice) can involve uncomfortable periods where one must depart from established patterns of activity, resulting in the system entropy described above. However, this is necessary to create new and richer

possibilities for thought and action (i.e., new basins of attraction and attractor layouts in DST speak).

In all, the DST perspective offers important tools for describing how agents develop new repertoires of meaningful action through interactions with the extended socio-material environments they are embedded in. As such, it can provide third-person descriptions that are relevant to a 4E perspective. In turn, the 4E approach can provide a useful framework exploring DST data in phenomenological terms. As we considered above, the ways agents develop new forms of corporally-based understanding unfolds in terms of their history of coupling with the environments they inhabit and actively shape. This occurs through sustained adaptive *embodied* action that occurs within the contingent socio-material milieu in which the agent is *embedded*. As such, “embodied” and “embedded” can be thought of as dimensions of experience whereby agents may describe how the interactivity between their corporeal states (muscular, emotional, affective, bodily feeling, and so on) and the dynamics of the environment develop over time (e.g., the feeling of creating a new attractor layout associated with the development of new skills and understandings). Additionally, and as we have just touched on, musical learning and creativity may be facilitated by goal-directed shifts in a musician’s relationship with the *extended* environment—for example, by the desire to learn and develop new musical possibilities—and often in collaboration with other musicians or teachers (Küpers et al., 2014; McPherson et al., 2012; e.g., Sawyer 2003). In line with this, the “extended” dimension can help to illuminate how the material (e.g., musical instruments, sound) and social aspects (other musicians, teachers) might co-constitute the mental and creative lives of individual agents—how periods of stability and perturbation engage different patterns of cognitive offloading; that is, new relationships with instruments and different forms of joint action (for relevant discussions in musical contexts see Tomlinson, 2015; van der Schyff & Schiavio, 2017; Schiavio & van der Schyff, 2018). Lastly, the “enactive” dimension examines what such developments mean for the life-world that is continually enacted by an agent, what new understandings and relationships have emerged.

With these ideas in mind, we now turn to consider a preliminary study by Walton and colleagues (2017) that examines interacting improvisers through the analytical tools of DST. In line with our interest in looking beyond the traditional focus on products, outcomes, and processes confined to individual creators, this will allow us to extend our discussion of creativity in a more explicitly social and collaborative direction that aligns with a 4E orientation.

Creative musical interaction: an example of an empirical study employing DST

As we have begun to explore, the possibilities of DST extend well beyond pairs of wagging fingers and limbs to

how embodied agents couple with the extended socio-material environments they are embedded in through the development of patterns of activity with the objects and other agents they interact with. This resonates with the work of researchers who examine musical listening as a process of “dynamic attending” that integrates neural, social, bodily, and ecological dimensions (Large & Jones, 1999; Large, Kim, Flaig, Bharucha, & Krumhansl, 2016; see also McGrath & Kelly, 1986). In the context of improvising musicians, however, numerous variables (i.e., control parameters) are associated with shifts or changes in expression (phase transitions) that emerge in musical performance. The unpredictable and fluctuating nature of improvised performances, in addition to their multiple interacting components, makes it such that identifying the dynamics of the phase transitions involved in such contexts is not a straightforward task. Because of this, developing truly meaningful analyses of multi-agent improvised performance will require analytical tools that can capture how non-linear interactions between multiple components evolve over various time scales. Recent developments in the mathematical analyses of dynamical systems are particularly well suited for these types of problems (Demos, Chaffin, & Kant, 2014; Walton et al. 2014). Here we discuss an example of how these tools were used to study the patterns of coordination that emerge between improvising musicians in different contexts, and how these kinds of measures might be used to identify such dynamics in relationship to creativity. We then consider how future studies of this kind might draw on the 4E framework.

Walton and colleagues (2017) observed changes in the coordination of the movements of pairs of pianists who were asked to improvise together in two different performance contexts. In doing so, they analyzed the relationships between coordinated motion, musical phase transitions, and the perception of creativity in participants. For half of the performances, the participants played over a backing track with the chord progression of the jazz standard *There’s no greater love*. For the other performances, they improvised with a drone consisting of the pitches D and A. The musicians performed eight 2-minute improvised sessions in each setting while their left arm, right arm, and head movements were recorded. Here, the backing tracks constituted different musical environments, wherein the paired improvising musicians coordinate adaptively and thus generate constraints on their co-performer’s musical expression—coordination is negotiated within the structure of the shared (extended) musical environment. In this case, the musical environment created by the swing backing track included harmonic and rhythmic structure, while the drone track provided only a single tone.

Results demonstrated that when improvising with the drone backing track the musicians showed more coordination in their movements than when improvising with the swing backing track. This aligns with the fact that as the musicians adapted to the performance environments,

improvising with the drone required more co-creation of rhythmic structure. Indeed, such activity appeared to demand the co-enactment of higher levels of constraint in their music and movement as they worked together to create and keep time. This study also suggests that the cooperative development of a stable musical environment may also support the moment-to-moment emergence of “freer” or more punctuated melodic and rhythmic expressions from each performer.

This is interesting when considered in light of the musicians’ reported experience in their post-session interviews. Musicians described having more “freedom” when performing with the drone as compared with the swing track. They claimed they could work together to “create time” and felt the opportunity to “truly interact” with one another (Walton et al., 2017). The freedom musicians reported when they could create time together demonstrates how the constraints on the temporal and social dimensions of musical interaction are highly interrelated. Musical environments that allow musicians to mutually constrain each other’s creative production—to obtain a balance between individual expression and group cohesion—may afford more creative opportunities for extended or “distributed” music-making (Linson & Clarke, 2017). Another interesting aspect of this study is the lack of a significant effect concerning visual information between the participating musicians. In other words, it seems that the degree of coordination may not always be affected by whether musicians are able to observe each other or not. A possible interpretation here is that the emerging musical environment does not necessarily require the integration of visual aspects for it to become self-sustaining. Rather, it may be that as long as certain basic requirements are met (e.g., “having a sense of freedom while performing” or being open to interact) musical creativity may develop in a range of contexts.

This moves our discussion above regarding the roles of stability and entropy for creativity and the enactment of new (musical) actions (finger wagging, drum-kit learning, and so on) into an explicitly shared, participatory, or socially extended context. Here we can hypothesize that the experience of freedom in music improvisation may involve the negotiation of a balance between stability and entropy—higher entropy does not necessarily indicate more creativity. This said, it appears that the introduction of entropy into the system is required to help to keep it creatively vital—it prompts participants to develop new meaningful relationships when previous ones become too repetitive or boring.¹¹ It is likely that anyone who has engaged in collective musical improvisation should be able to relate to this interpretation from experience. As we have discussed, this activity involves the constant negotiation of interactive dynamics—where periods of instability may sometimes be willfully introduced and developed by the players as a way of keeping the music “alive” (for related discussions in the context of jazz and free improvisation see Bailey, 1993; Berliner, 1994, p.378; Borgo, 2005; Corbett,

2016; Iyer, 2002, 2004a, 2004b; Toop, 2016). In such contexts, creativity entails in-the-moment “play” with the levels of entropy and stability in the system—a skill that master improvisers become highly adept at. And so, while the kind of improvised creative activity associated with the drone track just discussed might be understood as indicative of a gradual kind of evolution, other forms of improvising involve more radical, “punctuated” types of development that require the system to adapt in unexpected ways. Exploring such processes could offer an interesting “next step” for experiments of this kind.¹² Another challenge for future studies involves identifying more precisely where phase transitions reflect novel insights or new modes of activity. In addition to audio and video documentation and interviews with the performers, this might also entail conducting surveys with experienced listeners to have them identify major changes in the musical activity and then seeing if these correlate with changes in dynamical measures, such as entropy.

A 4E approach could be useful in framing and interpreting such research as it offers a way for the dynamics of corporeal and ecological (social, instrumental, sonic) dimensions to be examined within an overlapping, relational framework. As the preliminary experiment involving the improvising keyboard players suggests, correlations may be made between:

1. The *embodied* dynamics of creative musical action: the motor and affective aspects associated with how musicians simultaneously produce and experience musical sound.
2. The *embedded* dynamics of the shared creative niche: how musicians adaptively situate themselves in relation to the musical (physical and social) environment they are part of—that is, how they skillfully relate to each other, their instruments, and other musically relevant technologies, materials, and cultural factors they encounter.
3. The *enactive* dynamics of the performers’ relational autonomy—how unique musical identities and environments emerge through the self-organizing activity of musical agents, and how these processes shape relational and creative constraints in an ongoing way.
4. The *extended* dynamics of the musical event—how musicians use instruments and other technologies as parts of their cognitive domain; and how they adaptively offload and take on various social tasks related to maintaining a balance between stability and entropy within an ensemble.

While aspects of these dimensions can be objectively correlated and compared using DST, the 4E framework may afford more nuanced first- and second-person analyses. Integrating both perspectives could offer rich multi-dimensional accounts that describe and compare the

dynamics and experience of musical creativity from a wider range of “lived” perspectives.

Dynamical heuristics

Before we conclude, we would like to develop our discussion in a more philosophical and heuristic context by suggesting a few ways that DST and 4E concepts might be applied in terms of thinking about musical creativity in cultural and historical domains. One way to do this involves the idea of a musical *worldview* (Velardo, 2016; see also Gabora, 2017). Ideally, this describes the development (the transforming phase portrait) of a musical agent (x), showing how their musical values, ideas, and beliefs change over time (t) (Gimenes & Miranda, 2011). For example, a person who has listened only to Western-based music, might find it difficult to understand and to appreciate Indian classical music because this is outside of their musical worldview. However, this person’s world view could be expanded, among other ways, through sustained engagement with this music. This could involve more focused listening, whereby the agent may begin to perceive relationships in (and develop a personal relationship with) the music. It might also entail learning to play this kind of music and developing a deeper engagement with the culture it is associated with. This could result in new understandings and possibilities for perception and action—the *enactment* of new attractor basins in DST-speak.

Along similar lines, one might explore the subset of an agent’s worldview associated with musical style.¹³ In this case, the DST concept of a “strange attractor” we considered above could be used to represent a set of stylistic configurations that are similar and coherent—once the state of an agent is inside one of these attractors, they can freely move within its parameters. For example, one might think of an attractor for Baroque music and another for late Romantic music. Here the music of Vivaldi might be understood as confined to (or “embedded in”) the Baroque attractor. His musical evolution explores different flavors of Baroque music that correspond to different points within the Baroque attractor. The evolution of a composer like Schoenberg, however, highlights a different possibility as his development is characterized by a more radical change in compositional style from late Romantic music to dodecaphonic serialism. This could be thought of as a change (or addition) of attractors in the composer’s musical worldview—that is, from the late Romantic attractor towards the “dodecaphonic basin.” In line with our discussion of improvisers above, these two examples suggest the possibility of (at least) two general types of (stylistic) evolution; namely, *gradual evolution* and *punctuated evolution*. Agents following gradual evolution remain inside (or create within) a given attractor (e.g., Vivaldi). By contrast, in punctuated evolution an agent goes through a phase of increasing system entropy before a bifurcation occurs, and, as a result, the

agent exits the current attractor and enters, or indeed, “enacts” a new one (e.g., Schoenberg).¹⁴

Here, readers may note a similarity between the concepts of gradual/punctuated evolution and those of exploratory/transformational creativity as defined by Boden (2004; see above). Exploratory creativity is a form of gradual evolution, where an agent creates new artefacts within a given conceptual space (i.e., an attractor). Transformational creativity, by contrast, is a form of punctuated evolution in that it entails the generation of new possibilities for perception and action (and resulting artefacts) that are substantially different from those previously generated (i.e., motion from one attractor to another). However, from the 4E perspective, such dynamic evolution cannot be confined to an individual. Rather it is inextricably linked with his or her history of coupling with the embedded environment (Varela et al., 1991). This could involve macro-level shifts whereby an agent’s society comes in contact with or becomes more open to other cultures. Changes in worldview can also be associated with the emergence of new technologies (e.g., the pianoforte, electronics, the computer), socio-cultural transformations (e.g., free jazz and the civil rights movement; commodification and mass production) or when artists push against the boundaries of existing macro-level (cultural) attractors associated with aesthetics and practice. For example, consider how Beethoven’s late string quartets were highly criticized by his contemporaries for their bold use of quasi non-tonal harmonic structures (Knittel, 1998)—owing, perhaps, to a visionary shift in the musical worldview of the composer (brought about by decades of engagement with music) that many of his contemporaries found incoherent with their own. Today these works are generally considered to be masterpieces and arguably paved the way for later developments in Romantic and post-tonal music. One might trace the development of Coltrane or Hendrix in similar ways. Both were *embedded* deeply within the musical society of the mid-20th-century United States, and both played a key role in transforming that society. In the process, they expanded the sets of relationships within established genres of musical practice, and *enacted* new forms of music making. They developed new basins of activity and understanding involving novel *embodied* patterns of musical action and perception. This resulted in new sonic affordances for the saxophone and guitar, respectively—new *extended* musician–instrument–ensemble relationships that, in turn, contributed to the evolution of the broader cultural portrait (Clarke, 2005b; van der Schyff, 2015).¹⁵

And so, while creative musical agents do enact musical actions that imply simpler attractors (e.g., playing a repeating rhythm), and move within more established basins of activity associated with a given style, they can also willfully destabilize such attractors. In doing so, they can create music that (a) approaches completely chaotic dynamics or involves stochastic or aleatoric processes (e.g., Luciano Berio, John Cage); (b) involves the “collision” of multiple

(e.g., stylistic, rhythmic) attractors (e.g., Charles Ives, Ornette Coleman); or (c) they can co-enact new basins of attraction characterized by new sets of bodily, sonic, and social relationships (e.g., through free improvisation; see Borgo, 2005). 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 (Capra, 1996; Rosenberg, 2010; Schuldberg, 1999; Strogatz, 1994). Moreover, such “outcomes” need not be understood as a “finished product.” Rather, they alter the constraints of the environment, leading to new developments in the system. By this view, creative activity—on both historical and in-the-moment timescales—may be said to involve the enactment of ongoing recursive “feedback” and “feedforward” loops between embodied agents and the extended material, social, and cultural environments they are embedded in and actively shape (Borgo, 2005; for related discussions in developmental and evolutionary musicology see Schiavio, van der Schyff, Cespedes-Guevara, & Reybrouck, 2017; and van der Schyff & Schiavio, 2017).

To summarize, from this perspective musical agents and environments can be understood as self-organizing dynamic systems that develop through histories of interactivity—agents and environments are structurally coupled in a non-linear way and are therefore co-evolving. Thus, the enactment, maintenance, and development of stable basins of practice and understanding, as well as emergence of new ones cannot be reduced to the agent or the products they create. As the discussion above suggests, this approach might offer useful possibilities for thought and analysis in the context of case studies in the development of musical creativity (e.g., instrumental practice and compositional development) and for historical and cultural musicology. For example, the approach taken in the study by Walton and colleagues (2017) might be further extended to explore the development of individual performers or ensembles over different time scales (in both professional and educational contexts). This could involve the comparative analysis of (historical or field) video and audio documents through the lenses of DST and the 4E framework. Again, this could result in the useful integration of a range of perspectives (DST analysis, 4E/phenomenological perspectives, historical and cultural accounts, and more).

Conclusion

The study involving interacting improvisers discussed above offers a preliminary, but nevertheless highly promising example of how DST might be developed in empirical contexts. Using DST methods to measure changes in the structure of variability in musicians’ behaviors when they

experience higher levels of creative freedom could help us to better identify how certain environmental constraints give rise to dynamics that provide the “right” kind of tensions—the right kind of pushes and pulls between a system’s components—for this to occur. Among other areas, this has implications for music education in terms of understanding what kinds of environments may foster creativity. It may also have a great deal to offer for researchers in music performance studies. For example, the framework we introduced here might shed light on how a musical ensemble develops the relevant shared patterns of action and perception required to perform a difficult piece of music—how they enact unique ways of communicating as enmeshed components of a communal musical environment by adapting to and/or instigating moments of entropy and nudging the system into new shared basins of attraction. As we have also seen, this approach allows us to integrate aspects that are not limited to the sonic dimension—including bodily engagements, social and cultural developments, and the ways creative activity extends to the objects and other agents that constitute the musical ecology. Likewise, as we suggested, the notion of musical worldview and other dynamical/4E concepts might offer useful ways of thinking about and describing the creative development of musical agents and musical cultures—for example, how the perceptual boundaries of music, as well as what is recognized to be musically creative, depend on the musical worldviews of agents in interaction with the environments they are embedded in, and how such views evolve over time through the dynamic interaction of a range of components. This might be developed in the context of case studies of living musicians, as well as with historical figures. Importantly, all of this does not mean that the examination of creativity should eschew the idea of products and the study of processes associated with individual creators. Indeed, the approaches discussed at the outset all offer useful insights into various aspects of creativity. However, we suggest that these aspects should not be studied in isolation and that richer accounts are possible when a range of dimensions are juxtaposed.

In line with this, we have introduced here a few examples of how DST and 4E cognition might model the “preferences” and potentials for creative (musical) activity over a range of interacting dimensions. We have also considered how these orientations offer a multidimensional approach that could help better accommodate the complex range of phenomena we refer to with the words “music” and “creativity.” On a more fundamental level, we have also suggested that this orientation may help us better understand creativity as continuous with the self-organizing processes by which all living creatures reach out to, communicate with, and, in the process, enact viable (meaningful) relationships with a changing world. In all, we hope to have added new layers of descriptive possibility to the distributed and emergent approach to creativity discussed above, and that future research and theory will

develop this more fully. Indeed, while DST models cannot describe the rich phenomenology of musical experience, we suggest that they can be used as “guides to discovery” (Chemero, 2000, 2009) for a number of musically relevant processes. That is, they can provide general levels of analysis and description that may help to guide research and theory in more specific contexts. The 4E framework, for its part, does offer a way for relevant dimensions of creative activity to be examined and discussed from situated first-person perspectives—it could be used to interpret data and as a way of framing research questions in qualitative contexts (e.g., interviews). It may thus offer an important phenomenological grounding for DST. Taken together, then, these two approaches may offer a range of important insights in years to come.

Contributorship

D.v.d.S. made major contributions to content in all areas of the paper, especially in the sections “Perspectives on creativity” and “A view from dynamical systems theory”; he facilitated the collaboration and developed the final draft. A.S. developed the section “Toward a ‘4E’ approach to musical creativity”; made substantial contributions to the section “Perspectives on creativity”; and provided suggestions throughout the development of the paper that were implemented in the final draft. A.W. is the main contributor to the sub-section “Creative musical interaction: an example of an empirical study employing DST.” V.V. provided suggestions that were developed in early drafts of the paper and made contributions to the sub-section “Dynamical heuristics.” A.C. made contributions to “Creative musical interaction: an example of an empirical study employing DST” and provided suggestions for the section “A view from dynamical systems theory” that were implemented in the final draft.

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Notes

1. This includes important work in “embodied music cognition” (e.g., Leman, 2007), which differs in certain respects in its theoretical orientation from the more “radically embodied” approach discussed in this article. In many ways this mirrors recent discussions in embodied cognitive science. Some approaches understand the body as

playing a crucial mediating role between the environment and the representational information processing that occurs in the brain. By contrast, others argue that the body is more than a mediator between outer and inner realities. It is, rather, a cognitive domain in its own right – one that is dynamically integrated with the brain and environment. A key issue that differentiates these approaches is that the former relies on a notion of (internal) “representation” as the foundation for cognitive processes, while the latter does not (for more detailed accounts of the differences between these orientations see Barrett, 2011; Chemero, 2009). Likewise, while much research in embodied music cognition aligns with a representational orientation (e.g., MacRitchie, Varlet, & Keller, 2017), our discussion aims to develop the latter “radically embodied” perspective.

2. Like the concept of “game,” “music” and “creativity” appear to be phenomena with vague boundaries and arguably cannot be understood in separation from context (Wittgenstein, 2001/1953).
3. “c” stands for “creativity.”
4. Studies of individual creators have revealed a high degree of collaboration behind their outputs when researchers include their social and cultural contexts (see Csikszentmihalyi, 1996; Farrell, 2001; John-Steiner, 2000).
5. We hyphenate “bio-cognitive” here to stress that the biological and cognitive are continuous rather than discrete.
6. Similarly, research by Davidson (1993, 2001) has examined the expressive and communicative role played by the body in the context of performance (see also Clarke & Davidson, 1998).
7. As Iyer (2002) has shown, the microtimings associated with ways musicians engage bodily with their instruments and each other may be “tempered” by the culture and genre a performer is working in. The broader socio-cultural ecology provides constraints on the in-the-moment activities of creative musicians.
8. Two performances of the same piece, in other words, will never truly be the same. Here it is also worth noting that similar factors may be associated with music listening, where, again, the meanings that arise depend on the agent’s capacities for active sense making. This is developed by Clarke (2005b), for example, who considers a range of ways musical listening involves the imagination, and how listeners actively bring together a range of situated, personal, bodily, historical and socio-cultural factors to make sense of a given musical experience.
9. This might involve, for example, the implementation of neurally connected devices that communicate with extended databases, as well as virtual collaborative spaces and instruments, potentially allowing musicians to extend their creative reach in ways we are only just beginning to explore with current technology (for related speculations see Clark, 2003, 2010).
10. This has been developed in a range of contexts including weather systems, bird flocking, lasers, and insect swarming (see Strogatz, 1994, 2001).
11. See also Doffman (2009, p.144), whose findings suggest that intimacy and the sense of participation were not enhanced solely by higher levels of synchronization, but required the ability (freedom) to actively distort the musical structure.

12. For related approaches see Aucouturier and Canonne, 2017; Borgo, 2005; and Canonne and Garnier, 2012.
13. It should be noted that practical applications of this approach are currently being developed. Preliminary work is being done employing relevant mathematical tools associated with DST to model virtual creative music agents (see Gimenes, 2013; Gimenes, M. & Miranda, E. R., 2008, 2011; see also Velardo, 2016).
14. For a similar approach in the context of jazz composition see Rosenberg, 2010.
15. Likewise, from this perspective Schoenberg's move to serialism cannot be properly understood as restricted to the artist himself. Rather, it was facilitated by his interaction with a range of environmental factors that include the emerging critiques of European culture and aesthetics, the composers and other artists of his day, as well as his many brilliant students, who went on to develop their own influential worldviews.

References

- Albert, R. S., & Runco, M. A. (1999). The history of creativity research. In R. S. Sternberg (Ed.), *Handbook of human creativity* (pp. 16–31). New York, NY: Cambridge University Press.
- Amazeen, E. L., Sternad, D., & Turvey, M. T. (1996). Predicting the nonlinear shift of stable equilibria in interlimb rhythmic coordination. *Human Movement Science*, 15, 521–542.
- Aucouturier, J. J., & Canonne, C. (2017). Musical friends and foes: The social cognition of affiliation and control in improvised interactions. *Cognition*, 161, 94–108.
- Bailey, B. (1993). *Improvisation: Its nature and practice in music*. New York, NY: Da Capo.
- Barrett, L. (2011). *Beyond the brain: How body and environment shape animal and human minds*. Princeton, NJ: Princeton University Press.
- Barrett, M. (2005). A systems view of musical creativity. In D. J. Elliott (Ed.), *Praxial music education: Reflections and dialogues* (pp. 177–195). New York, NY: Oxford University Press.
- Beghetto, R. A. (2007). Ideational code-switching: Walking the talk about supporting student creativity in the classroom. *Roeper Review*, 29, 265–270.
- Berliner, P. (1994). *Thinking jazz: The infinite art of improvisation*. Chicago: University of Chicago Press.
- Bloom, B. S. (1985). *Developing talent in young people*. New York, NY: Ballantine Books.
- Boden, M. A. (1998). Creativity and artificial intelligence. *Artificial Intelligence*, 103, 347–356.
- Boden, M. A. (2004). *The creative mind: Myths and mechanisms*. London, UK: Routledge.
- Borgo, D. (2005). *Sync or swarm: Improvising music in a complex age*. New York, NY: Continuum.
- Bowman, W. (2004). Cognition and the body: Perspectives from music education. In L. Bresler (Ed.), *Knowing bodies, moving minds: Towards embodied teaching and learning* (pp. 29–50). Dordrecht, The Netherlands: Kluwer Academic Press.
- Bowman, W., & Powell, K. (2007). The body in a state of music. In L. Bresler (Ed.), *International handbook of research in arts education* (pp. 1087–1106). Dordrecht, The Netherlands: Springer.
- Bull, M. (2000). *Sounding out the city: Personal stereos and the management of everyday life*. Oxford, UK: Bloomsbury Academic.
- Bull, M. (2007). *Sound moves. iPod culture and urban experience*. London: Routledge.
- Burnard, P. (2012). *Musical creativities in practice*. Oxford, UK: Oxford University Press.
- Burnard, P. (Ed.) (2013). *Developing creativities in higher education: International perspectives and practices*. London, UK: Routledge.
- Burnard, P., & Dragovic, T. (2014). Characterizing communal creativity in instrumental group learning. *Departures in Critical Qualitative Research*, 3, 336–362.
- Byrne, R. M. J. (2005). *The rational imagination: How people create counterfactual alternatives to reality*. Cambridge, MA: MIT Press.
- Canonne, C., & Garnier, N. B. (2012). Cognition and segmentation in collective free improvisation: An exploratory study. *Proceedings of the 12th International Conference on Music Perception and Cognition and 8th Triennial Conference of the European Society for the Cognitive Sciences of Music*, 197–204. Retrieved from http://icmpc-escom2012.web.auth.gr/files/papers/197_Proc.pdf
- Capra, F. (1996). *The web of life: A new scientific understanding of living systems*. New York, NY: Anchor Books.
- Chemero, A. (2000). Anti-representationalism and the dynamical stance. *Philosophy of Science*, 67, 625–647.
- Chemero, A. (2009). *Radical embodied cognitive science*. Cambridge, MA: MIT Press.
- Clark, A. (2001). *Mindware*. New York, NY: Oxford University Press.
- Clark, A. (2003). *Natural born cyborgs*. New York, NY: Oxford University Press.
- Clark, A. (2010). *Supersizing the mind: Embodiment, action, and cognitive extension*. Oxford, UK: Oxford University Press.
- Clark, A., & Chalmers, D. (1998). The extended mind. *Analysis*, 58, 7–19.
- Clarke, E. F. (2005a). Creativity in performance. *Musicae Scientiae*, 9, 152–182.
- Clarke, E. F. (2005b). *Ways of listening: An ecological approach to the perception of musical meaning*. Oxford, UK: Oxford University Press.
- Clarke, E. F., & Davidson, J. W. (1998). The body in performance. In W. Thomas (ed.), *Composition – performance – reception* (pp. 74–92). Aldershot, UK: Ashgate.
- Colvin, G. (2010). *Talent is overrated: What really separates world-class performers from everybody else*. New York, NY: Portfolio.
- Cook, N. (2001). Theorizing musical meaning. *Music Theory Spectrum*, 23, 170–195.
- Cook, N., & M. Everist (Eds.) (1999). *Rethinking music*. Oxford, UK: Oxford University Press.
- Corbett, J. (2016). *A listener's guide to free improvisation*. Chicago: University of Chicago Press.

- Craft, A. (1999) Creative development in the early years: Some implications of policy for practice. *The Curriculum Journal*, 10, 135–150.
- Craft, A. (2000). *Creativity across the primary curriculum*. London: Routledge.
- Cremin, T., Burnard, P., & Craft, A. (2006) Pedagogy and possibility thinking in the early years, *International Journal of Thinking Skills and Creativity*, 1, 108–119.
- Cross, I. (2012). Music and biocultural evolution. In M. Clayton, R. Middleton, & T. Herbert (Eds.) *The cultural study of music: A critical introduction* (pp.17–27). London, UK: Routledge.
- Csikszentmihalyi, M. (1988). The flow experience and its significance for human psychology. In M. Csikszentmihalyi & I. S. Csikszentmihalyi (Eds.), *Optimal experience: Psychological studies of flow in consciousness* (pp. 15–35). New York: Cambridge University Press.
- Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. New York, NY: Harper & Row.
- Csikszentmihalyi, M. (1996). Creativity: Flow and the psychology of discovery and invention. New York, NY: Harper/Collins.
- Dacey, J. (1999). Concepts of creativity: A history. In M. A. Runco & S.R. Pritzer (Eds), *Encyclopedia of creativity, Vol. 1 A–H*. San Diego, CA: Academic Press.
- Davidson, J. W. (1993). Visual perception of performance manner in the movements of solo musicians. *Psychology of Music*, 21, 103–13.
- Davidson, J. W. (2001). The role of the body in the production and perception of solo vocal performance: A case study of Annie Lennox. *Musicae Scientiae*, 5, 235–56.
- Davidson, J. W., & Good, J. M. (2002). Social and musical coordination between members of a string quartet: An exploratory study. *Psychology of Music*, 30, 186–201.
- Deacon, T. (2012). *Incomplete Nature: How mind emerged from matter*. New York, NY: W. W. Norton & Co.
- De Jaegher, H., & Di Paolo, E.A. (2007). Participatory sense-making: An enactive approach to social cognition. *Phenomenology and the Cognitive Sciences*, 6, 485–507.
- DeNora, T. (2000). *Music in everyday life*. New York, NY: Cambridge University Press.
- Demos, A. P., Chaffin, R., & Kant, V. (2014). Toward a dynamics theory of body movement in musical performance. *Frontiers in Psychology*, 5, 477. doi:10.3389/fpsyg.2014.00477
- Di Paolo, E. A. (2005). Autopoiesis, adaptivity, teleology, agency. *Phenomenology and the Cognitive Sciences*, 4, 97–125.
- Doffman, M. (2009). Making it groove! Entrainment, participation and discrepancy in the ‘conversation’ of a jazz trio. *Language and History*, 52, 130–147.
- Dunn, R. E. (1997). Creative thinking and music listening. *Research Studies in Music Education*, 8(1), 42–55.
- Elliott, D. J., & Silverman, M. (2015). *Music matters: A philosophy of music education, 2nd Edition*. New York, NY: Oxford University Press.
- Ericsson, K. A. (2016). *Peak: Secrets from the new science of expertise*. Boston, MA: Houghton Mifflin Harcourt.
- Farrell, M. P. (2001). *Collaborative circles: Friendship dynamics and creative work*. Chicago: University of Chicago Press.
- Finke, R. A., Ward, T. B., & Smith, S. M. (1992). *Creative cognition*. Cambridge, MA: MIT Press.
- Gabora, L. (2017). Honing theory: A complex systems framework for creativity. *Nonlinear Dynamics, Psychology, and Life Sciences*, 21, 35–88.
- Gallagher, S. (2005). *How the body shapes the mind*. Oxford, UK: Oxford University Press.
- Gallagher, S. (2011). Interpretations of embodied cognition. In W. Tschacher & C. Bergomi (Eds.), *The implications of embodiment: Cognition and communication* (pp. 59–71). Exeter, UK: Imprint Academic.
- Gallagher, S., & Zahavi, D. (2007). *The phenomenological mind: An introduction to philosophy of mind and cognitive science*. London, UK: Routledge.
- Gardner, H. (1993) *Frames of Mind: The theory of multiple intelligences*. New York, NY: Basic Books.
- Gibson, J. J. (1966). *The senses considered as perceptual systems*. Boston, MA: Houghton-Mifflin.
- Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston, MA: Houghton-Mifflin.
- Gimenes, M. (2013). Improved believability in agent-based computer musical systems designed to study music evolution. *International Symposium on Computer Music Multidisciplinary Research*, Marseille, France. 15–18 October. Retrieved from https://www.researchgate.net/publication/318431949_Improved_Believability_in_Agent-Based_Computer_Musical_Systems_Designed_to_Study_Music_Evolution
- Gimenes, M., & Miranda, E. R. (2008). An A-Life approach to machine learning of musical worldviews for improvisation systems. *Proceedings of 5th Sound and Music Computing Conference*, Berlin, Germany. Retrieved from http://smcnetwork.org/files/proceedings/2008/session1_number1_paper5.pdf
- Gimenes, M., & Miranda, E. (2011). Emergent worldviews: An ontomemetic approach to musical intelligence. In Eduardo R. Miranda (Ed.), *A-Life for music: On music and computer models of living systems*. Middleton, WI: A-R Editions.
- Green, L. (2001). *How popular musicians learn: A way ahead for music education*. London, UK: Routledge.
- Green, L. (2008). *Music, informal learning and the school: A new classroom pedagogy*. Aldershot, UK: Ashgate.
- Greeno, J. G. (2006). Learning in activity. In R. K. Sawyer (Ed.), *Cambridge handbook of the learning sciences* (pp. 79–96). New York, NY: Cambridge University Press.
- Gruber, H. (1982). On the hypothesized relation between giftedness and creativity. *New Directions for Child and Adolescent Development*, 17, 7–29.
- Guilford, J. P. (1967). *The nature of human intelligence*. New York, NY: McGraw-Hill.
- Haken, H., Kelso, J. A. S., & Bunz, H. (1985). A theoretical model of phase transitions in human hand movements. *Biological Cybernetics*, 51, 347–356.
- Hargreaves, D., Miell, D., & MacDonald, R. (Eds.) (2012). *Musical imaginations: Multidisciplinary perspectives on creativity*. New York, NY: Oxford University Press.

- Hélie, S., & Sun, R. (2010). Incubation, insight, and creative problem solving: A unified theory and a connectionist model. *Psychological Review*, 117, 994–1024.
- Hennessey, B. A., & Amabile, T. M. (2010). Creativity. *Annual Review of Psychology*, 61, 569–598.
- Hurley, S. (1998). *Consciousness in action*. London, UK: Harvard University Press.
- Hurley, S. (2001). Perception and action: Alternative views. *Synthese*, 129, 3–40.
- Huron, D. (2006). *Sweet anticipation: Music and the psychology of expectation*. Cambridge, MA: MIT Press.
- Hutto, D., & Myin, E. (2013). *Radicalizing enactivism: Basic minds without content*. Cambridge, MA: MIT Press.
- Iyer, V. (2002). Embodied mind, situated cognition, and expressive microtiming in African-American music. *Music Perception*, 19, 387–414.
- Iyer, V. (2004a). Exploding the narrative in jazz improvisation. In R. O'Meally, B. Edwards, & F. Griffin (Eds.), *Uptown conversation: The new jazz studies* (pp. 393–403). New York, NY: Columbia University Press.
- Iyer, V. (2004b). Improvisation, temporality, and embodied experience. *Journal of Consciousness Studies*, 11, 159–173.
- John-Steiner, V. (2000). *Creative collaboration*. New York, NY: Oxford University Press.
- Johnson, M. (2007). *The meaning of the body: Aesthetics of human understanding*. Chicago: University of Chicago Press.
- Kaufman, J. C., & Beghetto, R. A. (2009). Beyond big and little: The four C model of creativity. *Review of General Psychology*, 13, 1–12.
- Kaufman, J. C., & R. J. Sternberg (Eds.) (2010). *The Cambridge handbook of creativity*. New York, NY: Cambridge University Press.
- Kelso, J. A. S. (1984). Phase transitions and critical behavior in human bimanual coordination. *American Journal of Physiology: Regulatory, Integrative, and Comparative*, 15, R1000–R1004.
- Kelso, J. A. S. (1995). *Dynamic patterns*. Cambridge, MA: MIT Press.
- Kirton, M. J. (2003). *Adaption-innovation: In the context of diversity and change*. New York, NY: Routledge.
- Knittel, K. M. (1998). Wagner, deafness, and the reception of Beethoven's late style. *Journal of the American Musicological Society*, 51, 49–82.
- Koestler, A. (1964). *The act of creation*. London, UK: Pan Books.
- Kozbelt, A., Beghetto, R. A., & Runco, M. A. (2010). Theories of creativity. In J. C. Kaufman & R. J. Sternberg (Eds.) *The Cambridge handbook of creativity* (pp. 20–47). New York, NY: Cambridge University Press.
- Krueger, J. (2011). Doing things with music. *Phenomenology and the cognitive sciences*, 10, 1–22.
- Krueger, J. (2013). Empathy, enaction, and shared musical experience: evidence from infant cognition. In T. Cochrane, B. Fantini, & K. Scherer (Eds.) *The emotional power of music: Multidisciplinary perspectives on musical expression, arousal, and social control* (pp. 177–196). Oxford, UK: Oxford University Press.
- Küpers, E., van Dijk, M., McPherson, G., & van Geert, P. (2014). A dynamic model that links skill acquisition with self-determination in instrumental music lessons. *Musicae Scientiae*, 18, 17–34.
- Laroche, J., & Kaddouch, I. (2015). Spontaneous preferences and core tastes: embodied musical personality and dynamics of interaction in a pedagogical method of improvisation. *Frontiers in Psychology*, 6, 522. doi:10.3389/fpsyg.2015.00522
- Large, E. (2000). On synchronizing movements to music. *Human Movement Science*, 19, 527–566.
- Large, E. W., & Jones, M. R. (1999). The dynamics of attending: How people track time-varying events. *Psychological Review*, 106, 119–159.
- Large, E. W., Kim, J. C., Flaig, N., Bharucha, J., & Krumhansl, C. L. (2016). A neurodynamic account of musical tonality. *Music Perception*, 33, 319–331.
- Leman, M. (2007). *Embodied music cognition and mediation technology*. Cambridge, MA: MIT Press.
- Linson, A., & Clarke, E. F. (2017). Distributed cognition, ecological theory, and group improvisation. In E. F. Clarke & M. Doffman (Eds.), *Distributed creativity: Collaboration and improvisation in contemporary music*. New York, NY: Oxford University Press.
- Loaiza, J. M. (2016). Musicking, embodiment and the participatory enaction of music: Outline and key points. *Connection Science*, 28, 410–422.
- Mace, W. M. (1977). James J. Gibson's strategy for perceiving: Ask not what's inside your head, but what your head's inside of. In R. Shaw & J. Bransford (Eds.), *Perceiving, acting and knowing* (pp. 43–65). Hillsdale, NJ: Lawrence Erlbaum Associates.
- MacRitchie, J., Varlet, M., & Keller, P. (2017). Embodied expression through entrainment and co-representation in musical ensemble performance. In M. Lesaffre, M. Leman, & P. J. Maes (Eds.), *The Routledge companion to embodied music interaction* (150–159). London, UK: Routledge.
- Malafouris, L. (2008). Beads for a plastic mind: The 'Blind Man's Stick' (BMS) hypothesis and the active nature of material culture. *Cambridge Archaeological Journal*, 18, 401–414.
- Malafouris, L. (2013). *How things shape the mind: A theory of material engagement*. Cambridge, MA: MIT Press.
- Malafouris, L. (2015). Metaplasticity and the primacy of material engagement. *Time and Mind*, 8, 351–371.
- Maturana, H. R., & Varela, F. (1980). *Autopoiesis and cognition: The realization of the living (Boston Studies in the Philosophy of Science, Volume 42)*. Dordrecht, The Netherlands: Reidel.
- Maturana, H. R., & Varela, F. (1987). *The tree of knowledge: The biological roots of human understanding*. Boston, MA: Shambala.
- McGrath, J. E., & Kelly, J. R. (1986). *Time and human interaction: Toward a social psychology of time*. New York: Guilford Press.
- McPherson, G. E., Davidson, J. W., & Faulkner, R. (2012). *Music in our lives: Rethinking musical ability, development and identity*. New York, NY: Oxford University Press.

- Menary, R. A. (2010a). Introduction to the special issue on 4E cognition. *Phenomenology and the Cognitive Sciences*, 9, 459–463.
- Menary, R. A. (Ed.) (2010b). *The extended mind*. Cambridge, MA: MIT Press.
- Menin, D., & Schiavio, A. (2012). Rethinking musical affordances. *Avant*, 3(2), 201–215.
- Merleau-Ponty, M. (2002). *Phenomenology of perception*. London, UK: Routledge.
- Mpofu, E., Myambo, K., Mogaji, A. A., Mashego, T.-A., & Khelefa, H. (2006). African perspectives on creativity. In J. C. Kaufman & R. J. Sternberg (Eds.) *The international handbook of creativity* (pp. 456–489). Cambridge, UK: Cambridge University Press.
- Mumford, M. D. (2003). Where have we been, where are we going? Taking stock in creativity research. *Creativity Research Journal*, 15, 107–120.
- Nagy, Z. (2017). *Embodiment of musical creativity: The cognitive and performative causality of musical composition*. New York, NY: Routledge.
- Niu, W. (2006). Development of creativity research in Chinese societies. In J. C. Kaufman & R. J. Sternberg (Eds.) *The international handbook of creativity* (pp. 386–387). Cambridge, UK: Cambridge University Press.
- Niu, W., & Sternberg, R. J. (2006). The philosophical roots of Western and Eastern conceptions of creativity. *Journal of Theoretical and Philosophical Psychology*, 26, 18–38.
- Nöe, A. (2006). *Action in perception*. Cambridge, MA: MIT Press.
- Odena, O. (Ed.) (2012). *Musical creativity: Insights from music education research*. Aldershot, UK: Ashgate.
- O'Neill, S. A., & Green, L. (2001). Social groups and learning in music. *British Education Research Association*, 1, 26–32.
- Preiser, S. (2006). Creativity research in German-speaking countries. In J. C. Kaufman & R. J. Sternberg (Eds.) *The international handbook of creativity* (pp. 167–201). Cambridge, UK: Cambridge University Press.
- Preiss, D. D., & Strasser, K. (2006). Conceptions of creativity in Latin America and the Caribbean: Views from psychology, humanities and the arts. In J. C. Kaufman & R. J. Sternberg (Eds.) *The international handbook of creativity* (pp. 39–67). Cambridge, UK: Cambridge University Press.
- Rosenberg, M. E. (2010). Jazz and emergence (part one) from calculus to Cage, and from Charlie Parker to Ornette Coleman: Complexity and the aesthetics and politics of emergent form in jazz. *Inflexions: A Journal of Research Creation*, 4. Retrieved from http://www.inflexions.org/n4_rosenberghtml.html
- Rowlands, M. (2010). *The new science of the mind: From extended mind to embodied phenomenology*. Cambridge MA: MIT Press.
- Runco, M. (2014). *Creativity: Theories and themes: Research, development, and practice, 2nd edition*. Amsterdam, The Netherlands: Academic Press.
- Salice, A., Höffding, S., & Gallagher, S. (2017). Putting plural self-awareness into practice: The phenomenology of expert musicianship. *Topoi*, 2017, 1–13. doi:10.1007/s11245-017-9451-2
- Sawyer, R. K. (1999). The emergence of creativity. *Philosophical Psychology*, 12, 447–469.
- Sawyer, R. K. (2000). Improvisation and the creative process: Dewey, Collingwood, and the aesthetics of spontaneity. *The Journal of Aesthetics and Art Criticism*, 58, 149–161.
- Sawyer, R. K. (2003). *Group creativity: Music, theater, collaboration*. Mahwah, NJ: Erlbaum.
- Sawyer, R. K. (2006). Group creativity: Musical performance and collaboration. *Psychology of Music*, 34, 148–165.
- Sawyer, R. K. (2007). Improvisation and teaching. *Critical Studies in Improvisation*, 2. Retrieved from <https://www.criticalimprov.com/index.php/csieci/article/view/380/626>
- Sawyer, R. K. (2012). *Explaining creativity: The science of human innovation 2nd Edition*. New York: Oxford University Press.
- Sawyer, R. K., & DeZutter, S. (2009). Distributed creativity: How collective creations emerge from collaboration. *Psychology of Aesthetics, Creativity, and the Arts*, 3, 81–92.
- Schiavio, A., & Altenmüller, E. (2015). Exploring music-based rehabilitation for Parkinsonism through embodied cognitive science. *Frontiers in Neurology*, 6, 10.3389/fneur.2015.00217.
- Schiavio, A., & Cummins, F. (2015). An inter(en)active approach to musical agency and learning. In R. Timmers, N. Dibben, Z. Eitan, R. Granot, T. Metcalfe, A. Schiavio, & V. Williamson (Eds.), *Proceedings of the 17th International Conference on the Multimodal Experience of Music*. Sheffield, UK: HRI Online Publications.
- Schiavio, A., & van der Schyff, D. (2016). Beyond musical qualia: Reflecting on the concept of experience. *Psychomusicology: Music, Mind, and Brain*, 26(4), 366–378.
- Schiavio, A., & De Jaegher, H. (2017). Participatory sense-making in joint musical practices. In M. Lesaffre, M. Leman, & P. J. Maes (Eds.), *The Routledge companion to embodied music interaction* (pp. 31–39). London, UK: Routledge.
- Schiavio, A., & Höffding, S. (2015). Playing together without communicating? A pre-reflective and enactive account of joint musical performance. *Musicae Scientiae*, 19, 366–388.
- Schiavio, A., van der Schyff, D., Cespedes-Guevara, J., & Reybrouck, M. (2017). Enacting musical emotions: enaction, dynamic systems and the embodied mind. *Phenomenology and the Cognitive Sciences*, 16, 785–809.
- Schiavio, A., van der Schyff, D., Gande, A., & Kruse-Weber, S. (2018). Negotiating individuality and collectivity in community music. A qualitative case study. *Psychology of Music*. Advance online publication. doi:10.1177/0305735618775806
- Schiavio, A., van der Schyff, D., Kruse-Weber, S., & Timmers, R. (2017). When the sound becomes the goal. 4E cognition and teleomusicality in early infancy. *Frontiers of Psychology*, 8, 1585. doi:10.3389/fpsyg.2017.01585
- Schiavio, A., & van der Schyff, D. (2018). 4E music pedagogy and the principles of self-organization. *Behavioral Sciences*, 8(8), 72.
- Schöner, G., & Kelso, J. A. S. (1988a). Dynamic pattern generation in behavioral and neural systems. *Science*, 239, 1513–1520.

- Schöner, G., & Kelso, J. A. S. (1988b). A synergetic theory of environmentally-specified and learned patterns of movement coordination. II. Component oscillator dynamics. *Biological Cybernetics*, 58, 81–89.
- Schuldburg, D. (1999). Chaos theory and creativity. In M. Runco & S. Pritzker (Eds.), *The encyclopedia of creativity, volume 1* (pp. 259–272). London, UK: Academic Press.
- Shiu, E. (Ed.) (2013). *Creativity research: An inter-disciplinary and multi-disciplinary research handbook*. Abingdon, UK: Routledge.
- Simonton, D. K. (1997). Creative productivity: A predictive and explanatory model of career trajectories and landmarks. *Psychological Review*, 104, 66–89.
- Simonton, D. K. (1999). *Origins of genius: Darwinian perspectives on creativity*. Oxford, UK: Oxford University Press.
- Skånland, M. S. (2013). Everyday music listening and affect regulation: the role of MP3 players. *International Journal of Qualitative Studies on Health and Well-Being*, 8(20595), 20595.
- Small, C. (1998). *Musicking: The meaning of performing and listening*. Middletown, CT: Wesleyan University Press.
- Smith, L.B., & Thelen, E. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge, MA: MIT Press.
- Stephen, D. G., & Dixon, J. A. (2009). The self-organization of insight: entropy and power laws in problem solving. *Journal of Problem Solving*, 2, 72–101.
- Stephen, D. G., Dixon, J.A., & Isenhour, R.W. (2009). Dynamics of representational change: Entropy, action, and cognition. *Journal of Experimental Psychology: Human Perception and Performance*, 35:1811–32. doi:10.1037/a0014510.
- Sternberg, R. J. (1988). *The nature of creativity: Contemporary psychological perspectives*. Cambridge University Press.
- Strogatz, S. (1994). *Nonlinear dynamics and chaos: with applications to physics, biology, chemistry, and engineering*. Reading, MA: Perseus Books.
- Strogatz, S. (2001). Exploring complex networks. *Nature*, 410, 268–276.
- Sudnow, D. (2001). *Ways of the hand: A rewritten account*. Cambridge, MA: MIT Press.
- Swanwick, K., & Tillman, J. (1986). The sequence of musical development: a study of children's compositions. *British Journal of Music Education*, 3, 305–339.
- Thompson, E. (2007). *Mind in life: Biology, phenomenology, and the sciences of mind*. Cambridge, MA and London, UK: Harvard University Press.
- Thompson, E., & Stapleton, M. (2009). Making sense of sense making: Reflections on enactive and extended mind theories. *Topoi*, 28, 23–30.
- Tomlinson, G. (2015). *A million years of music: The emergence of human modernity*. New York: Zone Books.
- Toop, D. (2016). *Into the maelstrom: Music, improvisation and the dream of freedom*. New York, NY: Bloomsbury.
- Torrance, S., & Schumann, F. (2018). The spur of the moment: What jazz improvisation tells cognitive science. *AI & Society*. <https://doi.org/10.1007/s00146-018-0838-4>
- van der Schyff, D. (2015). Music as a manifestation of life: Exploring enactivism and the 'eastern perspective' for music education. *Frontiers in Psychology*, 6, 345. doi:10.3389/fpsyg.2015.00345
- van der Schyff, D. (2016). From Necker cubes to polyrhythms: Fostering a phenomenological attitude in music education. *Phenomenology and Practice*, 10, 4–24.
- van der Schyff, D. (in press). Improvisation, enaction, and self-assessment. In D. J. Elliott, M. Silverman, & G. McPherson (Eds.), *The Oxford Handbook of Philosophical and Qualitative Perspectives on Assessment in Music Education*. New York: Oxford University Press.
- van der Schyff, D., & Schiavio, A. (2017). Evolutionary musicology meets embodied cognition: Biocultural coevolution and the enactive origins of human musicality. *Frontiers in Neuroscience*. doi:10.3389/fnins.2017.00519
- Varela, F., Thompson, E., & Rosch, E. (1991). *The embodied mind: Cognitive science and human experience*. Cambridge, MA: MIT Press.
- Veale, T. (2013). Once more, with feeling! Using creative affective metaphors to express information needs. In *Proceedings of the 4th International Conference on Computational Creativity*. Retrieved from <http://www.computationalcreativity.net/iccc2013/download/iccc2013-veale-1.pdf>
- Velardo, V. (2016). *Towards a music systems theory: Theoretical and computational modelling of creative music agents*. Unpublished PhD thesis, University of Huddersfield, UK.
- Wallas, G. (1926). *Art of thought*. New York, NY: Harcourt-Brace.
- Walton, A., Richardson, M. J., & Chemero, A. (2014). Self-organization and semiosis in jazz improvisation. *International Journal of Signs and Semiotic Systems*, 3, 12–25.
- Walton, A., Richardson, M. J., Langland-Hassan, P., & Chemero, A. (2015). Improvisation and the self-organization of multiple musical bodies. *Frontiers in Psychology*, 1. doi:10.3389/fpsyg.2015.00313
- Walton, A., Washburn, A., Langland-Hassan, P., Chemero, A., Kloos, H., & Richardson, M. J. (2017). Creating time: Social collaboration in music improvisation. *Topics in Cognitive Science*, 10, 95–119. doi:10.1111/tops.12306
- Ward, T.B. (1995). What's old about new ideas. In S. M. Smith, T. B. Ward, & R. A. Finke (Eds.) *The creative cognition approach* (pp. 157–178). Cambridge, MA: MIT Press.
- Weber, A., & Varela, F. J. (2002). Life after Kant: Natural purposes and the autopoietic foundations of biological individuality. *Phenomenology and the Cognitive Sciences*, 1, 97–125
- Wertheimer, M. (1945). *Productive thinking*. New York, NY: Harper.
- Wittgenstein, L. (2001 [1953]). *Philosophical Investigations*. Blackwell Publishing.
- Woodman, R., Sawyer, J.E., & Griffin, R.W. (1993). Toward a theory of organizational creativity. *The Academy of Management Review*, 18, 293–321.