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Developing Musical Creativity Through Movement: Navigating the Musical Affordance Landscape

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ABSTRACT

Schools too often undermine creativity, said Ken Robinson, an educationalist who has changed thinking on schools. In his famous TEDtalk "Do schools kill creativity?," he argues that the undermining of creativity results from being too focused on children's heads rather than on their bodies. In line with Robinson's observation, music education has been criticized for a lack of creative approaches, and a focus on disembodied learning experiences. In our view, the development of creative and embodied approaches to music education needs a deeper understanding of the embodied processes that underlie creativity, especially with regard to the use of the body in music learning. Using a dynamic, relational, and action-oriented perspective on creativity, we connect creativity to the concepts of affordance navigation, metastability, and cognitive flexibility. Next, we elaborate on how body movement may support creatively exploring the musical environment and developing a deepened musical understanding through purposeful affordance navigation.

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Introduction

Schools too often undermine creativity, said Ken Robinson, an educationalist who changed thinking on schools. In his famous TEDtalk "Do schools kill creativity?", Sir Robinson argues that schools' undermining of creativity results from being too focused on children's heads rather than on their bodies, leading to educational approaches that seek to form university professors.

Interestingly, similar critiques have been raised about music schools. For example, it is argued that instrumental music education too often focuses on training professional musicians, leading to approaches that emphasize score analysis and instrumental technique in function of adequately reproducing the "master's model of the music," too often at the cost of creativity and expressiveness (Nijs, 2019). Music education has also been criticized for neglecting the body in the development of musical understanding (Nijs & Bremmer, 2019). However, music educators such as Dalcroze, Orff, or Kodaly, acknowledged the importance of a "focus on the body" and developed music educational practices that integrate body movement as an important vehicle for the development of musical understanding, expressiveness, and creativity. These practice-based music educational approaches are increasingly supported by research findings on the embodied nature of music cognition (e.g., Leman, 2007, 2016; Lesaffre, Maes, & Leman, 2017). Within this paradigm, the role of the body in musical sense-making is empirically investigated from different perspectives, such as ecological philosophy (e.g., Clarke, 2005; Gibson, 1986; Reybrouck, 2005a), 4E cognition (e.g., Van der Schyff, Schiavio, Walton, Velardo, & Chemero, 2018), neuroscience (e.g., Lahav, Saltzman, & Schlaug, 2007), or dynamical systems theory (e.g., Bremmer & Nijs, 2020; Van der Schyff, Schiavio, Walton, Velardo, & Chemero, 2018), leading to research-based music educational approaches in which core aspects of embodied (music) cognition are implemented in the design of musical practices (Fortuna & Nijs, 2019, 2020; Kerchner, 2013; Nijs, 2019; Nijs & Leman, 2014). It is important to note that the diversity of perspectives is also related to different interpretations of embodied cognition. Indeed, in the broader domain of embodied cognition, different – still evolving – views on embodiment have been postulated. According to Palmiero et al. (2019) the different perspectives be differentiated on the grounds of their being more or less conservative, whereby the degree of conservatism is determined by the stance taken regarding mental representations. "Conservative and moderately embodied" approaches (Foglia & O'Regan, 2016, p. 183), such as the simulation view (Barsalou, 1999), adhere to the concept of representation; fully embodied

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approaches, such as the enactive (Thomas, 2014; Thompson, 2007) and the sensorimotor (Noë, 2004; O'Regan & Noë, 2001) approach, bypass the notion of mental representation (Palmiero et al., 2019). In the domain of embodied *music* cognition, these different approaches have been adopted (Matyja & Schiavio, 2013). For example, a conservative approach conceives music as an abstract and unidirectional stream of information encoded and processed by the brain (e.g., Lehrdahl & Jackendoff, 1983). More recently, Gruhn (2006) asserts that learning music is about developing mental representations (genuine musical conceptions) and gradually altering, differentiating, extending, and refining them. At the other side of the spectrum, music researchers adopt an enactive account of musical interactions, arguing that music is something that is "heard" and "enacted" instead of being merely imagined or represented (Matyja & Schiavio, 2013; Reybrouck, 2005b). Therefore, the enactive approach provides an anti-representational framework concerning musical activity (Hayes, 2019). A recent development here, is the introduction and elaboration of a dynamical systems perspective on musical interaction, positing that self-organizing, complex, systems emerge and develop over time (Van der Schyff, Schiavio, Walton, Velardo, & Chemero, 2018). For example, two improvising jazz musicians can be considered as a synergistic, teleodynamic system, whereby the musicians are highly attuned to each other's playing, responding in real-time to subtle cues and changes, and are jointly creating a musical piece that is constantly evolving and more complex and meaningful than what either musician could create independently (Walton, Richardson, & Chemero, 2014).

In this paper, we take a conciliatory stance, in which "traditional cognitive constructs such as internal models can be amended to better address active perception and control-oriented views of cognition" (Pezzulo, Donnarumma, Iodice, Maisto, & Stoianov, 2017). In such an "integrated embodied representation approach" (Palmiero et al., 2019) the basic idea is that the interaction with the world is mediated by mental representations that encompass both perceptual and motor components that are intrinsically related to specific experiences.

Despite the different perspectives on what it means for cognition to be embodied, a basic tenet of all interpretations is that the body and body movement play a significant role in higher order cognitive processes, such as creativity (e.g., Matheson & Kenett, 2020). This link between body movement and creativity has been addressed in a growing body of research (for an overview, see Frith, Miller, & Loprinzi, 2020), showing that movement may indeed enhance creativity. Whole body movement, and in particular unstructured, interactive, or spontaneous movements appear to introduce opportunities for unexpected perceptions and shifting perspectives (Frith, Miller, & Loprinzi, 2020). For example, Kuo and Yeh (2016) showed that divergent thinking is enhanced only when the participants walked their own unconstrained, free paths. Zhou, Zhang, Hommel, and Zhang (2017) used free vs. structured walking, with results showing better divergent-thinking performance with unconstrained than with constrained walking. Moreover, studies of musical creativity consistently indicate the involvement of motor regions, indicating that musical creativity might be about "movement for sound's sake" (Bashwiner & Bacon, 2019).

Despite findings on the positive impact of movement on creativity and, in addition, despite the intrinsic link between music and movement (i.e., musical sense-making is ground in bodily experience, e.g., Leman, 2016), the role of movement in the development of musical creativity has scarcely been addressed, both theoretically and empirically. Van der Schyff, Schiavio, Walton, Velardo, and Chemero (2018) theoretically discuss the embodied nature of creativity through the lens of 4E cognition and dynamical systems theory but do not elaborate on the involved processes and mechanisms, nor the role of the body in the development of musical creativity.

In this article, we provide a conceptual framework to help better understanding the role of the body and body movement for developing musical creativity. Note that we take a broad stance on creativity, not confining it to improvisation and composition, but including also performing (e.g., Stijnen, Nijs, & Van Petegem, 2023) and active listening (e.g., Kerchner, 2021).

Prior to explaining our conceptual approach, we would like to emphasize that the goal of this theoretical article is to spur the discussion on the embodied nature of musical creativity. We believe this contribution offers a new perspective on the embodied processes that underly creative interaction with music. As such, it may provoke and support building new hypotheses and research approaches to the study of creative interaction with music. In addition, this perspective offers new avenues that connect to ongoing developments in creativity research in other disciplines. For example, the idea that creativity is based on the flexible and adaptive interaction with a multiplicity of information has taken root in disciplines such as *bilingualism* (van Dijk, Kroesbergen, Blom, & Leseman, 2019) and *language-exchange interaction* (Ahn, 2016), *motor behavior* (Torrents, Balagué, Ric, & Hristovski, 2021), and *sports*

(Vaughan, Mallett, Davids, Potrac, & López-Felip, 2019).

Conceptual approach

Creativity has been conceptualized in many ways (Walia, 2019). However, according to Withagen and van der Kamp (2018), many different viewpoints display a similar underlying logic, whereby creativity starts with a novel idea "in the head." Such a mental idea is "supposed to instruct the (mechanical) body to impose the novel form on the material," whereby the process of creating is not constitutive to the creativity process itself (Withagen & van der Kamp, 2018, p. 1, 2). This rather linear conception is, however, increasingly criticized, advancing the alternative idea that creativity, rather than being something that resides in the individual mind, (1) *exists in the dynamic unfolding of the action*, i.e., through the interplay of movement and information (e.g., Gubenko & Houssemand, 2022; Withagen & van der Kamp, 2018), and (2) *is relational*, i.e., simultaneously depends on individual abilities and on the material and social world (e.g., Glăveanu, 2014).

Music education often adopts an approach to the development of musical skills that is similar to the linear conception of creativity, whereby the development of theoretical understanding ("in the head;" e.g., through analysis, solfege) too often precedes the development of an expressive and creative interaction with music. Also, here, this "traditional" view is more and more criticized and alternative – creative – approaches and practices are continuously developed, pleading for more exploration and improvisation in the musical curriculum (e.g., Hickey, 2009; Sawyer, 2011). This has led to a plethora of creative approaches in different domains such as ensemble settings (e.g., Norgaard, 2017), instrumental teaching (e.g., Moreira & Carvalho, 2010), well-being (e.g., Burnard & Dragovic, 2015), elderly and dementia (e.g., Martinec & Lera, 2018), composition (e.g., Kupers & van Dijk, 2020), early childhood music education (e.g., Peñalba, Martínez-Álvarez, & Schiavio, 2020), and music educational technologies (e.g., Lam, 2023). However, the design of new practices is often based on experience and practice, without any reference to theoretical or research-based findings (Bowman & Powell, 2007).

In our view, the design of innovative approaches and practices requires a deeper understanding of the embodied processes that underlie creativity, especially regarding the use of the body in music learning (e.g., Fortuna & Nijs, 2019, 2020; Lee, 2018) and teaching (e.g., Bremmer & Nijs, 2020).

In this article, we elaborate on these processes, adopting a dynamic, action-oriented and relational perspective on creativity, as advocated by for example Glăveanu (2012) and others. Focusing on creativity as our focal phenomenon, we selected specific – complementary – concepts and use their associated theories as method theories to conceptualize the embodied nature of creativity and in this way to adapt the theory of creativity (domain theory) and to argue in favor of an embodied educational approach to the development of musical creativity (Jaakkola, 2020).

The rationale of our argument regarding the embodied nature of creativity goes as follows:

- Music is a rich, information-bearing (affordance-laden) system (e.g., Krueger, 2011).
- Musical creativity is about purposefully exploring and flexibly responding to this richness of information (navigating the landscape of musical affordances) (e.g., Oppici, Frith, & Rudd, 2020).
- The openness, specification, selection, and flexible interaction with competing affordances require the ability to (1) rapidly switch between action possibilities (being in a metastable zone; Rietveld, Denys, & Van Westen, 2018), and (2) to adapt to changing tasks or problems (cognitive flexibility; e.g., Diamond, 2013).
- An embodied process of musical sense-making (enactment) and its basic mechanisms (entrainment, prediction, alignment) support the flexible navigation of the musical affordance landscape.

Our rationale is elaborated in the following way. First, drawing on the concepts of *affordances*, i.e., possibilities for action provided by the environment, and *affordance navigation*, i.e., the process by which individuals interact with their environment by perceiving and utilizing affordances (e.g., Pezzulo & Cisek, 2016; Rietveld & Kiverstein, 2014), *metastability*, i.e., a condition in which behavior dwells between stability and instability (e.g., Tognoli and Kelso, 2014), *cognitive flexibility*, i.e, the capacity to adapt one's thinking and behavior in response to evolving environments, tasks, or strategies (e.g., Diamond, 2013; Ionescu, 2012, 2019), and *enactment*, i.e., the transformation of a stream of sounds into a meaningful musical experience based on a sound-movement-intention connection (e.g., Bremmer & Nijs, 2020; Leman, 2016; Nijs & Bremmer, 2019), we discursively elaborate on the dynamic processes that may underly creativity. The concept of affordances and affordance navigation allow elaborating on the interaction with the environment (detecting and responding);

the concept of metastability and cognitive flexibility allow expanding on the flexible switching between responses to elements that pop up in the interaction; the concept of enactment allows connecting creativity to the basic mechanisms of an embodied interaction with music.

Next, we discuss how flexibly navigating the musical affordance landscape through movement may contribute to the development of musical creativity. We connect musical creativity to *audiation*, i.e., the process through which sound becomes music and meaning is attributed to that music (Gordon, 2007) and cognitive flexibility and propose an embodied approach to musical learning. We argue that moving to music may contribute to the development of musical understanding and supports recontextualizing and even reworking or restructuring the stream of sounds through an embodied interaction. Finally, we discuss the implications of the proposed conceptual framework.

Dynamic processes underlying musical creativity

Creativity is a process that occurs at different levels, i.e., the level of the person, the product, the process, and the press (Rhodes, 1961). Although these levels are often addressed separately, Kupers, Lehmann-Wermser, McPherson, and van Geert (2019) argue in favor of an integrative approach, based on dynamical systems theory, and as such focusing on the process of change based on *emergence*, i.e. distinct properties or patterns of behavior that come into existence and develop throughout the temporal interactions of complex systems (Schiavio, van der Schyff, Cespedes-Guevara, & Reybrouck, 2017), and *self-organization*, i.e. the dynamical and adaptive increase in order or structure without external control (De Wolf & Holvoet, 2004). For example, Walton, Richardson, and Chemero (2014) observed the emergence of increased coordination of pianists' movements while improvising. Rooney (2023) discusses the ecological dynamics of trumpet improvisation, considering the improvising musician as an adaptive system whose behavior adapts through self-organized responses to a set of constraints. This idea of emergence and self-organization aligns with van Dijk, Kroesbergen, Blom, and Leseman (2019), who define creativity as an individual skill that emerges in the interaction with the environment, involving the discovery of a complex whole of action possibilities (affordances). In this section, we elaborate on this discovery process. First, we address the notion of musical affordances, as it plays an important role in the (creative) interaction with music (Clarke, 2005; Krueger, 2011, 2014; Leman, 2016; Menin & Schiavio, 2012; Reybrouck, 2005b). Next, we elaborate on the processes that underly the discovery of action possibilities, such as detecting and choosing between different action possibilities (affordance navigation/competition), effortlessly switching between possibilities (metastability) and coping with the multiplicity of possibilities (cognitive flexibility). Finally, we elaborate on the embodied mechanisms that underly the transformation of sound into music (enaction).

Affordances: invitations to interact with the music

Creativity and meaning

Creativity is essentially about sense-making and meaning construction and consequently involves an active engagement with the environment (e.g., Davis, Hsiao, Singh, Lin, & Magerko, 2017). That is, original ideas and insights do not come about through the passive reception of information from the environment but through the active construction of meaningful interpretations of experience (De Jaegher & Di Paolo, 2007; Runco, 2014). While this has led to an emphasis on composition and composition as creative musical activities, it is important to acknowledge the creative aspects of playing existing music (Nijs, Bremmer, Van der Schyff, & Schiavio, 2023; Stijnen, Nijs, & Van Petegem, 2023). Moreover, such construction is not merely individual but co-created (Clapp, 2016; Schiavio, van der Schyff, Cespedes-Guevara, & Reybrouck, 2017). According to Mason (2014, p. 208), sense-making involves finding meaning from information, whereby information seeking is "both an outcome and a driver." Gibson argues that meaning does not have to be imposed (e.g., by cultural norms) but that it can be discovered, because the environment consists of possibilities for action, or: *affordances* (Gibson, 1986; Withagen & van der Kamp, 2018). This connects to London's view on creativity as "inquiry, the expansion of emotional depth and range, the tuning of the spirit, and the quest for meaning" (London, 1989, p. 18).

Music and affordances

In recent years, the concept of affordances has been increasingly adopted in music research. According to Krueger (2011), music is an affordance-laden structure whereby affordances constitute the attractive power of music that invite to creatively and expressively interact with it. Here, musical affordances are considered those aspects of music that define what we can do with it (Krueger, 2014). In this way, music is recognized as meaningful, in the sense that it presents itself as "something with a distinctive activity signature that we can use

or do things with" (Krueger, 2014, p. 2). Musical affordances constitute this activity signature, expressing the action possibilities in the musical environment that are specified by (1) specific elements in the structure of the music, as well as (2) the sensorimotor abilities that support detecting and responding to these elements (Krueger, 2014; Peñalba, Martínez-Álvarez, & Schiavio, 2020). In this sense, they are a function of the relationship between an individual and its environment. Consequently, they are not static, but change due to mutual changes in individuals and their environment (Windsor & De Bézenac, 2012). For example, gaining experience with baroque dance may lead to a different interpretation when playing baroque music (Coorevits & Moelants, 2016). This aligns very well with a dynamical systems perspective on human interaction with music, according to which musical sense-making emerges through multiple interactions over time between individual and environment, here the music (e.g., Bremmer & Nijs, 2020; Van der Schyff, Schiavio, Walton, Velardo, & Chemero, 2018), and with Leman's view on expressive musical interaction, in which the human expressive system is seen as a response system for expressive and emergent affordances (Leman, 2016, p. 3).

Considering the affordances in music, both the action ("what actions music affords") and perception ("what elements in the music afford action") side of interacting with music need to be considered.

First, when elaborating on the concept of affordance, many authors focus on "what music affords." For example, Krueger (2014, 2011) asserts that music invites to be interacted with through *movement*, *entrainment*, i.e., the compelling force that drives the human tendency to synchronize with music (Clayton, 2012), and *affective synchrony*, i.e., the pleasure we take in moving our bodies in time with the music. In other words, we experience music as something that naturally invites for a synchronized bodily interaction, and we take pleasure in moving our bodies in time with the music. Windsor and De Bézenac (2012) describe how music affords movement (e.g., Varlet, Williams, & Keller, 2020), synchronization (e.g., Witek et al., 2017), verbal/textual activities (Kerchner, 2000), mood management (e.g., Shifriss, Bodner, & Palgi, 2015) and interpretation (e.g., Héroux, 2018).

Second, while it is important to acknowledge that music should not be merely understood in terms of its acoustical qualities but in terms of what it affords to the listener (Reybrouck, 2015), it is nevertheless of interest to consider what elements in the music may become affordances through their connection to the dispositions, or: effectivities, of a listener (Chemero, 2003; Hirose, 2002). Music is often very complex, containing patterns with changing complexity at different levels (Lesaffre, Leman, De Baets, & Martens, 2004). As such, different aspects of the music, for example the beat and rhythmic, melodic or harmonic patterns, timbre and dynamics, or phrasing, may afford different interactions. For example, Van Dyck et al. (2012) show that, when dancing together to contemporary dance music, the sound pressure level (decibels) of the bass drum modifies the way people move to the music, inviting them to move more actively and increase tempo entrainment, i.e., the process of synchronizing to the beat through bodily interaction with the music. Burger, Thompson, Luck, Saarikallio, and Toiviainen (2013) found that clear pulses seem to induce movement with the whole body, i.e., by using various movement types of different body parts, whereas spectral flux and percussiveness seem to induce movement in specific body parts, such as head and hand movement.

One could say that these elements in the music constitute the invariants that can be directly perceived and invite particular ways of interacting with the music (see also Windsor & De Bézenac, 2012). First, it is exactly the existence of these invariants and their patterns that allows hearing sounds as music (Krueger, 2014; Leman, 2016), thereby creating its typical strong pull on people to (emotionally) interact with it (*affective allure*; Krueger, 2014). A fine example of this being pulled to interaction with music, is how music elicits a pervasive tendency to rhythmically engage our body through, for example, feet tapping or swaying (Dalla Bella, Białuńska, Sowiński, & Sinigaglia, 2013) and how rhythmic entrainment is a mechanism for emotion induction by music due to the "the powerful, external rhythm of the music [interacting] with an internal body rhythm of the listener (Tröst & Vuilleumier, 2013, p. 215).

Second, affordances are the interface between such invariances and the dispositions of the listener. In that sense, the presence of affordances can be situated within an emergence-disposition dynamics that underlies the expressive interaction with music. Such dynamics involves the interaction between innate and cultural dispositions, evoking emergent patterns in music from which new configurations may emerge (Leman, 2016). Dispositions can be auditory (e.g., the way the auditory physiology works; e.g., Bigand, Delbé, Poulin-Charronnat, Leman, & Tillmann, 2014; Leman, 2016, pp. 86–90), environmental (e.g., characteristics of the instruments; e.g., Chau, Wu, & Horner, 2014), and based on repertoires (e.g., acquired through enculturation; e.g., Hannon & Trainor, 2007) (Leman, Nijs, Maes, & Van Dyck, 2018).

Interestingly, next to properties of both music and listener, and next to repertoire, Leman also considers different mediators as components of this dynamics (Leman, 2016, p. 80). These mediators are supposed to intervene with the perceptual bottom-up process, and – as top-down factors – allow selecting, disambiguating or enhancing specific aspects of the music (Leman, 2016, pp. 139–146). For example, attention allows focusing on different layers of structures present in music, such as melody, tempo and rhythm, harmony (Jones & Boltz, 1989). Knowledge allows understanding different aspects of the music, such as style or context. This is in line with Krueger's (2011) argument that the realization of affordances is thus co-determined by the sensitivity and skills of the person interacting with the music (see also Rietveld & Kiverstein, 2014 on skills and affordances).

Of interest for our connection between creativity and movement, is Leman's perspective on movement as a mediator, arguing that movement can, for example, help to *disambiguate* ambiguous elements in the music, such as binary (1-2-1-2-1-2; e.g., a March) vs. ternary (1-2-3-1-2-3-1-2-3; e.g., a Walz) meter in Samba (Naveda & Leman, 2009) or sad vs. happy expression (Maes, Leman, & Snyder, 2013), or to *facilitate* the interaction with music by prioritizing a particular prediction channel (e.g. timing vs. harmonic progression) to the interaction with a certain musical pattern (Leman, 2016, p. 141). In this way, sensorimotor capacities become a means to detect and respond to specific features or affordances of the music. However, due to music's complexity, different aspects of the music may grasp the attention of the persons who interact with it, based on their mood (e.g., Pope, 2011), knowledge and experience (e.g., Creel, 2011), and skills (e.g., Reitan, 2013; Pagès-Portabella & Toro, 2020), and as such "afford things to do with it."

In the next section, we connect creativity to affordances, based on the concept of affordance navigation as a way to cope with the multiplicity of affordances in related to the complex interweaving of musical elements.

Affordance navigation: discovering and creatively making-sense of the musical environment

According to Glăveanu (2012, p. 196), creativity is "a process of perceiving, exploiting, and generating novel affordances during socially and materially situated activities," whereby affordances become apparent only when one is engaged with the environment. In that sense, engaging with the environment does not involve perceiving the layout of the environment, but perceiving the affordances of the layout (Mastrogiorgio & Mastrogiorgio, 2020).

Music can be considered an environment (Reybrouck, 2015) or sonic world (Krueger, 2011), displaying a layout that constitutes a rich and resourceful landscape of affordances, based on the many aspects of the music unfolding over time, such as meter, rhythm, tempo, melody, harmony, and timbre (Lesaffre, Leman, De Baets, & Martens, 2004) and its hierarchical organization (Lehrdahl & Jackendoff, 1983). For example, Kozak (2015) argues that active listeners project their motor intentional gestures inside music, where they reconstitute the very nature of musical space and its objects according to their own unique perspective. This aligns with Nussbaum (2007), who asserts that extramusical – semantic – content is constituted by layouts and scenarios in an imaginary musical space, by actions, events, and objects in a virtual musical space, in which the listener acts off-line and moves in imagination. Eitan (2013) argues, based on studies about cross-modal relation between music and space, that musical sounds and sound patterns may accordingly be perceived as virtual objects moving in a virtual space, delineating perceived spatial and kinetic attributes in a consistent, yet often surprisingly complex ways. Works on musical space point at the idea of music as a space of possible actions, in which musical elements constituted the affordances for a meaningful and expressive interaction with the music.

The musical affordance landscape

Given music's complexity at different layers (e.g., rhythm, harmony, melody) and the multiplicity of affordances it leads to, engaging with music can be considered an intentional action, and therefore as involving the *purposeful* navigation of the affordance landscape, i.e., an individual's perceptual experience of multiple affordances (Pezzulo & Cisek, 2016). Navigating the landscape of musical affordances concerns coping with the multiplicity of affordances, i.e., successfully responding to the relevant affordances, and is the driver of musical interaction (Reybrouck, 2015; Rietveld & Kiverstein, 2014). While in music this has not been investigated empirically, in the domain of sports, Passos, Amaro E Silva, Gomez-Jordana, and Davids (2020) have empirically investigated co-adaptive performance behaviors in football, showing how a landscape of opportunities (affordances) for penetrative passing might be specified by information emerging from continuous player interactions in competitive performance.

The idea of the affordance landscape not only addresses the multiplicity of available affordances but also their interrelatedness. Indeed, affordances should

not be seen as a set of separate action possibilities, but rather as a nested structure of interrelated affordances (Bruineberg & Rietveld, 2014). As such, affordances are not encountered one by one, but as an ensemble of affordances. They are entangled in many ways and, based on a mutual dependence, hide, enable, or reveal other possibilities for action. In music, being a highly complex phenomenon, examples of this entanglement of affordances are ubiquitous. Different rhythmical layers of rhythm (e.g., ternary and binary; see e.g., Leman & Naveda, 2010), the relation between melody and harmony (see Arthur, 2017 on the effect of harmony on melodic probability), between timbre and pitch, all leading to an interpretative multiplicity (Butler, 2019).

This nestedness of affordances supports gaining a grip on multiple relevant affordances, simultaneously, by dynamically coping with them and, often implicitly and automatically, evaluating their relevance. The challenge for an individual interacting with the environment is then to, in a particular situation, be selectively open to only the relevant affordances. The *openness* allows navigating the multiplicity of available affordances, the *selectiveness* supports the purposeful navigation of the affordance landscape to select the relevant affordances. According to Yakhlef and Rietveld (2020), skilled selective openness can lead the person to respond to affordances in unorthodox – and thus: creative – ways.

Coping with the multiplicity of affordances

Several factors determine this purposeful navigation. One such factor is the *perceptibility of affordances*. For example, while some affordances may be clearly and obviously perceivable, others may be more hidden (Neldner, Mushin, & Nielsen, 2017). As such, when there is no affordance for it nor any perceptual information suggesting it, a given action will not be considered (Gaver, 1991). However, hidden affordances can be inferred from other evidence or can be discovered. Soler and Santacana (2013) suggest that innovation involves the scaffolded process of disclosure of hidden affordances. This may be realized through a combination of exploration and chance encounter (Gaver, 1991). According to Parkinson (2013), interacting with music (e.g., listening, playing) involves the challenge to find the hidden potentials and affordances in sounds, and this can be achieved by changing the way we listen or recontextualising or even reworking the sound itself. The author gives the example of musicians such as Keith Rowe (guitar) or Evan Parker (saxophone), who reveal new sound worlds through extended playing techniques. This resonates with Glăveanu's ecological perspective on creativity, which makes a distinction between "unperceived affordances" and "unexploited affordances" (Glăveanu, 2012). The former are action possibilities one is not aware of and therefore does not realize. Through exploration and experimentation, they can be discovered. The latter remain unexploited because of, for example, existing norms (e.g., cultural, professional) or individual choices. In the case of musicians like Rowe and Parker, the conventional ways of playing an instrument are "extended" through exploring new action possibilities on the instrument and thus finding new sounds to express themselves (see also Bertinetto, 2021).

The perceptibility of affordances can be linked to another factor that determines the purposeful navigation of affordances, namely the *skills of the perceiver*. Rietveld and Kiverstein (2014), for example, argue that developing learners' attention skills involves learning to selectively pick up some aspects of the environment while ignoring others. Experts then have developed a "nose" that enables them to immediately "sniff out" which possibilities for action are better or worse in a specific situation" (Rietveld & Kiverstein, 2014, p. 27). This allows getting an optimal grip on a particular situation (Bruineberg & Rietveld, 2014), which involves a temporary equilibrium state between the skillful body and the environment.

In music, Einarsson and Ziemke (2017) define optimal grip as "having the full palate of artistic expression made available, in relation to the situational demands," mentioning for example the optimization of feedback monitoring, positioning in relation to the audience and/or fellow musicians, controlling muscular tension/level of anxiety in order to perform at his or her best, minimization of possible distractions or the acknowledgment and adaptation to room acoustics as ways of achieving this grip.

Getting an optimal grip on the music can also be seen from the perspective of Leman's transition processes of expressive alignment (Leman, 2016, pp. 167ef). Through the *enactment* (see also further) of the music's perceived intentionality, these processes involve the transformation of basic mechanisms in the lived experience (1) of being in control based on successful prediction (agency; e.g., end of a phrase, harmonic progression), (2) of being awake, alert, and excited (arousal) in relation to physical effort, and (3) of connecting to the other (musician, music) based on re-enacting the other using expressive reflexes and learnt behavior (e.g., moving in sync). Running in parallel, these processes induce a "homeostatic state," i.e., a state in which cognitive and motivational brain mechanisms reinforce each other (Leman, Buhmann, & Van Dyck, 2017) that empowers an individual that successfully, or with

optimal grip, interacts with music (Leman, 2016). For example, as such homeostasis is generated through synchronization and alignment of movements with sounds, a sudden change in tempo in the music might induce a breakdown in the lived experience, and urge to re-entrain with the music, so successful prediction can be restored and alignment of music and movement can be flexibly adapted.

The tendency to get an optimal grip, also named *skilled intentionality* (Rietveld, Denys, & Van Westen, 2018), is a central feature of everyday skillful coping with our environment. Being the result of a dynamic interaction between the landscape of affordances and the current state of an individual, this tendency determines the selective openness to the affordance landscape, making certain affordances "stand out" as relevant. As such, it becomes possible to unreflectively respond to the relevant affordances (Rietveld, Denys, & Van Westen, 2018).

Here, it is of interest to adopt the distinction between the *landscape* and the *field* of affordances. While the former concerns a set of affordances that relate to a certain form of life in general (e.g., humans), the latter concerns a set off affordances that relate to the skills, concerns, and needs of a specific individual (Kiverstein, van Dijk, & Rietveld, 2019). For example, one could say that music in general affords movement, but to a specific person particular affordances will stand out and invite to move in particular ways (e.g., Grahn & McAuley, 2009; Rajan et al., 2019). For example, Luck, Saarikallio, Burger, Thompson, and Toiviainen (2010) showed that personality, and particularly extraversion and neuroticism, lead to different patterns in music-induced movement. Zelechowska, Gonzalez Sanchez, Laeng, Vuoskoski, and Jensenius (2020) found that empathic concern predicts the way people spontaneously move to music. Therefore, another relevant distinction is the distinction between *affordances* and *solicitations*. The latter are those affordances that stand out as relevant to a situated individual and generate bodily states of action readiness (Rietveld, Denys, & Van Westen, 2018). An affordances' relevance emerges from aspects of the environment triggering patterns that shape the skillful individual's action-readiness for interacting with its environment. Due to the multiplicity of affordances, this is an important distinction. Relevance implies stimulating an engagement that is adequate to a situation and in line with an individual's interests, preferences, and needs and promoting to do one thing rather than another.

A third factor that determines the purposeful navigation of affordances is an *individual's concerns*, or interests, preferences, and needs. According to Rietveld, (), detecting an affordance that is relevant to one's current concerns promotes the aforementioned action readiness. As such, only those affordances that are relevant to an individual's current concerns will solicit an individual's actions. For example, Hargreaves, Hargreaves, and North (2012, p. 164) state "that sounds with different affordances are interpreted by listeners who have different individual needs and attributes, and this negotiation occurs in a variety of ways in different."

Finally, an individual's responsiveness to affordances is influenced by their past *experiences, habits, familiarity, and socio-cultural environment* (Yakhlef & Rietveld, 2020). For example, the specific motor pattern of activation due to familiarity with music influences engagement with music familiar tunes based on anticipating melodic, harmonic progressions, rhythms, timbres, and lyric events in the familiar music (Freitas et al., 2018). These data provide evidence for the need for larger neuroimaging studies to understand the neural correlates of music familiarity. Also, the perception of consonance and dissonance in music is different for people who have limited exposure to the Western musical culture (McDermott, Schultz, Undurraga, & Godoy, 2016). Furthermore, listeners perceive language-specific rhythmic properties in a musical context (Hannon, 2009).

The dynamic coupling with the musical environment

Considering the above factors, affordances navigation can be linked to dynamical systems theory, taking into account the different constraints that can influence the non-linear dynamic unfolding of the coupling between an individual (e.g., musician) and the environment (e.g., musical performance situation, encompassing the music but also the audience, the concert hall) (see also, Rooney, 2023). The main idea is that, when interacting with music, a brain-body-environment system is established that couples the individual and the music through an interactive dialectics based on the previously described emergence-disposition dynamics (Leman, 2016). As affordances are attributes of this brain-body-environment system and the affordance landscape changes over time due to events in the environment but also – importantly – due to an individual's own actions and concerns (Bruineberg & Rietveld, 2014; Pezzulo & Cisek, 2016), attuning to the relevant affordances can be scaffolded by introducing a set of constraints, i.e. interventions blocking out an ineffective involvement with a task (Abrahamson & Sánchez-García, 2016; Abrahamson, Sánchez-García, & Smyth, 2016; see also Bremmer & Nijs, 2020). Note that the affordances themselves also involve constraints, not

Table 1. The different constraints that shape the interaction with the environment.

Environmental constraints	Physical factors surrounding learners, shaping certain or limiting behavior
Organismic constraints	The characteristics of an individual
Task constraints	The goal of a specific task, Providing feedback on the task, Asking questions, or The materials used during a learning experience

only possibilities (Riccio & Stoffregen, 1988; see also the concept of affordance space in Zhang & Patel, 2006).

Newell (1986) distinguishes between three broad categories of factors that shape or limit certain behaviors, displayed in Table 1.

Constraints guide an individual attunement to the relevant affordances during interaction with the environment. As they shape an ongoing activity, they may change particular actions thereby yielding new affordances and lead to variations in opportunities for subsequent actions (Turvey & Shaw, 1999). In that sense, introducing constraints may stimulate to seek and exploit different affordances (Dicks, Davids, & Araujo, 2008). Manipulating the different constraints can therefore provoke or stimulate the discovery of novel information and the emergence of innovative and functional behavioral patterns (Hristovski, Davids, Araujo, & Passos, 2011). Interestingly, different scholars argue that there is a need to consider socio-cultural constraints as integral constraints on skilled action (Rietveld, 2008; Vaughan, Mallett, Davids, Potrac, & López-Felip, 2019). When interacting with music, whether playing, dancing, or listening, these constraints, involving, for example, style and traditions, play an important role in driving the interaction. According to Vaughan, Mallett, Davids, Potrac, and López-Felip (2019), creativity emerges and arises from a combination of such dynamic constraints.

Metastability: novelty through open and flexible interaction with competing affordances

Desirable states and actions

The above-described process of purposeful affordance navigation entails two parallel processes that guide the interaction with our environment, namely the *specification* and the *selection* of possible actions, whereby different actions compete before a decision is made about which action to realize (Pezzulo & Cisek, 2016). According to Cisek (2012), this decision making is based on a competition within the sensorimotor system and biased by the desirability of the outcome of the action (Pezzulo & Cisek, 2016). For example, when dancing to music, there are many – competing – possibilities to move to the music, out of which one may select the ones that are most likely to achieve a desired outcome, such as an expressive gesture that coincides with a certain element in the music.

A basic idea of this view, is that our brain is a feedback control system that serves meaningful interaction with the environment by keeping an organism in a desirable state (e.g., stable temperature of 37°C) based on a tight coupling between perception, i.e., evaluating the state of the organism (e.g., having fever), and action, i.e., influencing the state in the world (e.g., taking medicine). In music interaction, imagine dancing to the music, which most often involves the desire to synchronize movements to salient elements in the music such as the beat. When not yet in sync (perception), movements are adapted (action) until synchronization is perceived as successful (see also Leman, 2016, pp. 165–166 on finding, keeping, and being the beat). Such a desirable state can be seen as "a global state of relative equilibrium (homeostasis) that is empowering, energizing, and reinforcing" (Leman, 2016). Indeed, when experiencing successful synchronization with the music, an individual might feel empowered to add more expressive elements in her movements. The desirability of such state arguably stems from the affectively irresistible nature of music, exhibited through the *felt allure* of the musical affordances (Krueger, 2014). Being pulled to synchronize with the music, also called *entrainment*, is typical for such a felt allure (e.g., Clayton, Sager, & Will, 2005). Our being drawn to the music emerges from our almost immediate recognition as being meaningful, as something that invites us to do things with (Krueger, 2011).

During the interaction with the environment, the affordances serve as the simultaneous specification of possible desirable actions currently available in the environment. For example, one might move to the bass drum or the high hats in the drum section, or to the melody in the guitar. The choice between different actions is based on a competition between representations of these actions and influenced by the degree of the desirability (Pezzulo & Cisek, 2016). For example, when the desirable state is synchronization, moving to the bass drum might be a more feasible choose than moving the guitar solo. The control feedback loop monitors the execution of the selected action, using internal

predictions of the outcome in combination with sensory information in the environment. This allows fine-tuning or updating the ongoing action. According to Burr (2017), this competition occurs within the sensorimotor system itself, which is continuously processing sensory information to specify the parameters of possible actions. Importantly, other possible actions continue to be processed even during ongoing activity, allowing to rapidly switch between actions when it is necessary or when an opportunity arises. Selecting the best action is then based on the biasing input that is provided by other regions of the brain. Here, prediction again plays an important role. Indeed, rather than being merely reactive to available affordances, brains are continuously engaged in generating predictions (Clark, 2015). Switching actions (e.g., expressive moves) to adequately adapt interaction with the environment (e.g., music and other individuals) depends on the brain's ability to predict the consequence of selecting one action over another (Pezzulo & Cisek, 2016). Moreover, being able to predict the outcomes of several competing actions enables linking actions across different levels of abstraction, thereby biasing immediate actions by predicted possible long-term opportunities. This leads to a nested cascade of expectations, involving a hierarchy of control loops that compete in parallel at different levels and mutually influence each other through top-down and bottom-up signals (Cisek, 2012). The higher levels encode more abstract goals (e.g., play expressive) and create expectations for the lower levels, without precisely describing how the lower levels should produce these expectations (e.g., detach notes or not, but with adequate dynamics to elicit expressive phrasing). At the same time, what happens at lower levels (e.g., technical difficulty) may provoke changes at higher levels (e.g., technically correct playing).

Metastability

Switching effortlessly between different actions (or patterns of behavior) relies on metastability, i.e., the ability to possess different co-existent pattern forming tendencies (Kello, Anderson, Holden, & Van Orden, 2008). Metastability is a feature of multistable systems constrained to dwell between stability and instability, thereby facilitating novel, unpredictable and functional behavior (Hristovski, Davids, Araujo, & Passos, 2011). This enables rapidly accommodating small deviations (prediction errors) from the predicted outcomes of an action (Bruineberg & Rietveld, 2014). A fine example of a metastable state in music concerns groove. According to Vander Elst, Vuust, and Kringelbach (2021), rhythms with medium levels of syncopation generate a choice of how to adapt movements to the music in order to synchronize. This also leads to more pleasure (Witek, Clarke, Wallentin, Kringelbach, & Vuust, 2014). Low levels of syncopation urge less to move, high levels make it harder to synchronize. Another example concerns ambiguity of meter in Samba Music, where individuals can choose to move to the binary, ternary, or both (Leman & Naveda, 2010). Some of these deviations can be dealt with at the lower level whereby patterns that evolve slowly (e.g., synchronizing to a rhythm) can be left intact, while deviations that suddenly impact those slower evolving patterns (e.g., sudden tempo change) may provoke significant changes in an action. It is exactly these adaptivity and flexibility that characterize skillful coping with the environment, allowing us to adequately respond to the multiplicity of affordances. In music performance, for example, this is enabled through an optimal relationship with the instrument, in which the instrument becomes a natural – or transparent – extension of the musician and thereby allows an embodied expressive interaction with the music (Nijs, 2019; Nijs, Lesaffre, & Leman, 2013).

Metastability not only allows flexible switching between actions but also context-sensitive selective openness. Indeed, it enables the behavioral flexibility that is necessary for intentional affordance navigation. Flexibly switching between actions requires adequate attunement to the dynamically changing landscape of affordances. It involves a so-called *hypergrip* on a field of relevant affordances (Bruineberg & Rietveld, 2014). Such hypergrip involves being in a (relatively) optimal metastable zone, in which one is simultaneously ready for responding to multiple affordances and for flexibly switching between possible responses in line with environmental fluctuations (Rietveld, Denys, & Van Westen, 2018).

Supporting context-sensitive selective openness and flexible switching between activities, metastability plays an important role in creative affordance navigation, whereby new affordances are discovered or even created (Glăveanu, 2012).

In the following section, we couple the above described to cognitive flexibility, which has previously been linked to creativity, understanding it as "shifting" or creatively thinking "outside the box," seeing something from different perspectives, and quickly and flexibly adapting to changed circumstances (Diamond, 2013).

Cognitive flexibility: coping with multiplicity

Cognitive flexibility has not been easy to define due to the wide range of behaviors it includes. As such, there is no single definition or conception (Ionescu, 2012).

Rather, it is frequently used as an umbrella concept to describe different types of psychological constructs (Ionescu, 2012; Kraft, Rademacher, Eckart, & Fiebach, 2020). To improve our knowledge of cognitive flexibility, we need to unveil the common base of flexibility in the different contexts in which it appears, and also consider insights about the different involved mechanisms (e.g., shifting) or its connection with the role of contextual affordances (Ionescu, 2012). As has been suggested by affordance-oriented accounts, one recognizes that a single object, such as music, can have different meanings to an individual. As Gibson (1986) had already emphasized, a single object can afford different behaviors to an individual. As such, flexibly coping with the multiplicity of meanings (and as such the affordances) and spontaneously selecting appropriate actions is an important element within our dynamic interaction with the environment. Considering that cognitive and emotional phenomena are overlapped (Feldman Barrett, 2017; Gross & Feldman Barrett, 2011), Scherer (2009, p. 3459) proposed that "emotion is a cultural and psychobiological adaptation mechanism which allows each individual to react flexibly and dynamically to environmental contingencies."

Whether listening, moving to music or performing, cognitive flexibility plays an important role when interacting with music. It is necessary to decode and process different aspects of music (e.g., meter, tonality, tempo, pitch, rhythm,and articulation), and as such to make sense of the complexity of the music (Herrero and Carriedo, 2022). As such, it can also be connected to affordance navigation and metastability. For example, regarding the former, intentional navigation of the affordance landscape requires cognitive and behavioral flexibility to recognize and adapt to musical affordances such as changes in musical clef (Slama, Rebillon, & Kolinsky, 2017), changes in rhythm (Levitin, Grahn, & London, 2018; Manning & Schutz, 2016) or dynamics, enabling them to navigate the musical landscape effectively. Regarding the latter, Hellyer, Scott, Shanahan, Sharp, and Leech (2015) found reduced cognitive flexibility and information processing to be associated with a decreased metastability.

Cognitive flexibility has also been connected to creativity. For example, Nijstad, De Dreu, Rietzschel, and Baas (2010) proposed two pathways to creative performance: the flexibility pathway or flexible switching between categories and perspective, and the persistence pathway which implies hard and systematic work (Khalil, Godde, & Karim, 2019). Based on the same two pathways, Wu, Koutstaal, and Agnoli (2020) evaluated the generality of the association between cognitive flexibility and creativity assessing how often participants "shift" to work on a second problem versus "dwell" in solving the current problem. Both the dwell and shift measures explained a significant proportion of variance in measures of fluency, and originality (creativity).

However, the nature of this relationship has not been clarified. Cognitive flexibility (CF) is often considered a skill within the executive function (EF) construct and typically measured by set-shifting and task-switching tasks. For example, Diamond (2013) proposes that cognitive flexibility could be understood as shifting or creatively thinking "outside the box," seeing anything from different perspectives, and quickly and flexibly adapting to changed circumstances. However, it can also be considered a feature that emerges from the interaction of different cognitive processes (e.g., a flexible use of the language) (Ionescu, 2012). This conception about flexibility as a cognitive feature of different cognitive processes includes the ability to manage one's emotions flexibly, which is a key characteristic of everyday life and interpersonal exchanges (Kraft, Rademacher, Eckart, & Fiebach, 2020), since emotions are emergent acts of meaning-making in our relationship with the world (Gross & Feldman Barrett, 2011).

According to Arán and Krumm (2020) and Ionescu (2012), considering CF as a property rather than as a static skill could explain why cognitive flexibility may overlap, for example, with the concept of creativity. Here, cognitive flexibility concerns the interaction of sensorimotor processes with cognition and the context in developmental time (Ionescu, 2012). Grounded in the idea that several mechanisms interact to respond to particular environmental demands, this conception about cognitive flexibility is more aligned with the embodied cognition paradigm and with the ecological philosophy (Gibson, 1986). The basic idea is that several mechanisms interact to respond to particular environmental demands. As has been suggested, embodied cognition provides a way to look beyond pure mental processing to understand cognitive flexibility and its emergence (Ionescu, 2012).

Considering cognitive flexibility as a unified cognitive function for flexible behaviors, requires conceiving it within a larger framework of a brain – body–context interaction or in an embodied cognition perspective. Creative motor actions (adaptive combination of movements) are a function of the individual, as much as the task and environment (Hristovski, Davids, Araujo, & Passos, 2011; see; Orth, van der Kamp, Memmert, & Savelsbergh, 2017). They can arise in the temporal coupling between the organism and the environment, while the action unfolds (Orth, van der Kamp, Memmert, & Savelsbergh, 2017). This aligns very well with current insights on musical interaction, from the perspective on

cognition as *embodied*, *embedded*, *enactive*, and *extended* (in short, "4E"). Here, "musical minds are explored as active musical bodies that are embedded within, and that extend into, the social, material, and cultural ecologies they inhabit and actively shape or enact" (Van der Schyff, Schiavio, & Elliott, 2022)

Pezzulo (2008) has proposed that all knowledge for behavior, for all organisms, is derived from sensorimotor anticipation. An evolutionary pressure could have supported the development of predictive, and simulative mechanisms for action control, cerebellum hold an active role in instructing or "teaching" the frontal cortex to predict or anticipate (Koziol, Budding, & Chidekel, 2012), and also cerebellum participates in switching mechanisms which influence behavioral adjustment speed and the ability to do transitions in a changing environment (Koziol, Budding, & Chidekel, 2012). In a recent study, Ben-Soussan, Berkovich-Ohana, Piervincenzi, Glicksohn, and Carducci (2015) investigated the link between cognitive flexibility, movement, and creativity, or the flexibility-creativity-motor connection. For that purpose, they employed a whole-body movement contemplative practice or Quadrato Motor Training (QMT). Such practice requires a state of enhanced attention, combining dividing attention to the motor response and cognitive processing for producing the correct direction of movement (Ben-Soussan, Berkovich-Ohana, Piervincenzi, Glicksohn, & Carducci, 2015). The aim of the study was to explore a poorly investigated aspect of creativity as cognitive flexibility, and its possible connection to the motor system, which was already suggested by previous research (Cotterill, 2001; Dietrich, 2004; Koziol, Budding, & Chidekel, 2012; Matheson & Kenett, 2020). They found that QMT practice for four weeks increased cognitive flexibility, gray matter volume and fractional anisotropy in left and right cerebellum, in frontal areas, mainly in the inferior frontal and middle frontal gyri, and that these anatomical changes were also positively correlated with cognitive flexibility. Recent evidence has demonstrated that distributed networks throughout the brain are involved in movement, attention, flexibility, and creativity, and all these cerebral networks map onto cerebellum with topographic specificity (Schmahmann, 2019).

Different studies have shown that musical expertise is positively related to non-musical CF (e.g., Moradzadeh, Blumenthal, & Wiseheart, 2015; Zuk, Benjamin, Kenyon, Gaab, & Bruce, 2014). This is related to their "nose" to intuitively respond to the relevant affordances in the environment and, as such, get an optimal grip on the situation. Furthermore, the default-mode, executive, and motor-planning networks (bilateral cerebellum, medial premotor cortex) have been described as implicated regions in musical creativity. Considering "being musically creative" as improvising, composing, etc. (Bashwiner et al., 2020), this suggests that music cognition may be more motoric than has been considered before. Finally, Bashwiner and Bacon (2019, p. 146) concluded that "rather than conceptualizing music as an art of sound for sound's sake, it may be better to conceptualize it as an art of movement for sound's sake." In the following section, we elaborate on this idea.

Enactment: the creative transformation of sound into music through embodied mechanisms

Following the previous sections, it can be argued that the creative interaction with music involves a process of musical sense-making through the flexible navigation of the musical affordance landscape. In this section, we elaborate on the embodied nature of such interaction, building on a pragmatic view on musical interaction as developed by Leman (2016).

In this view, music is conceived as not being inherently meaningful. Rather, musical meaning is considered the outcome of a bodily involvement with music. The idea is that while interacting with music, the stream of seemingly random sounds is transformed into a meaningful musical experience based on a sound-movement-intention connection. This transformation process, also called *enactment*, occurs through the association of patterns in the sounds (e.g., chord sequence or melody) with movement patterns (e.g., shape, direction, energy) and thereby with the intentional states (e.g., an emotion) that underlie these patterns (see Figure 1).

The enactment process involves the emergence of higher-level musical patterns that reduce the complexity of the sound stream and as such facilitate the alignment of a movement or action pattern to the music and, consequently, the attribution of intentions to the music. Here, different auditory perceptual objects may blend together into a single auditory perceptual object. For example, separate notes are heard together as chords, which can be grouped into a chord progression; or separate notes are perceived as a rhythmic or melodic pattern. Within these emergent patterns, expressive cues appear as affordances and exploit the patterns' ability to function as biosignals that elicit responses of the human expressive system. As such, a specific melodic or harmonic change may elicit an expressive response. Expressive responses involve both a sensitivity and responsiveness to these affordances. As such, musical affordances play an important role in the attribution of meaning to music, inviting to unlock a value system that enables to load the perceived patterns with appraisal and

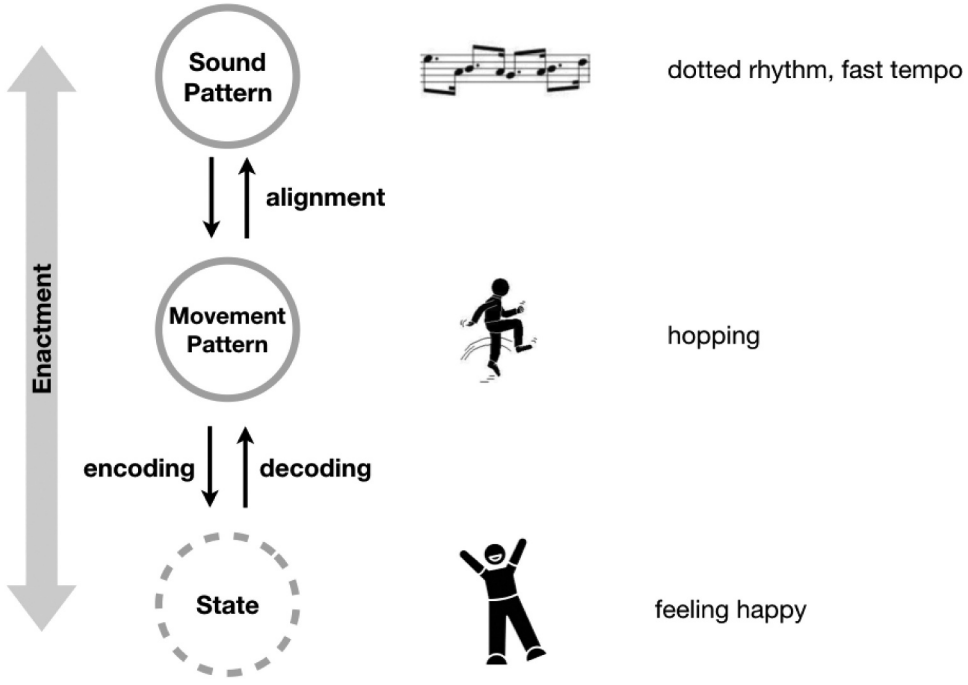

Figure 1. An example of the enactment process: when listening to music, the listener aligns (overtly or covertly) a certain movement (e.g., hopping) to the perceived sound pattern (e.g., dotted rhythm). Next, based on personal experience, this movement is decoded through its association with a certain state (e.g., feeling happy). Based on Leman (2016, p. 16).

intentionality. Moreover, the relationship between one's perception of musical patterns and their processing is affected by mediators that determine how particular aspects of a sound pattern (e.g., subdivision of a rhythmic pattern) are selected, disambiguated or reinforced. One such mediator is movement. Here, corporeal articulations to the music are seen both as a way to invoke the emergence of higher-level patterns and as an efficient means to capture the affordances.

The attribution of intentions to music by associating musical and movement patterns, is rooted in several basic mechanisms: alignment, entrainment, and prediction. *Alignment* concerns the matching of physical actions to what happens in the music, whether on the beat (*phase alignment*) or in between the beats (*interphase alignment*). Alignment becomes apparent in movement to music. For example, Kelkar and Jensenius (2018) investigated hand movement to melodic phrases, and came to the conclusion that while arch shapes were commonly used, participants adopted different strategies to map melody to movement. Such alignments are driven by processes that draw upon predictive, energetic, and affective states, i.e., the conditions that lead to patterns. Indeed, pattern matching in musical interaction is related to a reciprocal influence between patterns and states. Leman (2016, p. 248) hypotheses that this process can be considered based on three state-transition processes that "run parallel and, together with pattern processing, establish a cognitive-motivational loop that generates the rewarding and empowering nature of musical experiences." The first process concerns how *predictive processing* gives rise to a sense of agency and associated affects. The second process concerns how *energetic processing* gives rise to attention shifts and arousal, i.e., physiological and psychological state of being awake or reactive to stimuli. The third process concerns *alignment* as involving an interaction with expressive affordances, and how this realizes a pro-social attitude for interacting.

Alignment happens within a global timing framework that is established through the synchronization of movements with salient time markers in the music. *Entrainment*, or "the coordination of *rhythm, temporally* structured events through interaction" (Clayton, Sager, & Will, 2005) is the process of being pulled toward synchronization thereby supporting alignment with music. By attracting or pulling people toward the beat, entrainment enables three sensorimotor mechanisms: *finding*, i.e. recognizing the regularity in time of salient markers, *keeping*, i.e. and even being the beat (Moens & Leman, 2015). As such, it enables the emergence of an individual's overall timing framework. The transition from finding to being, a change occurs in effort. Finding the beat requires effort, but once the beat has been found and prediction runs smooth, it no

longer requires effort, and energy is freed up to spend on other aspects of the musical interaction.

Establishing a global timing framework through the mechanisms of entrainment and aligning to the music within that framework, is based on the ability to sense what comes next and the ability to predict the outcome of a movement aligned to a pattern that affords the movement. Such prediction is characterized by both biomechanical constraints (e.g., the length and form of our legs and arms; e.g., Dahl & Huron, 2007) and states of arousal (e.g., feeling fatigued or being energetic; e.g., Tröst et al., 2014). As such, *prediction* or anticipation of music is viewed as the expected outcome of bodily-mediated perceptions and physical actions with music. Leman (2016) distinguishes between different interaction situations with music that are determined by predictive control. First, *attenuation* occurs when, due to successful prediction, the self-generated sensory information that stems from playing or moving to the music no longer requires conscious monitoring and attention is freed up for other elements in the musical interaction. For example, when synchronization of feet movement to the music goes well (being the beat), there is no longer need pay attention to synchronizing (finding, keeping the beat) and attention can go to expressively moving with the arms. Second, *facilitation* occurs when the interaction with music becomes easier by facilitating the prediction of a certain channel in music, such as timing, over other channels, such as melody or harmony. Here, movement can play a role. Think of how musicians might indicate the beats by tapping the foot, thereby offloading consciously "counting" the beats. Finally, *disambiguation* occurs when uncertainties in the music in terms of perceptual or affective-expressive content (e.g., different meters, emotions) that may hinder prediction and interfere with pattern detection and emergence, are reduced. Again, movement can help to disambiguate metrical (e.g., Phillips-Silver & Trainor, 2005) or expressive (e.g., Maes, Leman, & Snyder, 2013) ambiguity.

Clearly, Leman's account of human interaction with music relates to the processes of affordance navigation, metastability, and cognitive flexibility. Through its basic mechanisms of alignment, entrainment and prediction, and the associated transition processes, sensorimotor mechanisms and interaction situations, the process of enactment supports the flexible navigation of the musical affordance landscape. Moreover, based on prediction, effort, and expression as the major ingredients of the enactment process, the pattern processing that underlies alignment and entrainment involves the co-occurrence of arousal, positive valence, and the feeling of being in control. As such, successful enactment supports cognitive flexibility.

According to Leman, a basis for expression can be the repertoire of action patterns, or gestures, that allow for expressive interaction. As such, it might be argued that acquiring a broad repertoire of music-related action patterns may facilitate this process and promote the creative navigation of the musical affordance landscape through movement.

Creativity in music learning: flexibly navigating the musical affordance landscape through movement

A great deal of research has been conducted on how to foster creative thinking in music education, adopting different perspectives: product, process, or performance based (Running, 2008), in real time (e.g., creative listening, improvisation), or delayed time (e.g., composition) (Webster, 1990, 2016). However, specific pedagogical practices that lead to creativity have not been identified (Sawyer, 2018). These perspectives have led to a wide range of tests being carried out to measure and quantify creative thought. Examples are the Torrance's Measure of Creative Thinking (Torrance, 1966), Guilford's Test Structure of Intellect (Guilford & Hoepfner, 1971), Webster's Measure of Creative Thinking in Music (Webster, 1990, 2002), Gordon's Measure of Musical Divergent Production (Gorder, 1980). Despite their different designs, these tests are based on two main standpoints:

(1) creativity may be measured according to four parameters: *fluency* (number of interpretations), *flexibility* (ability to use different categories), *originality* (uniqueness of idea), and *elaboration* (connecting ideas)
(2) creative thought requires a balance between convergent and divergent thinking.

The basic traditional pedagogical assumption is that creativity is mainly a linear mental process: musical ideas emerge in the head, where they are organized creatively, and then manipulated to produce a final product. Accordingly, the role of the body seems to be considered a means to materially realize musical ideas, without being involved in the creative process (Withagen & van der Kamp, 2018).

Musical creativity, audiation, and cognitive flexibility

According to Gordon (1989), the ability to be musically creative is related to audiation skills. Audiation, which he distinguishes from mere imitation,

recognition, and memorization, is the process through which sound becomes music and meaning is attributed to that music (Gordon, 2007). In other words, it is about "thinking music in the mind with understanding." In his theory on music learning, Gordon states that only after acquiring tonal and rhythmic patterns in various tonalities and meters, students have something to create, differently, the process of creation is reduced to a process of aleatoric exploration (Gordon, 1989). Moreover, in his view, musical creativity cannot be taught, only one's readiness to fulfil a potential for musical creativity. However, research has not convincingly shown positive correlations between audiation skills (as related to musical aptitude) and measures of creativity. However, early research found several negative correlations between measures of audiation and aspects of creativity. For example, Schmidt and Sinor (1986), who investigated the relationships among music audiation, musical creativity, and cognitive style, found negative correlations among second-grade children between rhythm audiation and two dimensions of Webster's (Webster, 1987) Measure of Creative Thinking in Music (flexibility and syntax). Josuweit (1991) found significant negative correlations between rhythm audiation and fluency. Based on these early studies, Kratus (1994) concluded that audiation (in children) is unrelated or negatively related to musical creativity. A metastudy by Hanson (2019) confirmed the weak association between the rhythmic audiation skills and creativity but concluded that tonal and composite constructs are associated more strongly with creativity.

Kratus (1994) pointed, however, at an important element, namely the importance of how creativity is conceived and measured (see also: Malinin, 2019). Indeed, Kupers, Van Dijk, and Lehmann-Wermser (2018) states that 80% of the studies employed measures on either the person or the product level. Here, we emphasized the process level of creativity and the different processes that are involved, such as affordance navigation, metastability, and cognitive flexibility. Audiation is strongly related to cognitive flexibility, the latter being essential in the creative navigation of the affordance landscape. In a recent study, Grinspun et al. (2020) show that audiation is related to attentional levels and the inhibitory control of attention. Selective attention or executive attention is an endogenous, voluntary, and top-down process that allows voluntarily choosing or ignoring stimuli and focusing on others (Diamond, 2013; Posner & DiGirolamo, 1998; Theeuwes, 2010). Inhibitory control of attention or interference control at the level of perception (Diamond, 2013) allows selectively attending or focusing on what we choose and suppressing attention to other stimuli (Diamond, 2013; Posner & DiGirolamo, 1998; Theeuwes, 2010), for that, it is necessary to inhibit previous perspectives and load others, and is in that manner that cognitive flexibility is connected to attentional processes (Cañas, Quesada, Antolí, & Fajardo, 2003; Moore & Malinowski, 2009).

An embodied approach to music learning

In their 4E perspective on musical creativity, Van der Schyff, Schiavio, Walton, Velardo, and Chemero (2018) state that musical creativity is deeply dependent on the bodily power of our actions and unfolds in terms of motor possibilities. Indeed, body movement not only serves generating a creative output but also may function as a resource for exploring and generating creative ideas and solutions (Matheson & Kenett, 2020; Oppici, Frith, & Rudd, 2020). It is not only something we just do because music invites us or "affords" to do so. Movement can be considered as a way to facilitate creative expression (Evans, Alibali, & McNeil, 2001; Torrance, 1981) and to provoke learners' readiness to fulfil their potential for musical creativity (Gordon, 1989). First, movement can be used to develop musical understanding. Eminent educators such as Dalcroze, Kodaly, Orff or Gordon understood the power of movement to develop musical understanding and develop music educational practices that integrate movement to cope with the different elements in the music, such as melody (e.g., Kodaly's use of the Curwen hand signs; Leman, Nijs, & Di Stefano, 2017) or rhythm (e.g., arm and stepping exercises in Dalcroze's Eurhythmics; Jaques-Dalcroze, 2014). Although empirical research on the effect of body movement on music learning is still scarce, some studies seem to confirm the practical knowledge of these educators. For example, Youngson and Persellin (2001) showed that the use of hand gestures helps children to improve singing a melodic motif. A similar positive effect on singing was also noted by Kim (2020) and Chen (2007). Martinovic-Trejgut (2010) shows in her work that movement has a positive effect on the memorization of text, rhythm and pitch.

Second, movement can be used to change the way we listen to music, recontextualizing, and even reworking or restructuring the stream of sounds through an embodied interaction. Indeed, moving to the music can support learners in attending to elements of the music, and as such to perceive, exploit, and generate novel affordances (Glăveanu, 2012; Oppici, Frith, & Rudd, 2020). By introducing a set of *individual* (e.g., body parts involved), *task* (e.g., move to the music) and

environmental (e.g., choice of music) constraints, movement-based learning activities that encourage perceptual-motor exploration of the musical environment engage students in the purposeful navigation of the musical affordance landscape. In this way, learners are provoked to perceive and utilize novel affordances thereby promoting the broadening of their field of affordances. Such engagement affects the way learners make sense of the music. As Leman (2016) argues, movement acts as a mediator for the enactment process through which learners attribute meaning to the music. Through specific tasks, learners can be invited to specify and select possible creative movement responses to the music. In doing so, they need to audiate the music in order to predict the outcome of the possible creative movements in relation to elements in the music. Moreover, the invitation to move to the music brings the learner in a metastable state, urging to make choices to gain a grip on the multiplicity of affordances.

To illustrate this, we refer to two studies by the first and third author. In a first study (Authors, 2020; Authors, 2019), one group of children engaged in learning activities based on talking about the music, the other group engaged in movement-based learning. Before and after 3 days of consecutive intervention, the children were invited to create a graphical representation (drawing) of the music and to provide a verbal explanation of the drawing in relation to the music. The drawings of the children who were involved in a bodily music interaction showed a significant increase of differentiated representations from pretest and posttest, capture one or more musical parameters, and focusing on the temporal organization of the piece (Authors, 2019). The increased differentiation was also found in the children's verbal explanation of the drawings. Thematic analysis and statistical tests on the verbal data revealed a significant change in semantic themes, time dimension, and the number of music parameters mentioned (Authors, 2020). In a follow-up study, the effect of movement on musical sense-making was further explored. Following the same design, one group of children engaged in learning activities based on continuous movements, the other group engaged in learning activities based on discrete movements. Similar to the results of the first study, children's graphical representations were more differentiated in the post test. Interestingly, and in congrats to the researcher's expectations, the drawings of the children in the group that used discrete movements were more differentiated.

Both studies point at the potential of moving to music, to discover new elements in the music, based on an increased attention toward specific aspects of the music. The drawing of attention to these elements may lead to the discovery of new affordances to move in creative ways to the music. As Oppici, Frith, and Rudd (2020) argue, the process by which creative movement emerges may influence and enhance how creative ideas are generated. As such, the use of movement to music in studies on creativity may lead to novel insight, for example, on creativity in daily life.

Conclusions and implications

Music education is about empowering personal and artistic growth through learning about music (e.g., structure, style, components), learning how to enjoy and aesthetically appreciate, how to make (e.g., compose, improvise) and perform music. Most educators will agree that the development of musical creativity is an essential part of this process. After all, whether listening, composing, improvising, playing, or dancing to music, the way one interacts with the music determines how meaning will be attributed to the music and as such how the interaction may become expressive and empowering. A creative approach to each of these activities will broaden and deepen one's understanding. However, scholars argue that creativity is not often addressed in the classroom (e.g., Beghetto, 2010; Rinkevich, 2011).

One of the reasons for this could be that music education has mainly adopted a linear and unidirectional perspective on creativity. In such perspective, it is assumed that the development of theoretical knowledge and instrumental technique must occur before the development of creativity and that musical ideas arise first in the head, are the, creatively organized, and finally manipulated to realize a creative outcome product (Withagen & van der Kamp, 2018). However, these assumptions do not align with current insights on creativity but adhere to a rather outdated view on cognition based on information-processing approaches to the mind (Van der Schyff, Schiavio, Walton, Velardo, & Chemero, 2018).

We believe that to foster the development of more creative approaches for music education, it is necessary to develop a solid theoretical account of creativity in music learning. Such a theoretical account necessarily aligns with current insights on human interaction from different disciplines such as (music) psychology (e.g., the work on embodied music interaction (Leman, 2016); on creativity (Glăveanu, 2012, 2014; Kupers, Lehmann-Wermser, McPherson, & van Geert, 2019)), music performance science (e.g., on the musician-instrument relationship (Nijs, 2017; Nijs, Lesaffre, & Leman, 2013)), sport science and physical education (e.g., the role of variation (Schmidt, 2008; Schöllhorn, 2000),

constraints-led approach (Hopper, 2012)), and educational sciences (e.g., non-linear pedagogy (Lee et al., 2014).

In contrast to the prevailing product- and person-oriented approaches (Kupers & van Dijk, 2020), this contribution considered creativity from a process-oriented view, by assuming a dynamic, relational, and action-oriented approach on musical creativity through movement. Starting from the concept of affordance navigation, creativity was connected to cognitive flexibility that, conceived as a unified cognitive function for flexible behavior in the brain-body-context interaction (Ionescu, 2012), allows a context-sensitive selective aperture. Such aperture was connected to the process of enactment that constitutes the embodied interaction with music and fosters musical sense-making. The basic idea that was put forward is that inviting to move to the music is a way to provoke a flexible and creative navigation of the musical affordance landscape by bringing the learner in a metastable state in which movement helps to make choices and gain a grip on the multiplicity of affordances. Arguably, this elicits a meaningful engagement with music, leading to novel insights and experiences that spurs the expressive interaction with music.

In our view, introducing movement in the development of musical creativity is a powerful way to adopt an integrative approach to creativity. Movement-based activities not only promote individual explorations of the music but lend themselves perfectly to engage in participatory sense-making through joint movement (e.g., Hermans, 2016; Peñalba, Martínez-Álvarez, & Schiavio, 2020). The individual engagement with the music invokes the use of one's own personality, skills, and experience. It can be the starting point of an individual perspective on the music rather than prior knowledge of established styles and performance conventions (Hubrich, 2016; Nijs, 2017; Schroeder & Newland, 2013). At the same time, affective resonance between learners is promoted through communicative musicality (Kondo, 2019; Malloch, Delafield-Butt, & Trevarthen, 2019). Moving may turn the individual sense of agency ("I do it!") into a collective sense of group agency ("We did it!") (Pacherie, 2014) and stimulate collaborative creativity in joint explorations of the musical affordance landscape.

Moreover, integrating movement in the classroom facilitates a balance between a product- and a process-oriented approach to creativity. According to Burnard and Younker (2004), the creative process is dynamic and non-linear, including different stages such as sensing, defining, clarifying or understanding the problem, moving between divergent and convergent thinking while generating and evaluating solutions. In each of these stages, movement can play a supporting role. Importantly, the authors include a final solution, one that may be used in other situations, as part of the process. Exploring and experimenting gestural (or choreographic) ideas in alignment to the music, may converge into a "choreo-musical" (e.g., Schroeder & Newland, 2013) or "kinemusical" (e.g., Nijs, 2019) outcome that displays novel ways of making sense of the music, ways that would not have been discovered when merely listening. Indeed, movement allow us to discover new elements in the music, based on an increased attention toward specific aspects of the music which could allow the discovery of new affordances through a creative navigation of the musical affordance landscape.

We believe that understanding the processes that underly creativity is important for music educators to understand the "whats" of creativity, creativity in music, and creativity in music education (Tsubonou et al., 2019) and to move music education forward in accordance with the newest insights from various disciplines. The operationalization of these insights in practice is what matters, supporting learners in becoming autonomous music lovers, players, makers.

Finally, while the presented discursive elaboration on creativity focused on music interaction, we believe the conceptual framework is of interest to scholars beyond the music domain. The novel approach presented in this article links coping strategies for the interaction with complex information (affordance navigation) to cognitive abilities (cognitive flexibility, audition) and brain states (metastability). This allows moving beyond the music-specific account of creativity. Considering the role of movement in relation to the different dynamic process, this article arguably situates at the intersection of domain-specific and domain-general creativity. First, movement in music is not just about physical coordination in synchronization with the music, but provides a form of expressive communication that transcends traditional musical boundaries, showcasing how domain-general creativity (involving for example cognitive flexibilty) relates to domain-specific skills (see also Schiavio & Benedek, 2020). Moreover, while Guilford (1967) asserts that creativity thrives on one's capacity to fluently and flexibly generate multiple thoughts, Lakoff and Johnson (1980, 1999) state that the body can influence and even change cognitive processes by playing a role in categorization. The body can also provide a scaffold for abstract concepts by metaphorically embedding cognitive content in sensorimotor systems (Landau, Meier, & Keefer, 2010). These effects of music and movement were shown by Slepian and Ambady (2012). In their study, fluid arm movement

promoted creativity in 3 domains: creative generation, cognitive flexibility, and remote associations. Similar results were obtained by Kirk and Lewis (2017), working with children. The presented work can contribute to this line of research in other domains. For example, movement has been used to promote creative thinking in mathematics (see e.g., Arzarello, Paola, Robutti, & Sabena, 2009; Farsani, Lange, & Meaney, 2022; Huth, 2022).

To conclude, the presented work contributes to the ongoing developments in conceptualizing creativity. It may spur and fuel the discussion on the underlying dynamic processes and on the role of the body in creativity, a topic that deserves more attention.

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