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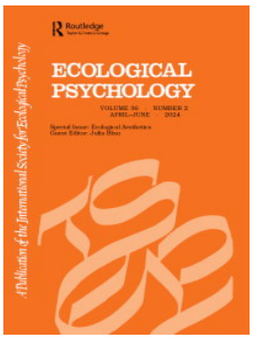

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How Do Aesthetics Get into Muscles and Muscles into Aesthetics? Insights from Musical Interactions in an Experimental Context

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ABSTRACT

In certain contexts, processes of perception, action and skill development and those related to aesthetic experiences can have mutual influence upon each other. Concepts from the domains of ecological psychology and aesthetics may therefore be distinct but entangled. These entanglements are explored here through observations from an experiment in which musicians' behaviours and experiences were recorded while they interacted with a computer music controller instrument operating different modes of sound synthesis. Processes of action-perception exploration and enacting the instrument's various affordances had an impact upon the musicians' aesthetic judgements about the instrument, and their imagining its virtual potential for application in music cultural practices. Conversely, musicians' prior experience in different aesthetic cultures constrained the affordances of the instrument that were discovered and taken up by them. These insights are used to expand upon the different ways that perceptual-motor and social aesthetic processes can constrain and shape each other. Ongoing and further directions for both theoretical and empirical research are highlighted.

Introduction

Michael Turvey once characterised a fundamental aim of ecological psychology as answering two reciprocal questions: 'How does light get into muscle and how does muscle get into light?' (Beek & van Wieringen, 1994). As challenging as this question is, it could be made more challenging in a (hopefully) interesting way by asking 'How do aesthetics get into muscles, and how do muscles get into aesthetics?' Unpacking this further, we propose that the topic of ecological aesthetics can helpfully interrogate the different ways that aesthetic experiences can shape perception, action, exploration and learning, and vice versa. In this paper, we will explore this relationship through the scenario of musical interactions designed for an experimental context.

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It will be useful to first put our conceptual cards on the table, in terms of how we understand key concepts from the ecological approaches that we intend to relate to aesthetics, and also what we mean by aesthetics. We will then introduce the setting in which musical interactions were studied and the context of this research, before discussing the ways that ecological and aesthetic concepts exert mutual influence upon each other.

Affordances and skill development

Concepts from ecological psychology relevant to a grounded understanding of aesthetics in digital musical instruments include affordances, perceptual learning, education of attention and intention, and skill development understood as an ongoing evolution of agent-environment dynamics. In all cases, consideration is given to the idea of the agent as co-forming a constant looping function with their environment, shaped by the specificities of their prior experiences, capabilities, and interactions within their physical and cultural milieu.

Some of these concepts will be defined and expanded upon *in situ* during the discussions of musicians' instrument interaction experiences. From the outset we want to clarify that we are adopting a dispositional interpretation of the affordance concept for these analyses. In this reading, affordances are properties of the environment (of objects, surfaces, events), defined relative to an organism, that can structure energy arrays (i.e. they can be directly perceived *via* invariants in energy) and that can causally interact with corresponding dispositional properties of the organism, sometimes called 'effectivities' (Turvey, 1992). This allows for a naturalistic, grounded analysis of affordances and their role in perception and action, as we can analyse how these properties interact with energy media and the bodies of organisms, identify task dynamics (Bingham, 1988), etc. There are other aspects of the organism-environment system that are vitally important for understanding experience, behaviour, etc. For instance, the above definition of affordances removes normativity from analysis - whether or not an object is sufficiently rigid as to resist deformation under the weight of an organism (e.g. whether it has the dispositional affordance of stand-on-ability to a person) is independent of whether or not they should stand on it in a given instance (Heras-Escribano, 2019; Heras-Escribano & de Pinedo-García, 2016). We will contend for now that these normative aspects of the organism-environment system require a different analytical mode to pick them out and describe their causal powers.

To give an example, consider a room with chairs in it. For a person with hinged legs and the coordination to maintain upright seated posture (the corresponding effectivity dispositions), a chair in the room has the affordance of sit-on-able. Brought together, these dispositions can afford sitting behaviour, and can be analysed in terms of the ecological physics of the chair (e.g. its physical properties relative to the size and abilities of the person), task dynamics (e.g. the manifold of joint angle rotations, displacements, etc. which will ensure successfully getting into and staying in the chair), and so on. Clearly though, there is a lot left out. The nested sequence of actions that gets the person through the door, across the floor while avoiding other objects, and into the chair, is not definable in relation to a single affordance. Rather, these are skilfully selected and realised by the individual as a temporally-extended pattern of engaging multiple affordances. These extended patterns of skilful activity are not analysable through

ecological physics or task dynamics of discrete affordances alone. Rather, this requires different additional analytical modes considering nested events and affordances (e.g. Blau et al., 2013; Wagman & Stoffregen, 2020), co-articulation of actions through time (e.g. Klapp & Jagacinski, 2011; Nordbeck et al., 2019), education of intention (Jacobs & Michaels, 2007), and so on. Moreover, the fact that the chairs in the room constitute a classroom, organised to direct the sitters' attention to the front where a teacher speaks from, with all the attendant socio-cultural norms and conventions (Heft, 2018), is not clearly analysable in terms of dispositional properties, invariants in energy arrays, or task dynamics. It requires consideration of many complex nests of interactions, at many time-scales, subject to precarious forces, and co-constituted by the behaviours of those who participate in it. The socio-cultural situation constituted by the classroom is no less real in terms of its causal effects on behaviours, actions, attention and so on. Nevertheless, its analysis will require descriptions of complex interacting social processes; a distinct form of description from the physics of how objects interact with biomechanics. Hence the need to carve up the analytical jobs for understanding this same scene. This approach will be implicit in the analysis of our instruments' affordances (the sonic behaviours they demonstrate in response to musicians' actions) as distinct but entangled with the musical and cultural setting in which they were encountered.

This approach is ontologically neutral as to what is a real feature of the organism-environment system. Indeed, all of it is real in terms of causal relevance. The behaviour setting of the classroom will affect and regulate the coordination of joint postures and rotations. And vice versa. Taking up the affordance of stand-ability of the chair can disrupt the classroom situation, turning it into a student rebellion. All of these virtualities and actualities are of interest and worth investigation. Calling everything involved an 'affordance' does not necessarily help with that though, and risks losing the naturalistic, pragmatist grounding offered by the affordance concept (Segundo-Ortin & Heras-Escribano, 2023). Hence, the advocacy for the dispositional rather than relational framing of affordances.

Another conscious choice of framing is to use the expression *skill development* over *skill acquisition*. This is a stance in which skills are not things that we acquire, like tools in a tool chest, but rather modes of being that we become. Through practice and experience, we develop patterns of coordination within task domains that map our actions to goals through the dynamics of the agent-environment systems we form (Clark, 1995). Research on infant gait development shows that walking is not a programme that gets coded into the nervous system, it is a result of progressively tuned coupling dynamics between brain, limbs and environmental forces (Thelen et al., 1991). Infants do not acquire walking knowledge, they become walkers. The same general principle is taken to be the case for specialised as well as typically developed skills. Through in-situ experience, we also develop perceptual sensitivity to the higher-order patterns of information relevant to our skill domain. This skilful perception draws us into contact with the available affordances that support activity in that domain, but also to the details of socio-cultural situations in which those affordances could be enacted, such as the rules of a sporting game, or the kind of venue in which a music performance is to take place (Heras-Escribano, 2019; van Dijk & Rietveld, 2016). Thus, skill development is an ongoing process of tuning oneself to the furniture of the skill domain's contexts, not the assimilating of discrete programmes of action. This ongoing

tuning, we argue, also results in sensitivity to the aesthetic characteristics of the settings and situations in which skilful behaviour is enacted.

(Social) aesthetics

Aesthetics is a notoriously difficult concept to define and restrain (Nanay, 2019). It has become associated with the appreciation of the arts (broadly speaking), but this is both too narrow to capture all experiences that could be considered aesthetic, and also an insufficient characterisation of the range of ways people can experience works of art non-aesthetically, e.g. using a cloth with a print of the Hokusai's Wave to dry the dishes.

There have been various attempts to provide a framework for aesthetics which is grounded in the pragmatic, ecological and enactive (e.g. Dewey, 1934; Noë, 2015), some of which we draw upon later. One particularly helpful approach is 'Social Aesthetics' (Born, 2011; Born 2017). This approach aims to expand the content of aesthetic research beyond its traditional targets (typically objects of 'high-art' and analyses of the judgments about these), while also exploring the sociological processes by which any object or happening comes to be a subject of aesthetic discourse. Aesthetic experiences are thus understood as being grounded, situated, distributed among agents and through time, and are neither located solely in objects (e.g. residing in the form of a sculpture) nor in subjects (e.g. located in activity in a particular region of the cerebral cortex). From a different but related perspective, aesthetic experiences have been argued to involve some form of interaction between the perceiver and the perceived (Nanay, 2019), that is, they should not be characterised as the product of a passive, detached and intellectual standpoint. These distinctly anti-Kantian views of aesthetics chime with the anti-Kantian approach of Gibson and ecological psychology as a field (Shaw, 2002).

A consequence of the above is that musical instruments do not have aesthetic properties in of themselves, to be appreciated in their design from a disinterested vantage point. Rather, anything which could be understood as aesthetic in musical instruments is going to be interactive, distributed, relational and social. Evaluation of musical instruments should reflect the specificities of a given agent, their history of interactions with instruments, the cultural milieu in which such judgements make sense, and will be precarious to the changes in relationships between all those things (Rodger et al., 2020). This is not intended to endorse rampant subjectivism about aesthetics, rather to emphasise the reality of perspectives and to ground aesthetics in complex dynamics as opposed to universal forms.

In offering our contribution to the burgeoning field of ecological aesthetics, we should be clear how we see social aesthetics and ecological concepts relating to each other. It is not our intention to replace descriptions of aesthetic experiences with ecological concepts, e.g. to call all aesthetic experiences perception of affordances. Nor is it helpful to try and identify the aesthetic character of all processes of perception-action dynamics. We see these fields as separate but entangled. And we anticipate that exploring this entanglement in the specific context of musical interactions within a research study may refine existing conceptual tools in and across both domains.

(Re-)mapping musical interactions in SARC – an ongoing study and its context

The scenario used to illustrate the interplay between ecological and aesthetic concepts is a research study into musicians' experiences and interaction with a prototype musical instrument which varied in its timbral[1] characteristics. We will describe key features of the apparatus, the study, and the broader context, in keeping with van Dijk and Rietveld's (2016, p. 10) stipulation that '(s)tudies on affordances should thus take note of the sociomaterial context by studying affordance perception in the context of a field of relevant affordances embedded in a behavior setting…and/or a sociomaterial practice'.

The computer-based instrument used in the study is of a class that is typically differentiated from acoustic instruments, which are seen as contained within a single object. Electronic musical instruments can be differentiated in general from acoustic instruments in that it is possible to separate the mechanical coupling between the point of action and the sound production process. Starting with the proliferation of computer music controllers in the 1980s, such as MIDI keyboards, which can be mapped to a seemingly infinite and arbitrary variety of sounds, the problem was identified of how to map action to sound in a meaningful way (Cook, 2001). This has since become the subject of a major international conference[2]. For us, this separation creates the opportunity to systematically investigate how variations in action-to-sound mappings affect performance and meaning-making with a newly-designed instrument.

The instrument consisted of a 24×13.8 cm, 2-dimensional pressure sensor with a contact microphone attached. The sensor and microphone data are connected to a desktop computer running the synthesis software, which is also connected to two speakers outputting the synthesised sound (see Figure 1). As a (prototype) musical instrument, it is visually of the computer music controller culture, and unlike typical single-object acoustic instruments. The versions of the instrument differed only in the sound synthesis process: one version used physical modelling synthesis, while the other version used a a very different technique, tone cloud amplitude modulation synthesis.

Figure 1. The prototype instrument used in the research study consisted of a 2D pressure sensor and contact mic, both connected to a Macintosh computer (out of shot) running the synthesis software, which outputted audio through two floor mounted speakers. The video camera was used to record gesture data during the study. Reproduced with permission from Smith et al. (2023).

Physical modelling is a sound synthesis approach based not on emulating the phenomenal properties of the acoustic waveform typically produced by an instrument, as many other synthesis approaches are, but by modelling the mechano-acoustic behaviours of the substances that constitute the instrument (Stapleton et al., 2018), and their mutually-interactive dynamics (e.g. of a spring attached to a metal plate in motion). The phenomenal perception of the resulting sound is almost guaranteed to be recognisable as that of the modelled instrument, in virtue of respecting the lawful mechanics of how the instrument's material composition disturbs the acoustic array when dissipating excitation energy. In a sense, it is a very 'ecological' way to approach sound synthesis, and has the potential to align action and perception in intuitive ways, if the control interface is suited to enacting the kinds of excitation and modulation events that would be conventionally used with the acoustic counterpart[3]. Both were models of plates attached *via* a bridge to a string, which relate broadly to the family of membranophone instruments, such as cymbals and gongs. The two versions varied in the initial parameterisation of the model between settings which were more or less non-linear in the plate-bridge-string coupling, leading to variation in complexity of the timbral characteristics. In each case, sounds were triggered by excitation forces on the pressure sensing interface, and damped by extended duration pressure, much like tapping then clamping a cymbal.

To create a deliberate contrast with the physical model synthesis approach, we also created versions of the instrument which used a very different sound synthesis method. In this case, we made use of a synthesis method called 'tone-clouds' (Agus & Pressnitzer, 2021). Tone clouds essentially consist of sequences of randomly pitched, short duration sine tones, which are also randomly distributed in their relative temporal onsets. The density of these can be varied in both the frequency and temporal domains, producing sounds that vary between something from old sci-fi TV to almost white noise (but with spectral characteristics distinct from white noise). Across this range, tone clouds do not resemble obviously recognisable mechano-acoustic interactions. To match the event loudness of corresponding instrumental actions of the physical model sounds, the amplitude envelope produced by the physical model synthesis was used as the amplitude modulation parameter of the tone clouds. Thus, this synthesis approach preserved the transformational invariants of the physical model's response to input actions, while implementing very different structural invariants, that is, timbres[4].

Participants in the study were twenty adult self-identified professional or expert musicians (following Zhang & Schubert, 2019) with varying instrumental and music-culture backgrounds. Some were trained and developed their instrumental skills within classical or other traditional (including Irish folk and Indonesian Gamelan traditions) music behavioural settings, while others had experience and skill within more experimental sound art environments. Musicians in the study reported a range of primary instruments, including piano, percussion, voice, guitar, electric keyboard. Approximately half also reported an active interest in experimental sound art and/or sound design. The study took place in a laboratory space in SARC: Centre for Interdisciplinary Research in Sound and Music in Belfast. SARC is a state-of-the-art contemporary sound and music research facility, and is also a metropolitan music and arts venue. As a behavioural setting, it is associated with experimental music, sound art installations, technology, science, and sometimes esoteric cultures of practice.

During the study, the musicians were asked to explore, compose with, and perform on the different versions of the proto-instrument. They were allowed to do these tasks freely, and were given a time limit of 40 min for exploration (to allow time to play with each sound type), 30 min to compose a short 20–30 s piece on one of the sound types of their choosing, and then asked to perform their composition on each of the sound types (taking as long as it took to play the piece four times). The experimenter was present with them in the room throughout the study. Along with other forms of data, their self-reported experiences of the instrument were recorded through semi-structured interviews in the same room immediately after completion of the three activities. Although the full description and analysis of this study is part of an ongoing PhD research project, examples and excerpts from participants' experiences can help to illustrate some of the different ways that aesthetic considerations and perception-action-skill processes can interact and mutually shape each other.

Computer-music controller based instruments are useful for this sort of research, in that they can completely deviate from what acoustic instruments can do (e.g. the tone clouds), or they can draw out the resonant properties of existing acoustic objects by modulating, transporting, or extending these (e.g. the physical plate model). In this sense they can help us probe the notion of aesthetics from Dewey (1934) and Noë (2015) as the 'drawing out' of significance from otherwise 'everyday' experiences. What do we think and feel about a musical instrument when its expected sonic behaviours are subtly or drastically altered? Any aesthetic judgements (beyond initial visual appraisal of the instrument's form) are going to require action, exciting and manipulating the interface to draw out its sonic affordances. Some have argued that such grounding in interaction is a fundamental property of all aesthetic experience (Nanay, 2023). Moreover, perception of instrumental properties is necessarily multi-modal, engaging auditory, haptic and visual systems. This may help encourage the movement away from a purely visually-grounded aesthetics as advocated for by philosophers such as Nicola Perullo (2022).

It should be noted that this context is one of an experimental study, and so the extent to which participants report experiences relevant to music-making in more natural settings (e.g. in a concert or playing with other musicians) has to be interpreted as a somewhat 'virtual', i.e. imagining what the instrument would be like for them in those settings rather than experiencing directly. Further, although we are using observations from musicians exploring and playing with a digital musical interface, this paper is not intended to be a treatment of music-making or musical cultures from an ecological and/or enactive framework. Work in that direction can be found in Nijs et al. (2023).

How do perception-action and skill development affect aesthetics?

When our musician participants come to explore the affordances of the instrument, there is first the visual perception of the experimental setup and the instrument interface. Its size, flat 2-dimensional surface and hard rubber texture visually specify some possibilities of interaction, such as touching and tapping. Typically, these are the first actions performed by participants. At this point, upon tapping and perceiving the auditory consequences, the sonic behaviours of the instrument come into play and the

interaction becomes a more richly multi-modal one. Thus, the initial interaction with the instrument as a visually-specified thing is fairly stereotyped. However, the subsequent exploration and discovery of sonic affordances become more divergent, both as a result of the different sound synthesis methods and the characteristics of the musicians. Some preferred to treat it as though it were a familiar instrument, even adapting their posture as though playing a small keyboard or MIDI controller. Others quickly discovered and exploited the less obvious affordances, like how the sounds respond to damping pressure or scratching the sensor surface (particularly with the physical model synthesis). These variations point to the idea from Eleanor Gibson and others (Gibson, 1988; Szokolszky et al., 2019) that the process of perceptual learning by exploration is an individual one, flowing from past experiences and existing dispositions.

Past experiences of participants in testing the boundaries of conventional techniques on musical instruments (either enacted or observed) can equip them to creatively uncover less 'obvious' affordances of the computer music controller. In a separate but similar experimental study, one participant with a background in experimental improvised music performance discovered that loudly vocalising into the interface could excite the plate physical synthesis model. The affordance of excitability-by-yelling was neither designed into the instrument, nor discovered by other participants. However, once that affordance has been discovered through an open-ended process of exploratory acting and perceiving, it has the potential to become a component of the aesthetic milieu of the 'musical ecosystems' (Waters, 2021) in which this instrument might develop and also be a constitutive component of. Examples of previously latent instrumental affordances coming to take an active role in shaping musical genres include saxophone multiphonics in jazz and two-handed tapping on the electric guitar in heavy metal (Cottrell, 2013).

The perceived responsiveness of some sound-synthesis versions, which can be understood as the perception that acoustic events are clearly excited, modulated and sustained by actions of the player, was often mentioned as a positive of the physical model synthesis instrument version. This sense of 'control intimacy' (Wessel & Wright, 2002) seemed to be a precursor for positive aesthetic appraisal of the instrument, and the anticipated possibility for it to support future musical activities. Moreover, the granularity of the instrument's action-perception mapping seems to matter. That is, the more differentiable the perceived sonic response of the instrument to variations in movement parameters, the more controllable the instrument seems to be. This is another dimension along which the physical model synthesis was often preferred to the tone cloud synthesis. In the former, small changes in continuous finger pressure could be related to small increases in resonance damping of the plate sound, for example. In the latter, such fine-grained co-variations between action and sound were less obvious or harder to perceive, leading some to feel dissatisfied with the controllability of that timbral version.

This observation can be linked to two concepts from ecological psychology. The first is perceptual learning as differentiation of invariants within the energy array (Gibson & Pick, 2000). Natural developmental learning of the sounds of flat resonant (metal) objects may have disposed participants to differentially perceive finer variations in the acoustic events excited and modulated by the instrumental actions.

This differential perception process could be thought of as enrichment of experience through filtering and diffraction, rather than by addition. With the tone clouds, the unfamiliarity of the sound type entails that this perceptual differentiation of features has not taken place prior to engaging with the instrument, and so the ability to perceptually differentiate variations in the sound events is attenuated. This seems to lead to a flatter or poorer experience of the fine details of the sound compared to the physical model.

The second related concept is education of attention. This is the process by which, through experience and practice, skilled perceivers learn to tune into the perceptual invariants which specify the relevant properties of the task dynamics for controlling action with respect to the task goal (Gibson, 1979; Jacobs & Michaels, 2007). Greater control (through sensitivity to relevant invariant properties of task dynamics) can lead to greater sense of control intimacy from the perspective of the player, which typically heightens the aesthetic experience of playing with the instrument. This is reflected in an excerpt from one of the participants' self-reported experiences in our study:

> the gong sounds [physical model synthesis] were more controllable because I'm used to tones like that, you know. Whereas with the clouds [tone cloud synthesis], that kind of digital noise, you find yourself fishing for some sort of melodic thing in it. I just found the gongs to be a bit more controllable, a bit more relatable.

The physical model synthesis, in virtue of the adherence to mechano-acoustic laws in its implementation, has invariant structures and textures which may become the variables of control for fine-grained musical actions (such as frequency dependent damping of the plate model, or attack-dependent scaling of detuning due to the non-linear string-bridge-plate coupling). The detectability of these invariants entail that they have the potential to become coordination variables, i.e. musicians can move-so-as-to affect these. For the tone-clouds, the stochastic nature of the synthesis entails a lack of structural invariants, beyond the amplitude envelope behaviours inherited from the corresponding physical model. Thus, there is nothing within the textural details of the sounds that could be finely controlled to which attention could be educated. These differences between the sound synthesis models, and corresponding differences in potential for education of attention, may account for some of the aesthetically relevant differences between the experiences of participants when interacting with the two sound types[5].

How do aesthetics affect perception-action and skill development?

Looking at the flipside of our entangled concepts, one way in which aesthetic dimensions of musician-instrument systems can affect perception-action loops is in the sustaining of the interactions themselves. When the mappings between actions and their acoustic perceptual consequences were described by participants as 'intuitive', 'familiar', 'pleasing', the musicians felt motivated to continue exploring and playing the instrument. Thus, these positive aesthetic experiences can encourage further exploration of the affordances of the instrument. Imagination of virtual musical scenarios in which they might play the instrument could also sustain the interaction, e.g. play acting a part of a concert, or composing as though for a performance. A plausible fit between

the aesthetic demands of those virtual situations and the perceived potential of the instrument would lead to greater immersion and extend the duration of playing further. The familiarity with and sensitivity to musical ecologies in which instruments of this sort are found could also expedite the affordance discovery process. Participants who study in or are familiar with SARC seemed particularly comfortable interacting with our computer music controller and the different synthesis modes. As Szokolszky et al. (2019, p. 14) note from a developmental context, '(e)xposure and experience with objects-in-contexts lead to the more precise, more efficient detection of affordances, and more refined motor behaviours'. Thus, past experience of such instruments in their aesthetic contexts can draw attention to some affordances that would not stand out without that experiential background.

This observation may relate to the idea that affordances can be more or less 'inviting' (Dings, 2018; Withagen, 2023; Withagen et al., 2012). Within our account, the invitations of affordances are not inherent properties of how the instrument behaves sonically when tapped, scraped, pressed, etc., but are dependent also on the prior experiences and aesthetic history of the player. As one participant commented:

> The Gong [Physical Model Synthesis] allowed me to compose from prior knowledge, adopting techniques used with a Gamalan or Japanese Taiko, I was able to play with the damping and volume aspects of it.

The invitations felt from the instrument, in terms of which affordances are most salient and taken up, are inviting not solely for their functional properties, but for their aesthetic characteristics. That is, how pleasing or rich they sound to the player, or how well they might be brought together within stylistic or genre conventions. These are relational properties between the instrument, player and broader socio-cultural contexts and histories, yet have influence on the perceptual-motor coordination and decisions in playing (or ceasing playing).

It has been argued that the personal history of the perceiver is central in understanding what makes some affordances more or less inviting, but also their own narrative about themselves as an agent (Dings, 2018). This 'psychobiography' (from Slors & Jongepier, 2014), entails that it is not merely having an experience that draws out the valence of a corresponding affordance, but also the way that experience is interpreted in relation to our sense of self, of who we are, how we relate to others, etc. As Dings (2018, p. 696) notes, 'the various objects mentioned in this quote (i.e. an alleyway, a crying baby, a walkway towards the airplane) all afford the same thing to different people (e.g. walking on, comforting, etcetera), but only solicit some people to act, and solicit these actions differently depending on (amongst other things) the narrative of the person who experiences the soliciting affordance'. We see this in our own study, in which some participants relate to the different versions of the instrument and its affordances in personal ways, as someone who has played or experienced Indonesian Gamelan music (responding to the physical model of the metal plate) or as evoking a memory of rain on a greenhouse roof (responding to the tone clouds). The phenomenal experience of inviting affordances is very much a feature of our personal histories and identities (Dings, 2018).

The aesthetic experiences of playing the prototype instrument and the relationship these have with the perceived broader culture or 'musical ecology' may shape

perceptual processes in the long run through the process of 'education of intention'. This is the concept, distinct from 'education of attention', that through formation of habits (in the Dewey-ian sense) and increasing sensitivity to cultural and situational norms, some of the available affordances in the environment come to be more readily and pre-reflexively taken up over others (Segundo-Ortin, 2024). One's intentional relationship with one's environment to seek out and engage with particular suites of affordances is shaped by socio-cultural interactions. Aesthetic experiences themselves may be characterised as drawing attention to a type of object, event or scene in a mode of appreciation different from how these show up in 'everyday' experience (Noë, 2015; Windsor, 2004). Say an object is typically perceived in terms of its canonical affordances (i.e. the sit-ability of the chair), the aesthetic act may be to force attention away from this affordance and towards overlooked properties of the chair, e.g. the woven texture of its cushion. Entrenchment in aesthetic practices and cultural situations can thus liberate perception to be more responsive to a broader range of affordances than those that are purely functional, ergonomic, or canonical to typical forms of life.

A further role of aesthetics in shaping perception-action processes is the influence of 'style' on the development of motor coordination. It has long been recognised that for most skilful actions there are more movement solutions available to an actor to achieve a task outcome than are constrained by the task goal alone (Bernstein, 1967). For example, there are many trajectories through space, and hand-arm-torso posture combinations, that will successfully get a hand to a cup on the table. This concept of 'motor abundance' (Latash, 2012) is thought to be important for adaptability and flexibility in movement to achieve movement goals consistently under variations of execution. It may also play a role in the development of movement styles, in which the variations in movement coordination that achieve the same goal have aesthetic or culturally relevant features themselves. People can walk with different dynamic configurations of upper limbs, lower limbs and torso to embody and/or convey sass, indifference, toughness, etc. In each case, the physical task of bipedally locomoting across flat terrain is achieved in different stylistic modes, with different social implications.

In musical interaction, the same principle can apply in that the physical task of exciting and modulating sounds can be performed through various movement coordination patterns with different stylistic characters. This has been observed in kinematic analysis of drummers performing accented drum strikes - musicians' arm movements between consecutive strikes varied depending on what playing tradition they were based in, e.g. drum kit players made higher inter-strike stick movements than orchestra drummers, reflecting stylistic differences between those musical cultures (Dahl, 2004). Playing styles affect not just which affordances are taken up and how, but also how they are nested together in ongoing activity. An example in classical music would be the distinction of moving between two separate notes such that they overlap in time (legato) or have distinct temporal boundaries (staccato). These different ways by which two instrumental affordances can be enacted (either temporally blending into each other or not) can have distinct stylistic qualities (Nijs et al., 2023). In our musical scenario, the virtual cultural setting that the participant imagines the instrument being played in may constrain the styles of movement they

adopt to explore and perform with the instrument. This would be expected to be a bi-directional influence through time. Playing styles developed with a new instrument may become cultural tropes for that instrument's culture/genre, which may constrain the behaviours of musicians learning to become agents in that instrument's milieu and so on. This does not preclude creative disruptions and breaks to an instrument's evolved movement style conventions, such as the saxophone multiphonics mentioned above being a catalytic component in the development of free jazz. In our study, more longitudinal recordings of the evolution of instrumental technique within musical situations would be needed to observe such hypothesised bi-directional influences between perceptual-motor coordination and aesthetic style.

Implications and further directions

The proposed entanglements between concepts from ecological psychology and social aesthetics has potential to create new directions of theoretical and empirical research. The dispositional approach to affordances allows for measurement and analysis of coordinated behaviour in terms of task dynamics, and analysis of the development of these dynamics with learning (e.g. Wilson et al., 2016). Identifying the co-constituting dependencies between these processes and social/cultural ones relating to aesthetics may lead to greater grounding of so-called 'higher-order' psychological phenomena in perceptual-motor functions, while also elucidating the rich meanings that the latter can form. It should of course be noted that the qualitative insights from the musical interaction scenario presented above are relatively coarse grain, more about identifying types of instrumental affordances than the specifics of how they are perceived and coordinated with. Further detailed analysis of perceptual information and motor coordination would be needed to understand these processes empirically.

It should also be noted that the musical scenario discussed here is very limited, and barely a musical behaviour setting at all (more an experimental setup in a music facility). There are lots of aspects of full-blooded music-making culture and practices missing, which would need to be incorporated to test these ideas properly. These include the fact that music is often made with other people, that musical practices are learned and encultured, that the intentions and sensitivities of musicians vary depending on whether they are rehearsing, composing, performing to an audience, or just playing for distraction and enjoyment by themselves. All of these different musical behaviour settings could be studied with appropriate methods. For example, the methods of inter-personal coordination research, which has already been applied to music-making (Demos & Palmer, 2023) could be brought to assess the relationships between interpersonal coordination dynamics of multiple musicians playing prototype computer music controllers with different affordance properties, and the bidirectional effects on aesthetic experiences of the players and/or audiences. Different ethnographic methods could also be used to track the evolution of perceptual-motor practices and conventions as a novel instrument is adopted into 'real-world' musical activities over a longer time. Finally, the study we mentioned here involved experienced musicians as participants. Research with less experienced and novice musicians is needed to understand learning and enculturation processes which forge the links between

perceptual-motor functions and aesthetic styles. It has been observed that skilled and non-skilled musicians have very different appraisals of the merits and demerits of computer music controller instruments (Jack et al., 2018). What is performed and described by trained players should not be assumed to generalise to beginners, nor should the aesthetic expectations of experts be treated as norms with which novices should align.

Conclusion

In this paper we have tried to draw links between key ideas from ecological psychology and social aesthetics, to begin to answer the starting question: 'how do aesthetics get into muscles and how do muscles get into aesthetics?' Using the scenario of a research study in which musicians interact with a prototype computer music controller based instrument, we sketched some different ways that their behaviours and reported experiences highlight these links. Past perceptual-motor experiences, and also pre-existing cultural sensitivities, shaped the affordance realising behaviours and aesthetic judgements of participants in these musical interactions. This scenario illustrates how the conceptual links between ecological psychology and aesthetics could be empirically investigated further, and brings together some of the theoretical groundwork for motivating and interpreting such investigations.

Notes

1. 'Timbre' can be defined as "Tone-colour; that which distinguishes the quality of tone or voice of one instrument or singer from another, e.g. flute from clarinet, soprano from mezzo-soprano, etc." (Kennedy, 2006, p890).
2. The International Conference on New Interfaces for Musical Expression, 'NIME': https://www.nime.org/.
3. Note that this does not relegate physical models to merely imitating acoustic instruments – there are interesting and artistic possibilities for morphing and distorting physical laws beyond what is found in existing acoustic instruments, and or playing with mis-matches between controllers and synthesis engines.
4. Examples of audio recordings of each synthesis mode can be found in the Supplementary Materials.
5. In computer music controller culture, tight coupling between action and sound is not necessarily as determining of aesthetic assessment as for other musical cultures, and so past education of intention through culture can influence the degree to which this is a determinant of aesthetic satisfaction of the musician in interaction.

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The authors report there are no competing interests to declare.

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