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Perceptual Learning and the Emergence of Performer-Instrument Interactions with Digital Music Systems

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Abstract

The relationship between human and computers within the area of HCI has shifted from being represented by cognitive, information-processing approaches to more recent situated and embodied perspectives. This matter has analogously developed within interactive digital musical system research. However, the nature of this interaction, while commonly drawing upon J.J. Gibson's theory of affordances for analysis, often fails to characterize the emergent relationship between performer and musical system. This has led to regard affordances as mere design features, as well as taking for granted the skillful contributions of the performer. Interactions in this manner are represented as static.

In this paper, I present the findings of a long-term phenomenological research study describing the evolving nature of performer-instrument interactions. I resort to E.J. Gibson's perceptual learning approach to frame the experiences of performers, both individually and socially, as they learned to play a new digital musical instrument, the Pulley Synth. I argue that the nature of such interactions is grounded on learning and that the changing perception of the system contributes to the process of enskilment. In this view, more than being an acquisition of conceptual knowledge of the instrument's operation, learning suggests a holistic behavioral change towards the system in which musical and sonic possibilities of the entire performer-instrument-environment ecology are explored and enacted.

I conclude that perceptual learning is significant within the context of HCI and musical technology, given that current design and performance practices with interactive digital music systems remain influenced by established musical practices (for example, Classical music). If one of the aims of this domain is the development of new musical interactions and practices, the ability to overcome the influence of musical traditions and to perceive new sonic possibilities must be considered in both the design and instrumental learning processes.

Introduction

Designing digital interactive musical systems takes much of its practice from the domains of Human Computer Interaction (HCI) and Computer Music, as developed from the late 20th Century. Not only does the practice derives knowledge from these areas, but also borrows many of the concerns and norms within them. This suggests that the resulting sonic or musical systems show the influence of both the technocentric discourse of mainstream HCI, as well as the musical norms inherited by Western European Art Music. As a result, research is often focused on the artifacts themselves, their design and how they satisfy the conditions of this particular musical tradition, rather than on the contingent performer-instrument-environment relationship.

In this paper, I present the findings of a long-term phenomenological research study describing the evolving nature of performer-instrument interactions. I resort to E.J. Gibson's Perceptual Learning approach to frame the experiences of performers, both individually and socially, as they learned to play a new digital musical instrument, the Pulley Synth. I argue that the nature of such interactions is grounded on learning and that the changing perception of the system contributes to the process of enskilment. In this view, more than being an acquisition of conceptual knowledge of the instrument's operation, learning suggests a holistic behavioural change towards the system in which musical and sonic possibilities of the entire ecology of performance are explored and enacted. The purpose of examining interactions under a Perceptual Learning view is intended as an initial move towards the development of new musical or sonic practices, outside of established traditions and conventions, with novel musical instruments.

Historically, the theoretical foundations of HCI were based upon cognitivist or information processing conceptual frameworks (Kaptelinin et al 2003). Interactions, under this scope, are determined by the relationship between the computer and the human mind. As identified by Card, Moran and Newel (1983), the primary computer-human interaction task is to enable the communication between the machine and the person. Interactions are analysed at the level of the individual person and focus on modelling the relationship though task goals such as operations and states. An interaction model will represent the rationality of the system and aims to become both optimised and predictable. In this light, the model is considered universally applicable to any given situation given its abstraction and context-independence. The scientifically generated design principles in which the interface are developed focus on symbolically mediated interactions, as well as the cognitive processing capacities of the user (i.e., stimulus identification, response selection, and response programming; Welsh, Weeks, Chua and Goodman, 2007).

In Computer Music research, a cognitivist approach is similarly conceptually reflected by focusing on rational processes and the control of music through abstract notions of operators and products (Tanzi 2004, p.31); and at the empirical level through the abstraction and generalisation of experimentally obtained design principles (Dobrian and Koppelman, 2006; Wanderley and Orio, 2002). The body-mind-machine separation is further driven by a prevalent technocentric discourse (Waters 2007), as well as the unique detachment of the sound control from the sound generation mechanisms (Bongers 2000; Chafe 1993). Given this condition, the nature of performer-instrument interactions are regarded as mainly intellectual, rather than body-centred as found with acoustic musical instruments (Bown, Eldridge and McCormack, 2009; Magnusson 2009, 2010). Thus, the focus of research is more oriented towards the usability and evaluation of the interactive musical system itself, rather than on the complex relationship of the system and the performer.

Anthropologist Tim Ingold describes this view of technology as the product from modernisation, rationalisation, and automatisation where practice and knowledge are dissociated and abstracted (Ingold, 2000). That is, conducting a practical activity, whether carpentry, basket weaving or music performance, is decontextualised from its original site of practice and both embodied knowledge and experience are reduced to a set of rules to be followed. This results in a state where the capacity to use such tools rests upon the design of the artifact itself and gaining knowledge through instructions or user manuals.

These multiple assumptions lead to designing interactions that are deemed fixed, thus leaving little space for contributions of the performer which include learning and skill development. The usability of the system is prized over performance practice. Following Ingold, more than playing a digital interactive musical system, the skill of the performer lies in coping with the system (Ingold 2000, p. 290).

Further contributing to an object-centred perspective is the particular misuse of the concept of affordance. Rather than applying J.J Gibson's later conceptualisation (Gibson, 1986), designers have incorporated Don Norman's formulation as originally presented in The Psychology of Everyday Things (1988). Affordances are in this light interpreted as design features, as in "I put an affordance there", rather than relations between the particular abilities of the subject and features of the environment (see Chemero 2009; Rietveld and Kiverstein, 2014), including objects and other organisms. By determining affordances as mere design features the unit of research is reduced to the object and its usability for a specific task. A relational approach, on the other hand, can shed light on the complex relationship between the system and performer, not as an optimal fit between the two, but as a dynamic process that responds and changes to different experiences and contexts.

Perceptual Learning

The ecological approach can indeed be very useful in designing interactions specifically when considering the full implications the relational view of affordances. That is, the interaction is not solely determined by the object's design; rather, the interaction results from the relationship between the object's design and the skills and experience of the user that determine the particular ways in which it is employed. Usage patterns (note the plural) are situated within a physical and social environment that further specify or constrain the interactions. For the purposes of this paper, the ecological approach to learning as developed by E.J. Gibson can shed light on the performer-instrument relationship.

E.J. Gibson's Perceptual Learning view (Gibson and Pick, 2000), informed by J.J. Gibson's (1986) ecological approach to perception, identifies animal-environment interactions as a dynamic system based on perception-action reciprocity. The environment offers opportunities for action (affordances) and the animal capitalises upon these affordances based on the perception, experience, and skills the animal has developed throughout their lifetime. For Gibson, the function of perceptual activity is to obtain information. To achieve this goal the animal must learn to perceive such opportunities in the environment. Learning is thus "an increased ability to detect information specifying affordances, events, and distinctive features" (Adolph and Kretch, 2015). The more one learns about the environment, more opportunities for action are possible. However, perceiving, as E.J. Gibson observes, is an active process: information must be actively sought. In essence, learning is the search for information *about* and the *what's* of the environment. It is important to note that Gibson's approach also recognises social and culturally generated affordances. This aspect is particularly interesting given that it anticipates the later developments proposed by Rietveld (2008).

According to Gibson, affordances in the environment are not automatically perceived and acted upon; rather one must learn to use them. While some affordances may be easy to learn, others may demand much exploration, practice, and time. This investment in deliberate learning along with developmental processes leads to changes in action capabilities or sensorimotor skills. With such improvements, new affordances can be perceived and learned. It can be said that perceptual learning, more than intellectual learning, is better identified as a process of skill development or enskilment (see Ingold 2001).

The ways in which information is revealed are both exploratory and performatory. Exploratory activity yields knowledge about environmental possibilities, affordances, and one's own capabilities. Performatory activity, on the other hand, works as a process of expectation and confirmation. Performatory activities also yield knowledge that may further spur exploratory information seeking. Spontaneous exploration, according to Gibson, is "the crux of learning what the world offers and how to use it" (Gibson and Pick, 2000, p.22).

Research Study

Methods and Protocol

For the purpose of investigating how performers experience the process of enskilment with interactive digital music systems, a nine month long-term observational study was developed. The research approach was qualitative in design informed by both Grounded Theory (Glasser and Strauss, 2009) and phenomenology (Creswell, 2012; Moustakas, 1994). A qualitative and experiential research method was selected due to the interest of examining performer's experiences, rather than the quantitative usability and evaluation metrics that are common in HCI and interactive digital music system research.

This study further employed a purpose-build, participatory designed, digital music device for the study named the *Pulley Synth* (figure 1). The Pulley Synth's interface presented an embedded speaker and two 3-axis joysticks mapped to the parameters of a two oscillator FM synthesis engine coupled to a bandpass filter. Additionally included was a tuning knob that allowed scaling the sound range to different string lengths. Thus, one could play the full sonic range with a smaller string length. Sound onset and offsets were controlled through a wireless remote. This design approach was selected, as opposed to using existing musical instruments or systems, for the reason of avoiding the imposition of existing performance practices, as well as minimising the influence of other external factors. In this case in particular the aim was to reduce skill transfer from acoustic musical instruments. Of course, as discussed by Gurevich, Stapleton, and Bennett (2009), one can never achieve a design that is entirely unaffected by external influences. However, it is possible to reduce and account for the minimal factors that do manage to influence the instrument design (see Gurevich, Marquez-Borbon and Stapleton, 2012).

Figure 1. Pulley Synth

Fourteen participants, ranging from first year university students to professional musicians, were selected. All had a minimal of experience with computer music or digital/electronic instrument design. The protocol involved giving a copy of the newly designed instrument to all participants. No information about the functioning of the Pulley Synth was given to participants, aside from how to change the internal battery. Additionally, no further instructions were given other that play and/or practice as much as they wished, as well as to document their experiences in their practice logbooks. Along with these logbooks, other data collection points, distributed along the nine months of the research study, consisted in individual interviews, focus group (practice sessions), as well as entry-exit questionnaires. Collected video data, as well as logbook entries, were subsequently transcribed for analysis.

General Findings

Learning

The unknown nature of the Pulley Synth, along with its novel design, created a particular learning situation that limited performer's skill and knowledge transfer from other musical instrument, whether electronic or acoustic. Performer's thus had to learn a new instrument "from scratch".

A key aspect in Perceptual Learning is that information must be actively sought, mostly through touch. Affordances of the system are not automatically perceived and acted upon, rather one must first explore the system in order to gain a sense of its operation and potential. Few instrument design features immediately led participants to perceive and understand what their functioning was. The most salient case was the joystick design. As one participant commented, the circular form of the joysticks suggested a circular playing pattern. This feature contrasts the hidden pulling feature of the joysticks, which at the tip offered a small tab that afforded pulling. Knowing this was possible required performers to physically engage with the instrument and discover this capacity for pulling.

Similarly, the device itself did not present itself in obvious ways due to its physical and sonic design, such that a simple interaction of pulling did not yield enough information to reveal the full sonic or musical potential of the Pulley Synth. Participants, therefore, had to further explore the instrument, pulling both joysticks at different length combinations, in order to identify and understand how the entire system behaved.

Although a simple two oscillator FM synthesis model was used, very few performers were able to identify the actual synthesis model employed. This perception resulted from the non-linearities product of the particular algorithm employed which yielded noise bands at particular frequency ranges. Therefore, the simplicity of the model was obscured by the introduction of such artifacts. How performers understood the synthesis model suggests that merely intellectually or conceptually knowing something, in this case a well-known sound synthesis algorithm, is not sufficient to completely understand its full functioning. For the Pulley Synth, performer's had to actively engage the full interactive and sonic range in order to form a complete picture of the system's operation. Consistent with E.J. Gibson's description of information pickup, performers engaged in *exploratory* actions to reveal information about the system. Additionally, *performator*y actions where participants engaged in a process of expectation and confirmation contributed to yielding new knowledge and further spurred exploration.

Enskilment as Development of Perception

EJ Gibson observes that as action capabilities changes (i.e, sensorimotor skills), new affordances can be learned. In effect, in developing skill one also develops or attunes their perception to the environment (also see Ingold, 2000, 2001). The more evident skills developed where intellectual and sensorimotor. As performers explored and learned to play the Pulley Synth they gradually began forming a more complete model of the implemented synthesis model, including non-linearities. This understanding was brought forth by physical exploration, which in turn became much more refined to the point in which performers began to accurately arrive and move between the thresholds of pure synthesis and noise. Achieving this accomplishment signaled an improvement of physical skills. Similarly, physical improvements were marked by a developed repertoire of performance gestures. In some cases, improvements in general were indicated by a sense of achieving an "instinct" for playing the Pulley Synth. Following Dreyfus (2004), this instinct can be interpreted as an embodied knowing of the device or system.

Such learning outcomes are perhaps expected; however, less so was how learning was impacted by intrinsic factors such as emotion. As observed, individual affect/emotion tended to regulate engagement with the device suggesting that a positive emotion towards the device leads to more engagement and practise time with the Pulley Synth. Indeed, for a few participants, the device produced a significant negative response which prompted them to abandon practising and learning altogether. On the other hand, a few others observed that the device produced in them a sense of vast musical potential to explore. In other words, given the sonic capacities of the Pulley Synth, according to the individual perceptions of the performers, it could be regarded as either full of musical/sonic possibilities or very constrained. How this view of the Pulley Synth was gradually solved depended on the development of different skills with the system.

For example, one important aspect in determining this dichotomy between perceived potential and constraint was the demand of several performers to play notes and melodies with the Pulley Synth. The device was often referred to as a noise box and lacked the affordances for immediately playing discrete pitches. This aspect was product of the design, in which there was no clear sign post indicating the space and separation between tonal pitches. The task of playing melodies was deemed too difficult by some, but in one particular instance a single performer was able to attain such goal. His strategy, aside from engaging in extended and structured practice, involved preparing the task workspace (Chow, Davids, Hristovski, Araujo, and Passos, 2011). This preparation consisted of fixing the tuning knob at a specific point, marking it on the faceplate, to a position where the string was reduced to a smaller range. This provided much more manageable pitch spaces so that jumping between tonal, discreet pitches became slightly easier. One important result for this performer was the ability to play, albeit a rather detuned, 'Twinkle, twinkle, little star.' Achieving this goal, not only implied engaging in extended practice, but also understanding the system as a whole, as well as having developed a physical familiarity with it. In addition, this task required preparing the taskspace so that the range of necessary gestures was reduced and optimised. Otherwise, this would indeed appear like an impossible feat. This particular example shows how the improvement of performer's skills contributes to the perception of new possibilities offered by the interactive system.

Designing New Possibilities and New Practices

The perception of potential and constraint with the Pulley Synth highlights a critical point for the design, learning, and performance with novel interactive digital music systems. It suggests that on one hand, the novelty of the system itself may yield a perception of unexplored and untapped artistic potential which requires a profound engagement and the development of skill. Perhaps one reason for this perception is the minimalistic design of the system. This condition has been previously described with a extremely constrained musical device, a one-button instrument (Gurevich, Stapleton, and Marquez-Borbon 2010; Gurevich, Marquez-Borbon, and 2012). Similarly, while not as extreme, the Pulley Synth is minimally constrained offering the performer limited degrees of freedom. In both cases, performers often expressed perceptions that the instrument had some sort of hidden potential yet to be discovered. As expressed by one participant, "Maybe there's some other way of producing sounds on it that I haven't worked out yet."

Such expressions were accompanied by a developed diversity of interaction styles. Some interactions are perhaps obvious given that they were in part purposefully designed, while others were not intended by design (for a full account see Gurevich and Marquez-Borbon 2012). These "unintended" interaction styles could be interpreted as *extended techniques* given that these interactions may produce novel and unexpected musical or sonic outcomes. Extended techniques in this light are both the *perception* and *enaction* of possibility within a particular system. Further, they are new patterns of behaviour emergent from the developed perception and skill expressed as experience and expertise; creative exploration and intentionality; and the context of performance practice. Thus, an experienced performer may find through extensive exploration of her instrument an unexpected feature that produces both a gesture and sound that lie outside of an established musical norm or tradition given the instrument and the context in which the performer exercises her practice.

In contrast, the influence of the context in which design and performance take place impact in profound ways the development of performance practice. In other words, for our particular situation, the normative musical practices established by Western European and American Art/Concert Music deeply mark not only the design process of a musical system, but also orient the preferences and ideals of performers. As previously commented, a system's design is not influence-free in spite of efforts to reduce or eliminate such factors. Similarly, a performer's background and history of practice cannot be rejected. This was evident in the musical preferences, desires, and goals (play melodies) several performers wanted to achieve with the Pulley Synth. However, this is not to say that Western Music is the only influence on musician's practice. Rather, this suggests that this particular musical tradition is deeply rooted in our Western cultural context and moving away from it can prove challenging. For Pulley Synth performers, perhaps this was one of the most important factors influencing their learning.

Given the desire and aims of HCI and NIME, to mention specific cases, the drive is to develop technology and design innovations. The constant search for the New assumes that through technological developments musical or artistic developments can be made.

This is in part true taking for example the development of New Media Art. However, this perspective also fails to recognise the contributions of the human element in the interaction. Further, this technocentric approach may not yield the development of new musical or sonic practices in spite of numerous technological innovations (see Marquez-Borbon and Stapleton, 2015).

Developing New Musical and Sonic Practices

The question now lies on, *how do we develop new musical and sonic performance practices?* One starting point given our previous arguments lies on the focus on the human contributions to the interaction. Namely, this implies designing for skill (Djajadiningrat, Matthews, and Stienstra, 2007) and on designing for learning. Both skill and learning go hand in hand, however, the latter suggests designing a learning environment specific to the new interactive digital musical system. Designing a learning environment involves the placement of structures that help guide and focus learning, as well as encouraging creative exploration (see Downey, 2008 and Downey, 2010). This approach stresses the development of skill and expertise with the particular musical system which contributes to the needed experience to perceive hidden possibilities.

Additionally, a learning approach can be enriched by the implementation of alternative musical pedagogies that question and go beyond the Western musical norm such as Free Improvisation (Borgo, 2007), nonlinear pedagogy (Chow, Davids, Hristovski, Araujo, and Passos, 2011), and enactive pedagogy (van der Schyff, Schiavo and Elliott, 2016). These pedagogies emphasise creative musical practices that are often ignored by the music conservatory tradition, such as improvisation, (deep) listening, and collaboration. A nonlinear pedagogical approach can further enrich such a program by focusing on the development of perceptual skills in relationship to the task at hand and the performance environment. This approach has been successfully applied in sports education, and as exemplified with the Pulley Synth, it has potential for being successful in a musical context.

Conclusions

This paper presents some initial insights on the development of new musical practices with novel interactive digital music systems. While it is recognised that such musical practices do not emerge within a vacuum, it is possible to challenge established traditions and norms if one is attuned or open to the unforeseen possibilities of a musical system. For his purpose, an ecological approach to learning, as developed by E.J. Gibson, is proposed as means for development. Given the unstructured learning condition of the empirical study presented here, the ecological view becomes valuable in that it orients a trajectory in which performer's establish a growing relationship with the musical system at hand. In other words, as the performer learns to play the instrument, they attune their perception to the multiple capacities of the system and are capable, in some instances, to perceive new possibilities that may yield possible paths towards the development of new musical or sonic practices. Interactions, more than operating a device, are represented by a rich history of engagement in which the performer develops a deep understanding of the system and what it may artistically afford. It is suggested that achieving this aim can be prompted by the introduction of alternative learning or pedagogical strategies that go beyond traditional music conservatory pedagogy. These multiple approaches invest in the development of other creative musical skills, such as improvisation, listening, and collaboration, which are often ignored by the dominant Western music tradition.

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