CHAPTER 19

SKILL IN INTERACTIVE DIGITAL MUSIC SYSTEMS

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It has been said that one of the primary reasons for attending musical performances is to experience skill (Schloss 2003): to see and hear musicians performing in ways that the spectator cannot or would not, in doing so demonstrating the fruits of years of laborious training and practice. Of course, this is but one reason among many to go to a concert, but it raises questions of how performers develop instrumental skill, how skill is expressed between performers and spectators, and how spectators draw upon their knowledge and experience to make sense and meaning of skilled performances. This chapter deals with these issues as they pertain specifically to performances with interactive digital music systems.

Interactive digital music systems have the potential to foster different types of relationship, of which skill is one important facet, in the ecosystem that exists between performers, instruments, spectators, and society. The simple question, "How do we know if a performance was skillful?"—the answer to which may seem to be intuitive or self-evident in most acoustic music situations—becomes quite thorny when it comes to performances with interactive digital systems. It would be futile to attempt to produce a universal checklist of criteria that could be used to answer this question. Instead, this chapter develops a framework for understanding how performers and spectators may arrive at a shared sense of what constitutes skill in a given situation, from which all may form their own opinions. This in turn will offer insight into how we can design interactive performance situations that foster a greater ability to develop, recognize, discuss, and critique skill.

19.1 Toward a Definition of Skill

Skill as a general phenomenon appears to be nearly universally understood instinctively, especially in its extreme cases: a pole-vaulter launching himself six meters over a bar; a chess player defeating twenty-five opponents in simultaneous matches; a nonswimmer struggling to stay afloat in a pool. Yet, it is important to specify what the term "skill" entails, which I undertake by way of discussing the essential characteristics of skill that are generally agreed upon by researchers in psychology and human motor control (e.g., Magill 1993; Proctor and Dutta 1995).

Fundamentally, skill involves "goal-directed" behavior (Proctor and Dutta 1995). It is evident in sports or crafts that skill should lead to a desired outcome or artifact that can be measured in retrospect, such as an arrow shot through a small target or a structurally sound, symmetrically woven basket. Yet where, as in dance, skilled activity is manifested as a continuous process–where the outcome may be ephemeral and unquantifiable—it remains that the practitioner has a goal in mind, however difficult to verbally specify, and that increasing skill will lead to more desirable performance more frequently.

There is a subtle but important distinction between two senses of the word "skill," highlighted by Magill (1993, 7). In the first sense, *a* skill is a goal-oriented act or task to be performed—whistling, snapping your fingers, finding the roots of a quadratic equation, or baking a pie. In the other, which is more useful for the purposes of the present discussion, skill is an environmentally situated human trait that leads to qualitative differences in performance. Skill in this sense fosters variability within and between performances, dependent in part on proficiency, but also on a range of environmental factors. This situated, qualitative notion of skill also suggests a challenge in measuring or characterizing an individual's skill. Above I hinted at two indicators—the desirability of an outcome and the frequency of positive results, the latter of which Magill (1993, 8) refers to as "productivity." Regardless of the dilemma of assessing skill, it is generally agreed that a hallmark of any skilled activity is some degree of efficiency (Welford 1968), what Proctor and Dutta (1995, 18) call "economy of effort." Several people may be able to produce a sophisticated knot with indistinguishable results, but a more skilled rigger would be able to do so with less exertion and possibly in a shorter amount of time.

Implicit in this and all of the previous illustrations is that skill exists within some domain of practice. Certain domains are more clearly demarcated than others, and some may overlap—one may conceive of a continuum from "baseball player" to "left-handed knuckleball pitcher"—but at some point, skill within one domain does not necessarily equate to skill within another. Although all involve coordinated rhythmic activities, many musicians are famously poor dancers, and may be even less skilled table tennis players. This is in part because skill is acquired and develops over time. Although individuals may begin with different abilities and may progress at different rates, novices will improve through practice, which may be a complex, multifaceted activity beyond simple repetition. Several authors have proposed distinct stages or levels that characterize skill development over time. Fitts and Posner (1967) describe three such stages primarily in terms of perceptual-motor qualities that can change with practice. Dreyfus (2004) identifies five stages from novice to expert, taking a wider, phenomenological view that accounts for a range of emotional, cognitive, neurological, sensory, and motor developments.

Even seemingly commonplace human activities like running and talking represent acquired, organized, goal-directed behavior, and are thus included under the umbrella of skill. Drawing on Dreyfus and Dreyfus (1986), Ingold (2000, 316, 353), emphasizes that skill is actionable knowledge—"knowledge how" as opposed to "knowledge that"—and as such can be learned only through doing, not through the transmission of abstract ideas. He illustrates this with an example of a futile experiment in which participants were given verbal or static visual instructions for tying a knot. Only in retrospect, after successfully tying the knot themselves, could participants make meaning of the instructions (Ingold 2001). This concept of "know-how" (Dreyfus and Dreyfus 1986) can be traced to Polanyi's (1966) term "tacit knowledge," which encapsulates the notion that the body can carry out activities that cannot be otherwise symbolically expressed or verbally articulated.

19.2 Cognitive and Sensorimotor Skill in Music

Skill research tends to distinguish between cognitive and sensorimotor skills (Colley and Beech 1989). The former broadly involve "intellectual" activities in which desirable outcomes are symbolic, whereas the latter, which are at times further subdivided into perceptual and motor skill components (e.g., Welford 1968), result in physical action. Although many activities include aspects of both cognitive and sensorimotor skill, and there is evidence that they may have common mechanisms of acquisition (Rosenbaum, Carlson, and Gilmore 2001), researchers tend to limit their scope to one domain or the other in part "as a matter of heuristic convenience" (Newell 1991, 213). Music is thus precisely the type of behavior that confounds yet provides rich fodder for researchers, as both cognitive and sensorimotor skills are deeply involved (Palmer 1997). As Gabrielsson (1999, 502) states, "Excellence in music performance involves two major components: (a) a genuine understanding of what the music is about, its structure and meaning, and (b) a complete mastery of the instrumental technique."

Researchers in music performance (e.g., Clarke 1988) have historically broken down the process of performance along the lines of this dichotomy, into a preliminary stage of "planning," a largely cognitive process based on knowledge of the music that is to be performed, which informs the subsequent "execution" by the motor system. The enactivist view (e.g., Varela, Thompson, and Rosch 1991) argues that the separation between these stages is also largely a conceptual convenience. Knowing what to play (as well as when and how to play it) is not a matter of merely selecting a sequence of events informed by an abstract understanding of what the body is able to play; it is fundamentally conceived in terms of the embodied relationship between the performer and instrument. Indeed, Ingold (2000, 316) describes skill as "both practical knowledge and knowledgeable practice." In his own account of playing the cello, Ingold (2000, 413) argues that the conventionally "mental" concepts of intention and feeling do not exist a priori to physical execution; they are immanent in and not abstractable from the activity of playing.

Nonetheless, skill psychologists and enactivists can at very least agree that both cognitive and sensorimotor processes, however inseparable they may be, play significant roles in skilled music performance.

As Gabrielsson's (1999) formulation implies, with few exceptions skilled music performance involves substantial physical interaction with an instrument external to the performer's body. Several useful models have been proposed to distinguish between fundamental types, levels or degrees of skilled interaction with technology in general. Prominent among these are Heidegger's (1962) *Vorhandenheit* (presence-at-hand) and *Zuhandenheit* (readiness-to-hand) (see also Dourish 2001); Fitts's (1964) cognitive, associative, and autonomous stages of skill development; Anderson's (1982) model of progress from declarative to procedural knowledge in skill acquisition; Rasmussen's (1983) framework of knowledge-based, rule-based, and (sensorimotor) skill-based behavior; and Norman's (2004) troika of reflective, behavioral, and visceral mental processes. Although not identical in substance or application, the endpoints of these theories generally align with the poles of cognitive versus sensorimotor skill from psychology. In spite of the obvious role of cognition, skilled performance with a musical instrument is often held as a prime example of one of these extremes—a visceral, autonomous activity in which the instrument is present-at-hand; one in which the performer plays *through* their instrument rather than *with* it. The requisite cognitive, reflective, or intellectual skill required for expert music performance is invisible to the observer, overshadowed by potentially stunning physical feats and their ensuing sonic manifestations.

19.3 The Problem of Skill in Interactive Digital Music Systems

The burgeoning trend of music performance with interactive digital systems has prompted observers to question to what degree skilled performance with such systems is the same as with acoustic instruments. As in other cases where digital technologies become entwined with a venerated cultural realm, there appears to be an instinctive sense that a critical and uniquely human aspect of music making is in danger of being lost. Perhaps the most pervasive challenge in the literature surrounding the nascent field of "new interfaces for musical expression" (NIME) is in addressing the notion that interactive digital music systems ("new" seems to imply "digital"), by virtue of functionally separating human action from the sound-producing mechanism, limit the potential for skilled practice and human expression that are associated with conventional acoustic instruments. From the NIME field have emerged cries of "whither virtuosity?" (Dobrian and Koppelman 2006) and questions of how performances with interactive digital systems can be meaningful, perceptible, and effortful (Schloss 2003; Wessel and Wright 2002). From very early in their development, authors expressed misgivings about the tendency for interactive digital music systems to diminish or obfuscate both the apparent effort of the performer and the relationship between their actions and ensuing sounds (e.g., Ryan 1991). Several authors have adopted the position that designers of digital music systems should aim to facilitate the type of *intimacy* that exists between performers and acoustic instruments (Cook 2004; Moore 1988; Wessel and Wright 2002). Intimacy is itself a difficult quality to define, but it is revealing that a term normally reserved for the most personal and delicate human bonds has become the standard for instrumental relationships against which digital systems are measured. Regardless of the specific term we adopt, there clearly exists a concern that the relationship between a performer and an interactive digital music system is somehow impoverished, which negatively impacts the musical experience. The following sections will attempt to dissect this concern and frame the problem in terms of skill.

19.3.1 Multiple Actors, Multiple Perspectives

The phenomenon of skill with interactive digital music systems must be considered from the perspectives of different actors in the performance environment, including those of the performer and the spectator. I contend that many of the unresolved problems in the existing NIME literature stem from confusion between these two distinct perspectives and from presumptions surrounding the relationship of the two. This is not to say that performers and spectators can be treated in isolation: they of course ultimately coexist within the same ecosystem, but they do have somewhat different and at times conflicting perspectives and concerns.[1] Performers want to be able to develop skill, to feel improvement in their ability to achieve increasingly complex goals in their performance as they practice over time. Performers also want their skill to be observed and to be appreciated by an audience. Insofar as music listening can be seen as vicarious experience (Cone 1968; Trueman and Cook 2000), spectators, among other goals, desire in turn to recognize, identify with, and appreciate the skill of a performer. But merely possessing skill is no guarantee it will be effectively communicated across a performance ecosystem, nor that it will be effectively apprehended by any given spectator. Below I consider first the phenomenon of skill as it exists between the performer and the interactive digital music system, and subsequently how that relationship is expressed or communicated between performers and spectators. Finally, I discuss what spectators themselves carry with them to the performance that impacts their experience of skill.

19.3.2 Performers

Many of the concerns around skilled digital music performance have emanated from musicians who are accomplished performers with acoustic musical instruments but who find the experience with their digital counterparts to be somehow deficient (e.g., Wessel and Wright 2002). The lack of intimacy is especially prominent among these authors. If we attempt to unpack this notion of intimacy, it appears at least in part to be facilitated or characterized by sensorimotor skill. Moore (1988) describes an intimate relationship with an instrument in terms of a feedback-control system involving a performer's perceptual and motor faculties and the instrument's dynamic behavior. Fels (2004) elaborates to describe intimacy in terms of a relationship where the performer embodies the instrument, reflecting the Heideggerian state of *Vorhandenheit* and Fitts's (1964) autonomic phase of skilled practice. This is a phenomenon that is well documented (e.g., Ingold 2000; Ihde 1979), one in which the instrument feels as if it has become an integral part of the body and ceases to be perceived as an external entity. Other authors who aspire to attain a similar connection between performer and interactive digital music system prominently discuss *gesture* (Wanderley and Battier 2000), *tangibility* (Essl and O'Modhrain 2006), and *effort* (Bennett et al. 2007), all suggesting that skilled sensorimotor activity is seen as essential in music performance.

That so many see a similar challenge or deficiency with regard to sensorimotor skill in this context suggests that the nature and/or implementation of interactive digital music systems may truly be problematic. Many authors point to the fact that these systems, at least as they presently exist, rely too heavily on cognitive skill and thus do not afford the cultivation of sensorimotor skill. Nowhere is this critique more apparent than in relation to the phenomenon of laptop music performance, in which performers use only the native input capabilities of a laptop. Somewhat tongue in cheek, Zicarelli (2001) identifies "two characteristics of the computer music process: it is driven by intellectual ideas, and it involves office gestures." Magnusson (2009) argues that even the tangible interfaces that digital musical instruments present to the world are merely arbitrary adornments to a fundamentally symbolic computational system, thus demanding a different modality of engagement—a *hermeneutic* relationship between the human performer and the instrument. In other words, interactive digital music systems allow the performer to specify only symbolic goals, and thus facilitate cognitive but not sensorimotor skill. Green (2011) admits this is often the case, but refutes the disembodied relationship that Magnusson (2009) and many others ascribe as a *necessary* or *essential* condition of interactive digital music systems, suggesting the concepts of *agility* and *playfulness* as indicators or manifestations of musical skill that transcend the acoustic and the digital.

Cadoz (2009) offers a more nuanced spectrum of relationships between performers and interactive digital music systems than Magnusson's (2009) embodied–hermeneutic duality, but similarly contends that the nature of the technology prescribes fundamentally different kinds of interactions. But, like Green (2011), Cadoz disagrees that *instrumental* interactions are solely the province of acoustic systems. Rather, instrumental relationships are characterized by what he calls *ergotic* interactions (Cadoz and Wanderley 2000), ones in which physically consistent, realistic exchanges of energy occur between elements of the system. However, the energetic relationships need not be manifested in actual mechano-acoustic systems in order to facilitate instrumental interactions; they may include any combination of material or simulated objects situated in real or virtual environments with human or nonhuman actors (Cadoz 2009).

Although not framed explicitly in terms of skill, the implication is that sensorimotor skill can indeed exist outside of strictly physical, acoustic interactions with instruments. A recent investigation of the user experience of an interactive virtual music environment based on physical simulation in fact revealed three distinct modalities of interaction between performers and the system: instrumental, ornamental and conversational (Johnston, Candy, and Edmonds 2008). These can be thought of as representing a fluidly shifting balance of cognitive and sensorimotor skill.

As mentioned above, *effort* is regarded as a quality in skilled sensorimotor interactions that is missing in digital systems that afford primarily cognitive engagement. The blame is assigned to the very nature of digital systems but also to their designers. "Too often controllers are selected to minimize the physical, selected because they are effortless. Effortlessness is in fact one of the cardinal virtues in the mythology of the computer" (Ryan 1991, 6). The lament for the loss of sensorimotor skill with digital devices is echoed outside of the musical context as well. Djajadiningrat, Matthews, and Stienstra (2007, 660) attempt to "chart the increasing neglect of the body with respect to human–product interaction," a phenomenon they attribute in part to the preoccupation with "ease of use" in interactive product design. Devices that simplify user actions shift "the complexity from the motor actions to the decision process of what to do. It is exactly because button pushing is so simple from a motor point of view that learning is shifted almost completely to the cognitive domain" (Djajadiningrat, Matthews, and Stienstra 2007, 659). Jensen, Buur, and Djajadiningrat (2005) attribute this shift to the proliferation of what Norman (1998) calls "weak general" products: those in which a user's actions are neither distinct from one another, nor are they associated with unique outcomes. Quite unlike traditional acoustic instruments, such devices preclude the development of specific sensorimotor skills that are particular to the interaction or to an intended result.

The critique of interactive systems at times extends beyond the notion that they make the human body's job "too easy," to assert that they may in fact overtake or overshadow much of the work of the human performer. Magnusson (2009, 175) contends that "software has agency" and thus digital instruments reflect the culture, identity, and skill of their designers as much as, if not more than, those of performers. Indeed, digital systems may be imbued with so much "intelligence" as to limit the possibility for intervention by human performers to simply setting processes in motion or adjusting high-level parameters (Schloss 2003). The notion that in replacing an acoustic instrument, the interactive system itself (and by proxy, its designer) may supplant the role of the skilled performer is reflected in Ingold's (2000, 300–302) synthesis of views on the difference between tools and machines. Although they clearly lie on a continuum (the potter's wheel and the sewing machine being somewhere in the middle), the historical concern is that in progressing from tools, which are guided and powered by the physical and volitional impulses of a skilled craftsman, to machines, which are externally powered and pushed along predefined paths by operators, the richness and reward offered to the skilled human practitioner is lost. The injection of computers, their mechanistic baggage in tow ("machine learning," "human-machine interaction"), into such a refined human tool-using activity as music has historically led to a concomitant decline in the directness between a performer's actions and sonic outcomes (Cook 2004) that no doubt fuels some of the concerns over the diminishing role of skill.

19.3.3 Between Performers and Spectators

Though motivated in part by dissatisfaction with their own experiences, the performer-centered critiques of interactive digital music systems are also informed by performers' own experiences and expectations as spectators. If a disconnect exists between the performer and their digital instrument, another appears between the performer-instrument system and the spectator. In the broadest terms, the challenge between performers of digital instruments and their audiences is framed as one of *expression*. There is a growing body of literature on musical expression both within and outside of the digital context that is too large to summarize or explore in depth here (see e.g., Gabrielsson and Juslin 1996; Juslin and Sloboda 2010), but it is necessary to discuss expression in as much as it pertains to the present discussion of skill. Although there is some question as to whether this is a reasonable universal expectation in new music (Gurevich and Treviño 2007), the very appearance of the term as the "E" in NIME (Dobrian and Koppelman 2006), suggests that spectators largely desire interactive digital music systems to support expression by performers.

I contend that "expression" in this context is largely a proxy for "sensorimotor skill." In general, the range of potential physical realizations of a particular sensorimotor skill is far more restricted than for a cognitive skill. Playing a violin inherently imposes greater constrains on the performer's actions than does playing chess: one can play chess masterfully regardless of how one holds or moves the pieces, or even by instructing another person to move the pieces; the same cannot be said of playing the violin (Rosenbaum, Carlson, and Gilmore 2001). Consequently, the relatively more subtle variations in performance take on greater significance in activities where sensorimotor skills are prominent. These differences in performative action are seen as meaningful regardless of whether they are expressive of any idea or emotion in particular. Indeed, many authors highlight the affective, emotional, or communicative potential of the kind of intimate, embodied relationship with an instrument that sensorimotor skill engenders (Fels 2004; Moore 1988; Trueman and Cook 2000; Wessel and Wright 2002). Here again, Djajadiningrat, Matthews, and Stienstra (2007) take the wider view that any activity involving refined sensorimotor skill has potential expressive and aesthetic value. Others have illustrated that seemingly mundane skilled technical actions such as preparing coffee (Leach 1976) or pouring a beer (Gurevich, Marquez-Borbon, and Stapleton 2012) can communicate cultural or personal values between actors and spectators.

In terms of the characteristics of skill described at the outset of this chapter, it would seem that efficiency is a primary obstacle when it comes to the negotiation of skill between spectators and performers with interactive digital music systems. In order for an observer to appreciate the "economy of effort" that comes with skilled performance they must be able to apprehend the potential difficulty. Imbedded in the adage that a skilled musician makes their performance "look easy" is the notion that for a less skilled musician a similar performance would visibly require a great deal more effort; for most (i.e., the average spectator) it would be impossible. In the case of traditional acoustic instruments, this phenomenon hinges on the performer's direct sensorimotor involvement in the sound-production mechanism. Even where the precise details of a performer's actions are not visible, such as when a pianist's hands are obscured, the spectator is on some level aware that the precise temporal and acoustic characteristics of each sound event are under the performer's direct control. When the spectator experiences a desirable performance, they are consequently aware that it is a result of the performer's skillful execution.

But when an interactive digital music system does not demand significant sensorimotor skill, the distinction between a performance *looking easy* (exhibiting the economy of effort that is a hallmark of skill) and actually *being easy* (requiring minimal effort altogether) may not be evident to a spectator. Cognitive skills do not generally involve physical exertion, and their outcomes may not be temporally or spatially immediate. Therefore the skill, effort, and difficulty of a cognitively demanding performance, as in the case of live coding (Collins et al. 2003), may not be apprehended by a spectator who can only see the performer's actions and hear the resulting sounds. Cognitive skill's lack of specificity of action and immediacy of outcome can be compounded by the potential for agency on the part of the interactive system, giving rise to the possibility that the spectator may confuse the performer's and system's contributions.

19.3.4 Spectators

The role of the spectator in the interactive performance ecosystem is perhaps the least well studied or understood. Yet they are active participants; their very presence and attention provide the impetus for performers to play, and they bring a set of expectations, experiences, and skills (of which performers are on some level aware) that they draw upon to make meaning of the performance. Whereas the previous two sections of this chapter dealt respectively with the performer's skilled relationship to their instrument, and with the consequences of that relationship for the spectator, this section focuses on what the spectator brings to the interaction and how it may impact their experience of skill.

In spite of the apparent desire for greater displays of sensorimotor skill in interactive music performance, we know that spectators do willingly experience and enjoy performances of cognitive skills in other domains. Television quiz shows offer not just the suspense and vicarious thrill of prize money won and lost, but as in music performances, the appreciation of a display of skill—cognitive skill in this case—beyond what most spectators can attain. Although chess is already a well-worn example of cognitive skill, it is illustrative of an important extension of this point. Large audiences routinely attend chess matches between highly skilled players, yet we do not hear protestations about the players' lack of expression or their physical detachment from the chessboard. Spectators remain engaged in what is almost entirely an intellectual, cognitive enterprise, but this is surely only true in cases where they arrive equipped with a prior understanding of what constitutes skill in the domain of chess. "Knowing the game" would seem to be crucial in the spectator experience of cognitive skills. Even a chess match at the highest level would be meaningless for a spectator who does not at very least know how the pieces move or what constitutes victory; *Wheel of Fortune* would not be very rewarding for a spectator who neither speaks English nor reads Roman letters. This is a fundamental difference from some sensorimotor skilled activities, which do not strictly depend on the spectator possessing knowledge or experience external to the experience at hand. A child need not arrive at the circus with a procedural explanation of the mechanics of juggling, nor need they have ever attempted to juggle. The embodied nature of many sensorimotor skills means that spectators can appreciate them in terms of their own bodily knowledge, even without direct experience of the activity in question. A growing body of evidence from the field of action perception, including the discovery of mirror neurons (Rizzolatti and Craighero 2004), supports the idea that we experience the physical behavior of others quite literally in terms of our own bodies (for reviews see e.g., Blake and Shiffrar 2007; Decety and Grèzes 1999).

This is not to say that a spectator's own prior knowledge and bodily skill cannot enrich the experience of sensorimotor skilled performances. In fact, there is evidence to the contrary. Even with small amounts of musical training, music listeners exhibit brain activation in the same motor control areas that would be used to perform the music they are listening to (for a review, see Zatorre, Chen, and Penhune 2007). Moreover, as we have established, even acoustic music performance is not purely a sensorimotor skill. Indeed, a spectator's own cognitive skills play an important role in forming an assessment of a performer's skill; to some extent "knowing the game" is important in music as well. An understanding of music theory, knowledge of the body of musical repertoire surrounding the work, and awareness of the social and cultural context in which a piece of music was conceived can all drastically impact a spectator's overall experience of a performance. These are in turn mediated by a spectator's perceptual skill in listening to the music and watching the performer, and possibly their sensorimotor skill from prior performance experience.

Recent studies of spectators of electronic and acoustic music performances have shown that spectators do indeed draw upon their perceptions of sensorimotor skill but also upon knowledge of stylistic conventions and performance practice in forming assessments of skill (Fyans and Gurevich 2011; Gurevich and Fyans 2011). Significantly, even when spectators in these studies had some basis for assessing embodiment and sensorimotor skill, they were unable to confidently form judgments of overall skill without intimate knowledge of the musical context. Furthermore, this phenomenon persisted whether the instrument in question was acoustic or digital, familiar or not. Thus it would seem that spectators' judgments of skill are indeed informed by factors well beyond performers' displays of speed, control, timing, and dexterity. Spectators, like performers, participate in the sociotechnical systems from which musical performances emerge. Indeed, Lave and Wenger (1991) propose that participation in a community of practice helps give meaning to learning and skill development. In performative domains such as music, it is important to recognize that spectators, in learning to experience, assess, and form opinions of skilled practice, are ultimately participants in the same community as performers (see also Chapters 18 and 20 in this volume).

19.4 On Virtuosity

Especially in the musical domain, skill is frequently uttered in the same breath as *virtuosity*. It seems we all know instinctively that virtuosity requires skill, yet the two terms are not exactly interchangeable: accomplishments involving high degrees of skill are not necessarily virtuosic. For one thing, virtuosity tends to be confined to the arts; apart from usages for rhetorical effect, we don't often hear of virtuoso sprinters or airline pilots, although both can be highly skilled. This is true in part because virtuosity requires not only "high technical proficiency," or sensorimotor skill, but also "critical skill," which Howard (1997, 46) describes as imaginative "interpretive judgment" in the execution of technical skill. In the musical domain, this interpretive judgment may be synonymous with "musicianship." Imaginative interpretive judgment may of course be applied in a number of intellectual domains without virtuosity—history or philosophy, for example—thus, what confines virtuosity to the province of the arts is the employment of imaginative interpretive judgment in the execution of sensorimotor skill (Howard 1997).

According to Mark (1980), it is an artwork's quality of having of a subject—an artwork is *about* something (even if it is about nothing)—that enables it to be virtuosic. In this formulation, a work of virtuosity then must require and demonstrate technical skill, but must also make skill its subject. In other words, virtuosic performances are fundamentally *about* skill. Therefore, the apprehension and attribution of skill are central to a spectator's ascription of virtuosity. This suggests that, like skill, musical virtuosity is socially situated, depending not only upon the performer's skill and musicianship, but also the audience's ability to reflect upon these with respect to both a broader community of musical practice and the perceived limitations of skilled action.

As a more constrained and specific manifestation of skill, virtuosity therefore presents special challenges for interactive music systems. In order to facilitate virtuosity, such systems must of course afford the development of extreme sensorimotor skill but also allow enough room for imaginative interpretive judgment so that performers can exhibit musicianship. However, beyond these, virtuosity requires a musical culture that allows spectators to reflect on how great is the technical and musical accomplishment. This is a difficult proposition for interactive music systems that may be unfamiliar and unique, and that may blur the distinction between human and machine contributions. Reflecting upon the emerging notion of machine musicianship (e.g., Rowe 2001), Collins (2002) considers that plausible "machine virtuosity" would have to be rooted in human sensorimotor and psychoacoustic abilities. A virtuosic machine performance would have to appear to extend human abilities, to transform from human to inhuman, and to be susceptible to mistakes. Although it may be difficult for some spectators to attribute interpretive judgment to the machine performer itself, rather than its programmer, such a performance could certainly fulfill Mark's (1980) criterion of being about the skills that are on display. But it is less evident how virtuosity may emerge in a performance between a human and a machine, where the attribution of skill and interpretive judgment may be fluid or vague. By potentially divorcing a complex sonic outcome from the necessity for high technical skill, interactive systems may leave the performer to rely upon musicality or judgment, which are in themselves insufficient for virtuosity.

19.5 Breakdowns in the Social Construction of Skill

The prevalence of calls for greater and more refined development and expression of skill in performances with interactive digital music systems suggest a number of potential breakdowns in the performer–instrument–spectator ecology. In what follows, I frame these breakdowns in terms of the essential characteristics of skill laid out at the beginning of this chapter.

The most evident breakdown can occur between the performer and the instrument, most likely because the instrument is unable to support attainment of increasingly complex or desirable goals through sustained practice. This situation is an instance of the dilemma of ceilings, floors, and walls: How can we design systems with a low floor to support easy initial access, high ceilings to support sustained skill development, and wide walls to support an acceptably broad range of activities (Resnick et al. 2009; Wessel and Wright 2002)? Although normally framed as a challenge for the development of skilled practice in general, there is a tendency to conflate this breakdown with the aspiration for specifically sensorimotor skill. An incomplete list of properties, some of which I have previously mentioned, that authors suggest are crucial for sensorimotor skill development includes: mapping between gesture and sound (Fels, Gadd, and Mulder 2003), jitter and latency in the system's temporal response (Moore 1988; Wessel and Wright 2002), tangibility (Essl and O'Modhrain 2006), specialization and simultaneity of action (Djajadiningrat, Matthews, and Stienstra 2007), force feedback (O'Modhrain 2001), and effort (Bennett et al. 2007).

Yet the challenge of the floors–ceilings–walls problem can also be addressed through interactive systems that involve primarily cognitive skills. Live-coding laptop practice is a domain in which performers regularly display dazzling feats of cognitive skill in performance (Collins et al. 2003). The primary breakdown in the development and expression of skill may therefore not occur exclusively between the performer and the interactive digital music system, where most tend to locate it, but rather in spectators' perceptions of cognitive skills. Recalling that skill develops within domains of practice that are circumscribed by finite bounds, there may exist a mismatch between the spectator's embodied cultural knowledge and the domain of practice in which a skilled performer is operating. Just as being a skilled distance runner has minimal bearing on my ability to play football, being a skilled oboist may have a very tenuous connection to my skill as a turntablist or practitioner of live coding. "Music" is an excessively broad domain when it comes to skilled practice, and this applies to spectators as well as performers. That skill is a goal-oriented activity that exists within a domain of practice means that in order to apprehend skilled performance, spectators must be aware (or made aware) of how that domain is circumscribed, and be able differentiate between more and less desirable performances according to the performer's goals.

Accordingly, it has been argued that spectators lamenting the feeling of disconnection, disembodiment, or lack of sensorimotor skill between performers and interactive digital music systems are unrealistically transposing their expectations from one subdomain of music to another (Stuart 2003). Perhaps they are failing to understand what constitutes the primarily cognitive domain of skilled practice in which a performer is operating. In the context of laptop music, Stuart (2003) asserts that at least some digital music performances are fundamentally aural phenomena in which, unlike acoustic music, the performer's bodily relationship to sound is unimportant. The onus is thus placed on the listener to overcome their misplaced desire for sensorimotor skill.

A further mismatch may exist between performers' and spectators' notions of what constitutes a desirable outcome. This is always a potential concern in a performative domain, one that is especially salient in contemporary music. Stirring a listener's emotions or displaying physical dexterity may not be among the goals guiding a performer's activity; misapprehension of these goals may lead to another breakdown in the ecology of skill.

Finally, especially in cases where the interaction is largely cognitive, it may be difficult for the performer's skill to be separated from that of an instrument builder, designer, composer, or software programmer. Spectators of acoustic music performances generally understand the bounds between the contributions of instrument makers and performers; it still takes a highly skilled performer to make even a Stradivarius sound good. But insofar as the interactive digital system has greater potential for spontaneity, programmability, or agency, it can be difficult to attribute the outcomes of the system to the skill of the performer or to properties that were built into the system.

19.6 Authenticity

Auslander (2008, 98) contraposes Stuart's (2003) renunciation of the necessity of the visual with Schloss's (2003) emphasis on perceptible effort. He situates the "decorrelation" of visual evidence of music performance from the means of sound production within the larger frame of a supposed ontological distinction between "live" and "mediatized" forms of performance, one that he ultimately rejects (Auslander 2008, 5). In this view, calls for intimacy, transparency, and evidence of skill in the relationship between performers and interactive systems may be seen as a demand for *authenticity*, analogous to the function of live performance in validating the credibility of rock performers whose primary outputs are recordings (77). Although most music created with interactive digital systems lies outside of rock culture, the classical or "new music" culture from which it tends to derive has its own norms and expectations for authenticity on the part of performers, which include demonstrable skill in live performance. It is clear that for some spectators, a display of sensorimotor skill is a necessary constituent of an "authentic" performance with an interactive system.

It is interesting to note that Schloss and Jaffe's (1993) earlier article positing "the demise of the performer" emerged at exactly the same time as the crisis of authenticity in rock music that is Auslander's (2008) primary case study reached its apex. Auslander chronicles the Milli Vanilli lip-syncing scandal of 1990 and the role that *MTV Unplugged*—in particular Eric Clapton's performance and *Unplugged* album that earned six Grammy awards in 1993—played in restoring a semblance of authenticity to the rock music establishment. Although there is no evidence that this episode directly affected Schloss and Jaffe's writing, it foregrounded questions of musical authenticity within the wider societal consciousness, and, as Auslander traces, contributed to a subsequent cultural reassessment strengthening the need for apparent authenticity, even in nonrock music. It is worth considering to what extent the broader cultural discourse on authenticity and its relationship to "liveness" (Auslander 2008) forms the background for expectations of demonstrable skill in interactive music performances.

19.7 Conclusions

From this complex suite of relationships emerges a picture of skill not just as a property of a performer to be assessed by a spectator, but rather as a situated, multidimensional, socially constructed phenomenon that emerges within the performance ecosystem. It is a phenomenon for which society has largely been able to converge, if not upon universally agreed judgments, then upon at least a basis for informed critique within certain well-established traditions of music performance, but a basis that remains almost completely untamed in the jungle of interactive digital music systems. Although there is an undeniable tilt toward the relative importance of the cognitive versus the sensorimotor in digital music performance, this binary opposition is inadequate for fully characterizing and problematizing the phenomenon of skill as it applies to interactive music.

Overcoming the potential breakdowns in the ecology of skill cannot solely be a matter of imbuing interactive systems with greater potential for sensorimotor engagement, nor one of spectators needing to overcome an anachronistic desire for physical performativity and immediacy. Skill emerges from a performance ecosystem that includes a performer, instrument, and spectator, all as active participants that also exist within a society and draw upon cultural knowledge. Anything resembling a consistent conception of skill between a performer and spectator relies on some degree of shared understanding of the performer–instrument relationship, confluence between the performer's and spectator's goals and expectations, commonality of cultural experience, and participation in overlapping communities of practice. Of course, this framework represents just a single spectator. For informed discussion or shared experience of skill to emerge between different spectators, these relationships must extend outward to the larger social ecosystem of the audience.

Although I have painted a picture of an undeniably complex and fragile system, the intention is not to say that all hope is lost. In fact, quite the contrary: as a society we have already managed to negotiate this ecosystem rather effectively (and somewhat organically) in a large number of acoustic musical performance situations. There is no doubt that we can accomplish the same as we set out to incorporate new interactive technologies into skilled music practice, as long as we bear in mind the complexity and potential for disruption to the existing ecosystem. We must expect that new forms of technological relationships between performers and instruments require simultaneous reconsideration and recalibration of what skill means throughout the performance ecosystem and how design can facilitate its emergence.

Note

1. At this point it is worth highlighting that there are valid and accepted musical situations in which skill is unimportant or unnecessary from both the spectator and performer perspectives (e.g., certain experimental pieces by John Cage, Cornelius Cardew, and members of Fluxus), but this chapter is specifically concerned with circumstances in which skill is desirable.

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