Jonathan De Souza

Music at Hand

Instruments, Bodies, and Cognition

Oxford Studies in Music Theory

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For Heather

CONTENTS

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ABOUT THE COMPANION WEBSITE

www.oup.com/us/musicathand

Like many texts in music theory and analysis, *Music at Hand* invites readers to listen, watch, and play. The book's companion website presents audiovisual examples, comprising performances by the author, motion-capture videos, and music-analytical animations. These online examples are indicated in the text with the symbol ▶. To access the website, enter the username [Music5] and password [Book1745].

Much of the music discussed in the book, however, is not represented on the companion website. In such cases, recordings can generally be found in libraries and online. And readers of all levels of musical expertise are encouraged to try out examples at an instrument, as the website unfortunately cannot replicate the feeling of fingers on a keyboard or lips on a harmonica.

Music at Hand

Introduction

Music is fleeting. It disperses as it is heard. And though I sometimes feel its vibrations, I cannot touch, cannot see, and cannot hold them. Because of this, music has often been considered the most abstract, most metaphysical art. Yet at the same time, music is bound up with physical things: upright pianos and electric guitars, tambourines, turntables, violas, bagpipes, microphones, headphones, and iPhones, sitars, French or English horns, marimbas, flutes of metal, bone, or wood. And all of these, in turn, are bound to human bodies.

Music at Hand investigates music's corporeal grounding. This, in itself, is not especially original, for questions of embodiment are hardly new to music studies. In the 1990s, for example, some musicologists asked about music's role in the history of the body (e.g., Leppert 1993; McClary and Walser 1994). Attending to the embodiment of sexual and racial differences, their work recognized music as "one of the means by which people learn about their bodies—how to move, how to feel, how (finally) to *be*" (McClary 1998, 87). Contemporaneous theorists, drawing on psychology and philosophy, argued that embodied knowledge shapes musical concepts (more about this in Chapter 1). These perspectives, which are often combined, are complementary: where the first showed how music mediates bodies, the second clarified how bodies mediate music. A third, related approach considered aspects of musical organization and meaning that may be felt by performers but not always heard by listeners. Suzanne Cusick (1994, 18–20), for example, discussed a moment from one of J. S. Bach's organ preludes that creates a sense of physical imbalance for the player. For this style of "embodied music theory," musical sound and text are supplemented by performing bodies.[1]

Though inspired by these precedents, *Music at Hand* has a slightly different task: it emphasizes that performing bodies themselves are supplemented by instruments. That is to say, certain forms of musical embodiment are possible only with instrumental mediation.[2] As such, I am specifically interested in musicians'

1. Modes of analysis that focus on performers' bodies have been deployed by various scholars, including Fisher and Lochhead (2002), Le Guin (2006), Rockwell (2009), Montague (2012), Yearsley (2012), and Bungert (2015). This research participates in a broader musicological trend, theorized in Nicholas Cook's *Beyond the Score* (2014), that conceives of music as performance rather than text.
2. These kinds of musical embodiment are by no means universal, since there are musicians who do not play instruments and musical cultures that do not make them (Kartomi 1990, xvii–xviii). Nonetheless, humans have used musical instruments since prehistoric times (see De Souza 2014).

engagements with concrete objects, rather than musical gesture in general.[3] Insofar as players' actions take shape around keys, fingerboards, mouthpieces, and so on, it is necessary to examine how instruments are structured, how they make actions audible and sounds manipulable. Here the book can be understood as a music-theoretical counterpart to recent research, inspired by media theory and history of science, on instruments' epistemological significance (e.g., Dolan 2013, 10–13; Tresch and Dolan 2013; Moseley 2015). From this viewpoint, musical knowledge is grounded not in bodies alone, but in an interplay of techniques and technologies.

A theory of musical bodies, then, requires a theory of musical technics. This uncommon word "technics" refers to technical matters in general.[4] It corresponds to the German *Technik* or the French *la technique*, which, depending on context, can be translated as either "technique" or "technology." The ambiguity can productively bring these elements together, revealing their commonalities, their complementarity. Every technology, in this view, is associated with some technique. Technics, moreover, is an inclusive concept. It encompasses seemingly disparate objects and practices, from laptop computers to prehistoric hand axes, from the tools of industry and warfare to those of art and play. Accordingly, "music technology" would go beyond electronic devices and recording technology to include instruments and forms of musical writing. And "musical technique" would involve performing skills but also listening skills. Indeed, this book insists that such skills are closely connected, that the acquisition of instrumental technique—a process of bodily "technicization"—affects the ways that players perceive, understand, and imagine music.

To support these theoretical claims, the book marshals diverse musical examples—classical and popular, old and new. It also mixes several modes of performance analysis.[5] I examine specific recorded performances (many of which are improvised), while also reading scores in terms of their performative possibilities. I reflect on my own experiences as a multi-instrumentalist, while also exploring pieces and instruments that I cannot play, which I approach from the outside. And though I have not conducted formal fieldwork or interviews, I often consider statements by expert performers. Each of my case studies, of course, is historically and culturally specific. As such, I often have recourse to scholarship from music history and ethnomusicology. (In fact, though the examples reflect my own expertise in Western music, ethnomusicology offers some important antecedents to my approach.)[6] Yet my main goal is not to illuminate the musical cultures or social

3. Robert Hatten's approach to musical gesture, for example, is predicated on an expansive definition of the concept (2004, 93–95). By contrast, I tend to follow a distinction made by the psychologist David McNeill (1992, 78), who separates spontaneous communicative gestures from skilled forms of object manipulation. From this perspective, playing "air guitar" is gestural, but playing a real guitar is not.

4. Prominent writings on technics include Lewis Mumford's *Technics and Civilization* (1934) and Bernard Stiegler's *Technics and Time* series (1998, 2009, 2011). Gallope (2011) discusses technics and music.

5. For recent methodological reflections on performance and analysis, see Cook (2014, ch. 2) and the collection of essays titled "Performance and Analysis Today" in *Music Theory Online* 22/2, introduced by Barolsky and Klorman (2016).

6. Aspects of my work are anticipated in John Blacking's reflections on human musicality, which engaged both musical instruments and the anthropology of the body (1973, 17–21), in John Baily's (1977) study of body-instrument interaction in the performance of Afghan lutes, and in Bell Yung's (1984) work on kinesthetic and choreographic aspects of music for the *qin*, a seven-string Chinese zither.

contexts from which these examples are drawn. Instead, their juxtaposition allows generalizations about instrumental performance to emerge. Musical and analytical variety thus serves as a methodological feature. With this in mind, the book might be imagined as a kind of collage.

This collage of music and ideas mixes disciplines, too, relying most consistently on cognitive science and phenomenology. While I engage with experimental research from music psychology, I am equally interested in theoretical work related to embodied cognition. Embodied cognition—like "embodied music theory"—distinguishes itself from approaches that treat mind and body as independent entities. To be specific, embodied cognition principally reacts against a computational conception of mind, which emerged in the mid-twentieth century. According to this model, bodily input is converted into "nonperceptual" data, and the brain deals in abstract symbolic representations that are essentially independent of the senses. Proponents of embodied cognition, by contrast, argue for the integration of perception and cognition, body and mind.[7] Claiming that knowledge and experience are based in the body's sensorimotor capacities, they draw on behavioral studies, brain imaging, cognitive anthropology, and so forth. This discourse, then, provides a repository of theoretical concepts and empirical evidence about the relations among mind, body, and world.

Meanwhile, phenomenology—a philosophical tradition inaugurated by Edmund Husserl—offers a first-person standpoint that complements cognitive studies.[8] This, again, involves a blend of theory and observation. On one level, phenomenology is a descriptive method, a set of techniques for analyzing lived experience. Husserl examines things as they appear to consciousness, attending to the correlation of object and subject, to individual senses, to real or imaginary shifts in temporal and spatial perspective. His reflections on the sound of a violin provide a characteristic example:

> The tone of a violin with its objective identity is given through perspectives, it has its changing forms of appearance. They differ according as I approach the violin or recede from it, according as I am in the concert hall itself or listen through its closed doors, and so forth. No way of appearing claims to rank as giving its data absolutely, although a certain type, appearing as normal within the compass of my practical interests, has a certain advantage; in the concert hall, at the "right" spot, I hear the tone "itself" as it "really" sounds. (Husserl [1913] 2012, 83)

Briefly put, the phenomenologist develops *variations* on experience, much as a musician might compose variations to explore a familiar theme.[9] Such techniques

7. Embodied cognition does not necessarily invalidate findings of the symbolic-processing approach. Theoretical work in this relatively new area often aims to show how earlier results can be reinterpreted in terms of sensorimotor grounding, moving toward methodological synthesis (Barsalou 2010). Note also that these two streams of cognitive science have long inspired music theorists: for example, Fred Lerdahl and Ray Jackendoff's *A Generative Theory of Tonal Music* (1983) adapts hierarchical structures from Noam Chomsky's computationalist linguistics, whereas Lawrence Zbikowski's *Conceptualizing Music* (2002) adapts work on embodied metaphor from later cognitive linguistics.
8. For example, Varela, Thompson, and Rosch combine cognitive science with phenomenology in *The Embodied Mind* (1991). There is even a journal, *Phenomenology and the Cognitive Sciences*, devoted to this methodological pairing.
9. Here I am indebted to Don Ihde's use of phenomenological variations in his work on the phenomenology of sound (2007) and technology (2009, 16–19). For a practical introduction to the technique, see Ihde (1986).

can be separated from Husserl's transcendental philosophy. For example, David Sudnow's *Ways of the Hand* (1978)—a book that describes how the author learned to play jazz piano—employs these methods without explicitly discussing phenomenological theory. When analyzing my own experiences as a performer, I continue this style of applied phenomenology.

I also deal with phenomenology at a philosophical level, where experience is linked to ontology. Here my principal interlocutors are later figures: Martin Heidegger and Maurice Merleau-Ponty. Neither wrote much about music—Heidegger was more interested in poetry, Merleau-Ponty in painting—and some commentators have critiqued their treatment of sound (Dyson 2009, 85–95; Cimini 2012). But I am mainly concerned with other aspects of their thought, namely Heidegger's account of technology and Merleau-Ponty's philosophy of the body. For Merleau-Ponty, "the body is our general means of having a world" ([1945] 2012, 147). That is to say, my body—unlike external things that come and go—is always here for me. It is felt directly, imbued with affect and kinesthetic sensation. My body makes perception possible. Merleau-Ponty's *Phenomenology of Perception*, then, does more than celebrate somatic self-awareness. Its attention to bodily experience supports ontological claims that challenge computationalism's emphasis on disembodied informational patterns. In this view, we do not simply *have* bodies. We *are* bodies.

To some, these interdisciplinary commitments might seem to lead away from music theory proper. But I would argue, on the contrary, that this type of methodological synthesis is characteristic of the field. The history of theory is full of musician-scholars who took inspiration from contemporaneous science, philosophy, mathematics, linguistics, and so on. Furthermore, this particular triad—music theory, cognitive science, and phenomenology—is central to a well-known essay by the influential theorist David Lewin.[10] In "Music Theory, Phenomenology, and Modes of Perception," Lewin contends that theories of musical perception should consider production as well as listening. When we play the final movement of Beethoven's "Appassionata" Piano Sonata, he writes, "we are *not* matching the fingers and positions of our right hands to a preconceived 'perception' of the theme; rather we are *in the act of perceiving the theme* as we move the parts of our bodies to play it" (1986, 382, emphasis in original). As one way of responding to Lewin's phenomenology, the present book builds on his work in mathematical music theory, constructing transformational models of various instrumental interfaces.

Certain aspects of these models will interest mainly readers with a background in transformational theory. Yet this analytical apparatus also exemplifies something that music theory can bring to interdisciplinary conversations. While Lewinian formalism fixes aspects of musical performance, it also makes them legible for close analysis. It has helped me to listen more carefully and to think more rigorously about performative actions and instrumental spaces. In this regard, the associated musical excerpts and technical diagrams might be compared to the data and statistics presented in the

10. As Brian Kane (2011) has demonstrated, Lewin's phenomenology relies on a particular interpretation of Husserl (associated with West Coast phenomenology), even as he anticipates certain post-Husserlian developments. For an applied phenomenology of musical listening, see Clifton (1983).

results section of a psychology article. They test intuitions about particular pieces and performances. They reveal expected or unexpected patterns, confirming or denying musical hypotheses. That is to say, in the wealth of musical detail gathered by analysis, music theory seeks a kind of evidence. Such evidence might support claims about "intra-musical" principles (e.g., conventions of tonal harmony or form in classical music). But it might equally speak to broader humanistic and scientific concerns, involving cultural history, cognitive processes, representations of gender, race, and disability, or the co-constitution of bodies and technologies. Music-analytical results are admittedly partial, provisional, and susceptible to bias. Nonetheless, I cannot help but believe that music, if we listen to it truly, can teach us about the world. With this in mind, I have tried to keep the book's analytical discussions accessible to nonspecialist readers, who may find the audiovisual materials on the companion website particularly useful.

The book's opening chapters theorize connections among body, instrument, and sound. Chapter 1 takes performances by the deaf Beethoven as an instance of body-instrument interaction. It shows how instrumental practice gives rise to distinctive patterns of auditory-motor coactivation in players' brains, which may be reanimated in perception and imagination. Elaborating on this general framework, Chapters 2 and 3 examine particular instrumental interfaces. They focus, respectively, on sound production and instrumental space, on how instruments translate action into sound and how they distribute musical materials physically. Chapter 3 also introduces transformational tools that are used throughout the rest of the book. Its analyses—which compare various styles of harmonica playing—suggest that idioms emerge at the nexus of instrumental "sweet spots" and players' embodied habits.

Processes of instrumental alteration are explored in Chapter 4. When musicians alter their instruments, they open up new possibilities for sound and performance. But a series of analyses related to guitar improvisation indicate that this process, by disrupting established auditory-motor mappings, can also affect players' perception.

The final two chapters ask how composers and listeners relate to instruments. Chapter 5 focuses on the music of J. S. Bach, considering how instrumental idioms may function as a resource for composers. Ultimately it argues that composition is deeply intertwined with instrumentation. Turning to listeners who do not play instruments, Chapter 6 reflects on the interplay of sound and source in Haydn's use of valveless horns. If historically situated audiences recognize schematic textures referring to instruments—if, for example, they can hear virtual horns in a string quartet or piano piece—this implies that their perception also reflects multisensory associations centered on instruments. Like performance, then, listening would be both embodied and conditioned by technology.

CHAPTER One

Beethoven's Prosthesis

More than a decade after Ludwig van Beethoven's death, his secretary Anton Schindler remembered the composer at play:

> Beethoven was very fond, especially in the dusk of the evening, of seating himself at the piano to improvise, or he would frequently take up the violin or viola.… In the latter years of his life, his playing at such times was more painful than agreeable to those who heard it.… The most painful thing of all was to hear him improvise on stringed instruments, owing to his incapability of tuning them. The music which he thus produced was frightful, though in his mind it was pure and harmonious. (Schindler 1841, 174–76)

This intimate scene of musical pleasure is also, poignantly, a scene of breakdown. Deafness does not simply block Beethoven's hearing. It alters his music-making too.

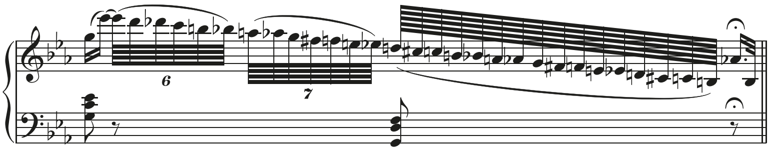
Later accounts, unlike Schindler's, often romanticize this disability, claiming that it benefited Beethoven's music.[1] Hearing loss, in this view, distanced the composer from the perceptible materiality of sound and inducted him into an ideal, spiritual musicality. His late string quartets came to represent the belief, historicized by Carl Dahlhaus, that absolute music "'dissolves' itself from the sensual" (1989, 17). Understanding music as an unmediated expression of the Will, this discourse metaphysically opposes "pure musicality" and "mere technique." Beethoven's music, it argues, has nothing to do with instruments or manual skill.

Yet Beethoven enjoyed the physical practice of instrumental music despite his hearing loss. He continued to play privately and probably continued to write music at the keyboard (Ealy 1994, 273). Perhaps this is unsurprising, given his background as a composer-pianist and a renowned improviser. Still, what was it like for Beethoven to perform music that he could *feel* but not *hear*?

I want to use this scene not to demonstrate Beethoven's exceptionalism, but to explore cognitive processes that are common among hearing instrumentalists. The scene, on a certain level, suggests a kind of phenomenological reduction. In music scholarship, this Husserlian technique has been prominently associated with "reduced listening," a mode of purely aural perception in which sounds are freed

1. K. M. Knittel (1998) traces this view to Richard Wagner's 1870 Beethoven essay. For further discussion of Wagner's influence here, see Goehr (1998, 123) and Kane (2014, 114–16), and for a general discussion of Beethoven and disability, see Straus (2011).

Figure 1.1 Ludwig van Beethoven, Piano Sonata no. 8 in C minor, "Pathétique," op. 13, mvt. i, end of m. 10.



from their worldly sources.[2] By contrast, Beethoven's experience highlights everything that reduced listening excludes—kinesthetic, tactile, visual, and technological aspects of performance. Asking about Beethoven, then, is a way of asking a broader question: How do bodies and instruments condition musical experience?

Listening with the Body

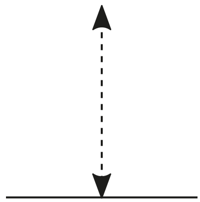
Beethoven might have imagined music while resting in an armchair or strolling through the city. But in Schindler's anecdote, the composer moves his arms, wrists, and fingers, pressing keys, pulling a bow across strings. Insofar as the story connects Beethoven's bodily actions and his inner hearing, it resonates with arguments that present musical experience as essentially embodied.

Consider a brief excerpt from Beethoven's "Pathétique" Sonata, shown in Figure 1.1. The melody hovers, then descends through a chromatic scale, over the dominant harmony that closes the piece's slow introduction. It is a striking move, for several reasons. It falls more than two octaves, a distance that effectively covers the introduction's entire melodic range. At the same time it picks up speed, culminating in a series of one-hundred-twenty-eighth notes that are commonly performed in a free accelerando. This melody, then, gives a sense not only of musical movement, but of musical momentum. It does not simply descend. It plummets.

My description of the passage is obviously metaphorical, and it plays with an opposition of "high" and "low" pitches that pervades Western musical discourse.[3] Yet this spatial mapping, however familiar, is far from universal. For example, Sundanese musicians from West Java describe pitch relationships in terms of size and tension (van Zanten 1986, 85). High notes are "small" or "pulled"; low notes, "large" or "slack."[4] Many music theorists—drawing on work by the cognitive

2. The most influential proponent of this method is the French composer Pierre Schaeffer, to whom I return in Chapter 6.
3. As Lawrence Zbikowski notes, the high/low metaphor is not limited to theoretical language. It also supports "text painting," where composers use musical motion to represent ascent or descent (2002, 63–74).
4. These theoretical metaphors obviously relate to the construction of instruments. On pitch-related metaphors in other musical traditions, see Cox (1999), Zbikowski (2002, 67–68), and Eitan and Timmers (2010).

Figure 1.2 Diagram of the verticality schema (after Zbikowski 2002, 69).



linguist George Lakoff and the philosopher Mark Johnson (1980)—argue that such linguistic metaphors are made possible by underlying conceptual metaphors. For Lakoff and Johnson, metaphoric processes of cross-domain mapping are basic to thought and action. And empirical research indeed shows that the conceptual mapping between pitch height and vertical position can affect perception and motor performance.[5] For example, in stimulus-response compatibility experiments, participants—with or without formal musical training—respond more quickly and accurately when higher pitches are paired with higher visual stimuli (Rusconi et al. 2006; Lidji et al. 2007). Conceptual metaphors are theoretically founded on "image schemas," gestalts abstracted from sensorimotor perception.[6] The orientational metaphor of pitch height would engage a verticality schema (illustrated in Figure 1.2), a pattern that remains invariant throughout countless experiences of up-and-down. For a Western listener, the passage from Beethoven's "Pathétique" might evoke such experiences: running down stairs, riding a roller coaster, dropping a stone, or watching an Olympic diver. For a Javanese listener, it might more readily suggest a process of expanding or loosening. In both cases, the conceptual metaphor for pitch is culturally specific, while also grounded in embodied experience.

Phenomenological terms can help clarify the meaning of "embodied experience" here. Edmund Husserl distinguishes between two German words for "body," *Körper* and *Leib* ([1909] 1973, 42–55). On one level, the human body is a material object. My hand and the piano are both concrete things, both physical bodies (*Körper*). This is, in fact, a precondition for their interaction: without this common substantiality, my fingers and the keys could not touch. Yet at the same time, my own body differs from external objects, because I experience it as a lived body

5. Eitan and Timmers review experimental research on pitch and space (2010, 405–6). Empirical research also suggests connections between the motor system and the perception of rhythm. Bodily movement seems to facilitate different metrical interpretations of an ambiguous rhythmic pattern (Phillips-Silver and Trainor 2005, 2007). And functional magnetic resonance imaging studies show that beat perception engages a network of motor-related areas in the brain, involving the basal ganglia, premotor cortex, and supplementary motor area (Grahn 2009).

6. Image schemas were introduced by Johnson (1987). Rohrer (2005) discusses neurobiological evidence consistent with the theory. Music-theoretical applications of the concept have been explored by Saslaw (1996), Brower (1997–98), Cox (1999), Mead (1999), Zbikowski (2002), Adlington (2003), Johnson and Larson (2003), Straus (2011, 107–12), and Larson (2012).

(*Leib*). It is always present for me, imbued with kinesthetic sensations, and I move it directly. Image schemas are based on this level of lived embodiment.

Husserl also extends the doubling to other people's bodies. I might see your hand as a material object or as a living hand like my own. Later phenomenologists, notably Maurice Merleau-Ponty, develop this theme further, conceiving of intersubjectivity as a kind of intercorporeality. We understand each other—and the world we inhabit together—via shared sensorimotor capacities. This resonates with recent investigations of a "mirror-neuron system," which is involved in both performing and perceiving actions.[7] Along these lines, Arnie Cox has proposed that metaphors of musical verticality (and musical meaning in general) involve "mimetic motor imagery": that is, imitation, either real or imagined, of performers' movements and sonic patterns (1999, 108).[8]

All of this suggests a preliminary interpretation of Beethoven's late improvisations. Building on the cognitive perspective that approaches metaphor as a basic structure of thought grounded in image-schematic structures, the composer's actions can be understood as *kinesthetic analogues* for the sounds in his mind, as embodied representations. If listeners perceive actual sound in terms of imagined movement, Beethoven would instead perceive actual movement in terms of imagined sound. The muscular exertions of his hands, arms, and feet would mirror the music's melodic, temporal, or textural outlines. Moving at the keyboard for Beethoven would be like dancing to a silent soundtrack, like a kind of musical mime that actualizes motor imagery already involved in musical listening.[9]

Though this interpretation accounts for some cultural influences, it does not yet address the role of practiced techniques or musical technologies. It does not yet consider Beethoven as a pianist or violinist. In the earlier-cited experiments, musicians had more complex associations between pitch and space than participants without musical training (Rusconi et al. 2006; Lidji et al. 2007). Besides mapping pitch height to vertical position, they also connected higher pitches with the right and lower ones with the left—as on a piano keyboard.[10] Studying performers, then, may nuance theories of musical embodiment, by highlighting the effects of bodily skill.

Cognitive neuroscience can help reveal musician-specific connections between listening and playing. In one representative study, experimenters played familiar piano melodies for a group of student pianists (Haueisen and Knösche 2001). Though they listened while sitting still, the pianists exhibited significant

7. Rizzolatti and Sinigaglia (2008) examine the mirror-neuron system in general, while Overy and Molnar-Szakacs (2009) discuss its relation to music.
8. Mariusz Kozak argues that an overemphasis on musical mimesis is problematic. If listeners merely imitated performers, then their own bodies would be inessential to musical understanding, and listening would be only "quasi-embodied" (2015, 1.6). As an alternative, Kozak examines ways in which listeners' nonperformative movements organize musical experience, combining Merleau-Ponty's phenomenology with motion-capture analysis.
9. Cox's (2006) discussion of subvocalization also fits suggestively with Beethoven's habit of "growling" instead of singing (Schindler [1860] 1966, 125).
10. This mapping also affects action: for example, experienced pianists have great difficulty playing on a reversed keyboard (Laeng and Park 1999).

activation in the contralateral primary motor cortex (M1), as measured by magnetoencephalography (MEG). In another, amateur and professional violinists tapped left-hand fingerings for Mozart's Violin Concerto in G major, KV. 216 (Lotze et al. 2003). Though this performance was silent, functional magnetic resonance imaging (fMRI) showed activation in the right primary auditory cortex and left auditory association area. (Unsurprisingly, this activation was stronger for professionals.) But when the same violinists imagined playing the piece without also moving their fingers, the auditory-motor coactivation disappeared, leading the authors to conclude that "the motor and auditory systems are coactivated as a consequence of musical training but only if one system (motor or auditory) becomes activated by actual movement execution or live musical auditory stimuli" (1817). These studies showed distinctive patterns of *auditory-motor coactivation* in musicians' brains.[11] Note that this connection is bidirectional: sounding music elicits activity in motor areas, and action elicits activity in auditory areas. This auditory-motor coupling might be figuratively described as a *link between the ear and the hand*.[12]

Such results—and embodied listening more generally—can be explained via Lawrence Barsalou's theory of perceptual symbol systems (1999). As a proponent of "grounded cognition," Barsalou argues that cognition is based on sensory experience, not disembodied computational processing. In his account, perception activates sensorimotor areas in the brain: visual areas capture aspects like shape and color; auditory areas capture aspects like pitch and timbre; others involve proprioceptive states, bodily movement or action, emotion, and so forth. The brain, then, takes in distinct perceptual components, forming sense-specific representations. At the same time, different sensory modalities are coordinated through "convergence zones" that record patterns of coactivation (Damasio 1989). And such patterns may be reactivated through top-down processing to support mental simulations that, Barsalou claims, ground even the most abstract concepts and categories.

This empirical and theoretical work suggests another approach to Beethoven's improvisations. Early in his life as a pianist, Beethoven practiced common scales and melodic gestures, idiomatic textures and chordal patterns. He developed modally specific memories for their physical actions and sounding results, as any competent pianist does. These coordinated sensory representations supported

11. For further evidence of auditory-motor coupling in pianists, see Bangert, Haeusler, and Altenmüller (2001), Drost et al. (2005), Bangert et al. (2006), Lahav, Saltzman, and Schlaug (2007), and Chen, Rae, and Watkins (2011). Margulis et al. (2009) extend such research to violinists and flutists.

12. In general, instrumentalists' brains have a larger than average hand area in the motor cortex (Altenmüller and Gruhn 2002, 72). Yet there are also specific differences, depending on the instrument. Professional violinists, for example, have larger areas for left-hand fingers but not for the left thumb or right-hand digits (Elbert et al., 1995). And players who make music with other body parts—feet, mouth, and so forth—have corresponding differences in auditory-motor integration. For example, Schulz, Ross, and Pantev (2003) found that trumpet players develop strong connections between the auditory cortex and the lip area in the primary somatosensory cortex (but not the corresponding area for the index finger). Neural reorganization, finally, is more pronounced in players who began to study their instrument in childhood.

musical schemas and concepts that he could reactivate and creatively recombine. While improvising, for example, Beethoven could imagine a melody and realize it with his hands. Yet since auditory-motor coactivation goes both ways, moving his hands on the keyboard would activate auditory regions in his brain. This suggests that *Beethoven's actions would also enhance auditory simulations after his hearing loss*.[13] This conclusion is consistent with reports from musicians with significant hearing loss, who describe powerful experiences of auditory imagery during performance (Miller 2011). And it goes some way to explaining a statement by Beethoven himself: "when I am playing and composing, my affliction still hampers me least; it affects me most when I am in company" (quoted in Ealy 1994, 273).

The music Beethoven "heard" at the piano, then, would parallel the "phantasmal voices" sometimes experienced by people who become deaf after learning to speak—people who "hear" simulated speech while lip-reading.[14] Perceptual symbol systems theory would readily accommodate this auditory-*visual* integration. As a general theory of coordination between the brain's sensory systems, the model equally accounts for visual-motor coactivation in expert dancers watching dance and in musicians watching other instrumentalists (Calvo-Merino et al. 2005; Behmer and Jantzen 2011). However, even as this account of multisensory integration extends image-schematic and motor-mimetic perspectives from music theory, it prompts further questions. How are body-sound relations mediated? How is playing an instrument different from singing or dancing?

Instrumental Affordances

Embodied aspects of Beethoven's "inner hearing" challenge a spiritualism that often haunts Romantic visions of the deaf composer. Yet fixating on Beethoven's body can lead to other philosophical problems. First, to promote body over mind would court a materialism that is just as dualistic as the idealism it inverts. Both positions treat one term in the mind/body binary as essential and the other as accidental. Both positions, then, would inhabit the black-and-white world that Jacques Derrida calls "the metaphysics of presence."[15] This kind of metaphysics

13. Barsalou (1999, 586) emphasizes that such simulations must remain partial, and this is philosophically significant. Claiming that simulations can be complete would effectively reduce perception to the thought of perceiving, falling into an idealism that Merleau-Ponty critiques in *The Visible and the Invisible* (1968, 29–43).
14. Oliver Sacks discusses these phantasmal voices in his *Seeing Voices: A Journey into the World of the Deaf* (1989, 5–7).
15. As Derrida explains, this metaphysics involves "the enterprise of returning 'strategically,' ideally, to an origin … held to be simple, intact, normal, pure, standard, self-identical, in order *then* to think in terms of derivation, complication, deterioration, accident, etc. All metaphysicians, from Plato to Rousseau, Descartes to Husserl, have proceeded in this way, conceiving good to be before evil, the positive before the negative, the pure before the impure, the simple before the complex, the essential before the accidental, the imitated before the imitation, etc." (1988, 93). Derridean deconstruction, in part, examines the inherent contradictions of such thinking, extending earlier critiques of metaphysical presence by Heidegger (2010, 21–25).

prioritizes one term in a pair (such as presence/absence, mind/body, nature/culture, or masculine/feminine).[16] The privileged term is thought to stand on its own, even though it is actually defined in relation to its partner, its supplement, its conceptual shadow. Second, the mind/body distinction cannot easily be dissolved. Arguments for radical integration risk reducing the body to the mind or vice versa. It seems more productive, then, to maintain the tension between mind and body, to accept that they intertwine without fully converging.

It can also be helpful to decenter the mind/body complex by situating it in an environment. In other words, cognition is not only embodied, but also ecological. The verticality schema, for example, is not simply a consequence of human anatomy. Rather, up and down are defined by gravity, by the earth under my feet and the sky over my head. For Merleau-Ponty, this means that a theory of the body must already be a theory of the body's integration with a world. I find myself always in the world, and each worldly perception is "synonymous" with some bodily perception (2012, 212).

Here phenomenology anticipates ecological psychology. Founded by James J. Gibson, ecological psychology argues for direct coupling between action and perception, between organism and environment.[17] Gibson describes this as a kind of "resonance" or "tuning" (1966, 271). Animals tune in to the world around them, as a radio tunes in to the airwaves, responding to both flux and regularity. This mix of variance and invariance can be illustrated with a visual example. When I walk toward a chair, it becomes larger in my field of vision. But because other aspects of the scene are constant and because the shift in perspective correlates with my movement, I do not think that the chair is growing. Invariants here provide information about the chair and the surrounding environment, while changes provide information about my own motion (Gibson 1979, 73).

Gibson would further claim that I see the chair primarily in terms of its *affordances*—for instance, my ability to sit in or stand on it. I perceive it not as a bundle of properties or qualities, but as a thing I can use (1979, 134). In Heideggerian language, I am oriented toward its "handiness" (*Zuhandenheit*). Affordances involve a specific complementarity of animal and environment. That is, they are possibilities for action *by a particular agent*. The chair affords sitting for me because of my abilities and because of its size and shape relative to my body. It would not afford sitting for a newborn baby or, to take an extreme

16. Such oppositions are often layered over each other. For example, Cusick argues that mind/body and masculine/feminine together color the music-specific opposition composer/performer. "The composer is masculine *not because so many individuals who live in the category are biologically male*," she writes, "but because the composer has come to be understood to be *mind*" (1994, 16, emphasis in original). Later in the essay, Cusick wonders whether the instrument/voice binary would be gendered in the same way, with singing as a feminized, bodily counterpart to instrumental performance (21). While this is plausible, the situation here is complex. Eighteenth-century Cartesian dualism, in fact, favored the opposite mapping: voice was thought to imbue music with rational expression, whereas instrumental music was merely a mechanical affair, a "body without a soul" (Chua 1999, 82–91).

17. I find ecological psychology to be a useful theoretical resource, whether or not one subscribes to Gibson's radical anti-representationalism.

example, for a humpback whale. Affordances and abilities, then, are essentially codefined (127).

While many ecological psychologists focus on invariant structures based in natural law (like the changes in vision just described), affordances may also be based in cultural regularities. For Gibson, the environment is both natural and cultural, so these aspects of affordances should not be opposed (1979, 130; 1982, 412).[18] Indeed, they are combined in musical instruments. A guitar's pitches, for example, become higher when the vibrating portion of the string is shortened, and each string affords harmonics at the octave, at the twelfth, and so on: these are physical invariants based in the acoustic properties of oscillating strings. Fret placement and tuning involve cultural invariants, the products of musical tradition. The fretboard is designed for hands, resonating with human physiology, but it also demands learned cultural techniques.

To capture some instrumental affordances in action, I return to the introduction from Beethoven's "Pathétique" (shown in Figure 1.3). The piece opens in a low register and slowly climbs, with voice exchanges expanding minor and then diminished-seventh chords. The opening dotted motif is recast in m. 5 as a lyrical melody, which continues to rise—before the aforementioned descent in m. 10.

Again, consider this massive chromatic descent. If the scale seems unremarkable, note that many instruments—even Western ones like harmonicas and valveless horns—do not afford this pitch collection or range. By using the smallest intervals available on the instrument, Beethoven enhances a sense of continuity in the sonic descent—and also makes audible one of the piano's defining invariants, its linear arrangement of twelve pitch classes within the span of each octave. The player's movement, like the sound, is conditioned by the instrument's affordances. When I play this measure, my right hand sweeps across the keys.[19] (Video 1.1 ▶ uses motion-capture imagery to trace this movement.) If I played the same notes on the clarinet, though, my hands would remain in place while my fingers and mouth did most of the work. And if I played them on a guitar or violin, I could think of two kinds of falling gestures: one that moves down *along* the fret- or fingerboard and one that moves down *across* the strings.

From this perspective, thematic elements in the sonata's introduction explore diverse pianistic affordances. Before the plummeting close, the quiet singing theme in octaves requires arm movement with a more or less fixed right-hand shape, while the left hand provides steady pulsing chords (mm. 5–8).[20] The melodic doubling exploits acoustic relationships between octave-related frequencies, but also

18. Along these lines, Eric Clarke extends the concept of affordance to music: "music affords dancing, worship, co-ordinated working, persuasion, emotional catharsis, marching, foot-tapping, and a myriad of other activities" (2005, 38).

19. This sweeping action returns in the descent that crashes into the recapitulation (mm. 186–93). Unlike the introduction's closing, this is not fully chromatic. But at the level of the hand, the movement from right to left, even larger than before, feels very much like an intensification of m. 9. The feeling, I think, is enhanced because both drops are followed by the same music, the allegro theme with thrumming left-hand octaves and rising right-hand dyads.

20. Beethoven sometimes specifies that parallel octaves be played in this manner, when they might be split between the hands. This creates a particular keyboardistic effect, discussed by Taub (2002, 27–28).

Figure 1.3 Ludwig van Beethoven, Piano Sonata no. 8 in C minor, "Pathétique," op. 13, mvt. i, mm. 1–10. Fingerings from an edition by Heinrich Schenker.

a keyboard that loosely coordinates this pitch distance with the average span of an adult hand. In Figure 1.3, the fingering for the octaves given by editor Heinrich Schenker alternates between thumb-pinky and thumb–ring finger pairings. This performance strategy is facilitated by differences in finger length—which make the distance from the tip of the thumb to the tip of the ring finger longer than the corresponding distance between thumb and pinky (Baber 2003, 71–72).

The sonata's opening involves two-handed chords with little lateral movement (mm. 1–4). The player's hands are rhythmically coordinated but move in contrary motion. This facilitates voice exchanges but also gives the player's actions a mirrored quality, reflecting the symmetry of the pianist's body.[21] Again, this reflects the instrument's affordances, the complementarity of piano and pianist. It is possible because pianists' hands develop more or less the same technique (as compared with the specialization of violinists' hands), because each finger can activate a note, and because both hands are free to roam around the instrument (as compared with saxophonists' hands). When Beethoven repeats this opening motif—before the development (mm. 132–35) and before the coda (mm. 294–97)—both sounding and kinesthetic patterns recur. This obviously reflects an invariant correlation between a pianist's action and the resulting sound. But more importantly, both sound and action are facilitated and constrained by the instrument's affordances.

Just as gravity grounds the verticality schema, *instruments provide the invariance that enables players' body-sound coordination*. Although instruments are not needed for gestural analogues to music, their consistent mediation is essential to instrumentalists' auditory-motor correspondences—that is, to specific mappings between actions and musical materials.

It is worth noting that perceptual symbol systems theory includes such external grounding: sensory representations map the world and may also be reactivated by affordances in it (Barsalou 1999, 587–88). Barsalou argues that situated simulations—like Beethoven's improvised auditory imagery—are organized around "the action-environment interface" (2003, 551–52). And this ecological emphasis distinguishes "grounded cognition" from "embodied cognition." The former assumes multiple forms of grounding, which might include bodily states but also aspects of the environment, situated action, cognitive simulations, and so forth (Barsalou 2008, 619).

A neuroimaging study by Marc Bangert and Eckart Altenmüller (2003) aligns suggestively with this theoretical account of instrumental affordances and embodied knowledge. The experimenters gave non-musicians a series of ten lessons during which they learned to play simple five-finger melodies on a keyboard (see Figure 1.4). The participants' brain activity was measured by electroencephalography (EEG) at the beginning, middle, and end of this five-week process. During the EEG recording, they listened to melodies like the ones they had played (but without actually playing), and they played the keyboard (but without hearing the output). In other words, their training always combined auditory and motor activity, but the testing kept them

21. Mirroring at the keyboard has been explored in various pieces, including Johannes Brahms's Intermezzi in E minor, op. 116, no. 5, and B♭ minor, op. 117, no. 2 (analyzed by Rings 2012, 41–43), and Béla Bartók's "Fourths" and "Reflection" (nos. 131 and 141 from *Mikrokosmos*).

Figure 1.4 Five-finger melody used by Bangert and Altenmüller (2003, fig. 8), representing the highest level of difficulty in the study. Pianists use numbers to label fingers, counting up from the thumb (1) to the pinky (5).

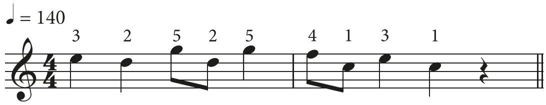
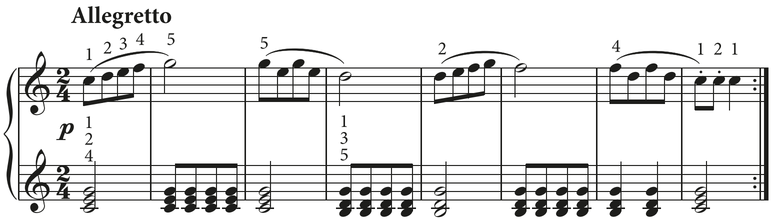


Figure 1.5 Carl Czerny, "The Five Fingers," op. 777, no. 1, mm. 1–8.



separate. There was one difference between the groups: one played on a regular keyboard; the other played on a keyboard where the mapping between pitch and key changed randomly after every piece. For the first group, then, the instrument's affordances were invariant; for the second, its affordances constantly changed. Bangert and Altenmüller found that the group with regular affordances developed a strong pattern of auditory-motor coactivation—the same kind of pattern seen in expert pianists. And these connections started to emerge after only twenty minutes of practice. The other group, despite weeks of practice, lacked this coactivation.[22] With a highly variable instrument, the usual links between hand and ear did not appear.

Though Bangert and Altenmüller use five-finger melodies as experimental stimuli, such tunes have been common in piano pedagogy since the early 1800s. Carl Czerny—a pianist-composer who studied with Beethoven—was a leading proponent of the method, and he exhorted fledgling pianists to practice five-finger melodies "daily, with untiring diligence and the greatest attention" (1851, 13). As is typical, Czerny's "twenty-four exercises on the five notes," entitled "The Five Fingers," start with the right-hand thumb on the tonic of C major (see Figure 1.5). Further exercises in the set transpose this basic position to other keys. Moving the hand during play, however, is deferred to a later stage, where it can be understood as a shift between familiar positions. This pedagogical approach, then, aims to establish a "home position," in which associations between finger and scale degree are fixed.[23]

22. Further experiments with this general design might tease out the effects of varied repertoire. With disjunct, dissonant melodies, it might take significantly longer to form a common representation of ear and hand. I would expect simple diatonic chord progressions, however, to give results closer to the five-finger melodies from the original study.

23. The first pieces in the Suzuki violin repertoire reflect a similar strategy, albeit adapted to the affordances of the violin: they are all in A major, using only the top two strings. The two semitones of

Such exercises do not simply strengthen the hands. They discipline students in a broader sense, through a process that Michel Foucault calls the "instrumental coding of the body" (1995, 153). As an example, Foucault cites instructions for handling a rifle, found in an eighteenth-century military treatise. Whether lifting, carrying, or lowering his weapon, a soldier must follow a series of precise steps. At each step, the instructions specify the position of hands, elbows, knees, fingers, and so on, as well as their contact with parts of the gun. Soldier and rifle are integrated like cogs in a machine, forming a body-tool complex that may, in turn, be incorporated into a larger military apparatus (164). Training in posture and movement helps turn recruits into soldiers. It empowers bodies in new ways, while also subjecting them to strict control.

In a similar way, Czerny's teaching restricts and reshapes the piano student's bodily comportment.[24] He explains how to sit at the piano and how to strike the keys through a set of detailed rules (Czerny 1851, 3–6), which recall the military's pursuit of correct posture and efficient movement. And his five-finger exercises coordinate parts of the body and parts of the instrument, combining and recombining basic action components. Limiting students' engagement with the keyboard, of course, limits musical possibilities. But these restrictions also guarantee a high level of invariance, a predictability that should help sensitize them to the instrument's tonal and physical affordances—or at least a basic subset thereof. Even if these exercises foster somewhat rigid correspondences, they may still effectively introduce beginners to instrumental links between action and sound.

Earlier I argued that Beethoven's piano playing would stimulate his inner hearing, but by now it is clear that this auditory-motor coupling depends on instruments. Beethoven's instruments provided invariant correlations that engendered patterns of neural coactivation. His instruments, then, did not just ground the sound of his improvisations or his physical technique. By systematically connecting the two, instruments made his embodied experience of phantasmal tones possible. Focusing on ecology thus leads to technology: the instrumentalist's musical capabilities emerge through interactions of body and world, technique and tool.

Habit, Concealing and Revealing

On this account, Beethoven's improvisations are thoroughly habitual. They rely on overlearned connections, developed through years of practice. Habitual playing,

A major are, in consequence, always located between the middle finger and ring finger, with the same fingering on each string. Other strings and then finger positions are gradually introduced throughout the method's first book.

24. This discipline, of course, is not unique to Czerny. Elisabeth Le Guin considers its role in instrumental method books and dance pedagogy from the eighteenth and early nineteenth centuries (2006, 148–53), while Ruth Solie (2004) shows how pianistic discipline contributed to the gendered experience of middle-class Victorian girls. Leslie Blasius (1996) relates this pedagogy, with its decomposition and reconstruction of action, to earlier epistemologies of sensation.

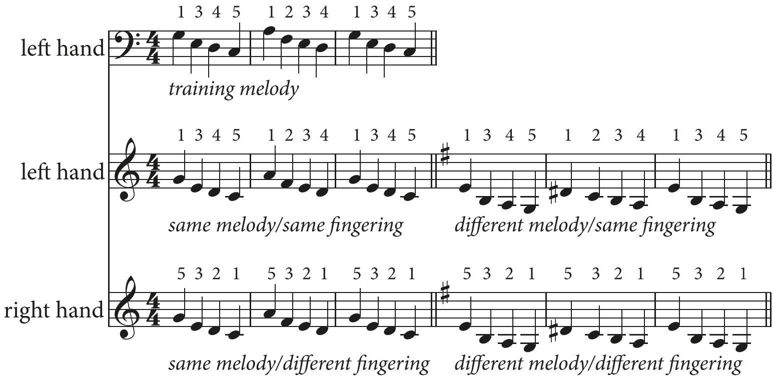
Figure 1.6 Basic keyboard chromatic-scale fingering. The pattern uses the thumb (1) on white notes and the middle finger (3) on black notes, adding in the index finger (2) when there are two white notes in a row.

of course, is often derided as mechanical, unthinking. But is this not another variation on the metaphysics of presence? A version that imagines self-directed subjectivity as the true origin of creative expression? This fantasy of pure self-awareness and self-control mixes easily with other dualisms—for example, setting the creative mind against the automatized body. Yet habit may be both motoric and mental. To be sure, because I am not fully aware of my habitual actions, they may at times work against my conscious intentions (as when I drive home "on auto-pilot," even though I had planned to go to the grocery store). Nonetheless, habit also enables human performance.

What do my fingers do when I play that descent from the "Pathétique"? They enact a series of interrelated moves, a chromatic-scale pattern. The most popular approach—known as the "French fingering"—alternates between the thumb and middle finger, interpolating the index finger whenever there are two white keys in a row (see Figure 1.6). Schenker's fingering in Figure 1.3 follows the same logic but exchanges the roles of the index and middle fingers.[25] In both versions, the thumb is kept on white notes, reflecting a general preference rule of keyboard fingerings: do not make this shorter digit reach for the black keys. (This principle is clearly set forth, for example, in Carl Philipp Emanuel Bach's *Essay on the True Art of Playing Keyboard Instruments* [(1753/1762) 1949].) If asked, most expert pianists could explain the rationale for this fingering. But they would rarely attend to this while playing the sonata. In performance, the fingering feels automatic. After all, how could they perform the piece fluently if they needed to consciously initiate every finger movement?

25. It locks into this pattern at the sixty-fourth-note septuplets. This fingering is associated with the Polish-Viennese pedagogue Theodor Leschetizky, a friend of Brahms (Verbalis 2012, app. 4).

Figure 1.7 Training melody and transfer melodies from Palmer and Meyer (2000, 64).



The action must become habitual, so playing the scale feels like a single flowing gesture.[26]

Such habitual actions are, again, both embodied and ecological. They integrate hand and tool, body and world. Strictly speaking, Figure 1.6 does not present a sequence of finger actions: it presents a sequence of *finger-key relationships*. Though pianists practice this fingering enough that it comes to feel relatively invariant, the chromatic scale's pattern of keys is actually more stable. Changing the fingering does not necessarily change the sound; changing the keys does.

An experiment by Caroline Palmer and Rosalee Meyer (2000) reflects this difference between bodily and instrumental elements. They presented experienced and novice pianists with a transfer-of-learning task. After practicing a particular sequence, they would play another one as quickly as possible. The new examples might share elements of the training melody: some had the same sequence of pitch classes but with different fingering; others preserved fingering patterns but had different pitch classes (see Figure 1.7). With novice children pianists, learning transfer involved both physical actions and pitch relationships. With skilled adult pianists, however, transfer occurred for pitch relationships, not motor relationships. Palmer and Meyer's results point to an important difference between experts with established performance habits, who may focus more on sound, and less experienced players, who must focus more on hand movements.

Yet the way these authors frame their results is, in some ways, at odds with my perspective, and examining these differences can help clarify the ecological importance of tools for perception. Palmer and Meyer write that "compared with novice performers, skilled performers demonstrate more dissociation between abstract sequence dimensions and movements, and a lower weighting of the movement dimension" (2000, 67). In my view, this formulation is slightly misleading. Palmer

26. Habitual actions generally involve less activation in the brain and greater reliance on subcortical regions than do novel actions. For a review of the neural underpinnings of habit, see Yin and Knowlton (2006).

and Meyer's description of pitch-class sequences as "abstract" or "conceptual" is, for example, somewhat problematic. The sound itself is immaterial, to be sure, but it is also perceptually immediate. Furthermore, the repeated pitch classes have a visible, tangible correlate in the pattern of keys on the instrument. The excerpts that Palmer and Meyer call "conceptually same" are simply transposed by an octave. In other words, this condition might just as accurately be described as "pitch-class same"—or even "keyboard same." This seems "abstract," then, only when the materiality of the instrument is overlooked.

Musical concepts, moreover, are not unique to the score or instrument: they are also present in the pianist's actions. After all, this experiment would not be possible if the musical notation could not represent both the notes and the fingering.[27] To interpret the notation, participants in the experiment needed pianistic finger categories (which differ from those of guitarists or violinists). Such categories are deeply ingrained: for example, pianists have difficulty sight-reading a notated melody that has incongruent fingering indications (Stewart et al. 2004).

Finally, the "dissociation" between pitch and movement might be better understood as a mobile, flexible *association* between action and instrument. While beginners often have one-to-one associations between fingers and keys (supported by the "home-position" pedagogy discussed earlier), skilled pianists can associate the same pitch-key pattern with any number of motoric patterns. Palmer and Meyer's experiment shows that this remapping is effectively effortless for experts, having no effect on their performance. Paradoxically, then, particular motor patterns seem less important for expert pianists—but only because they have developed their instrumental skills to a point where they require minimal attention.[28]

Phenomenologically, this situation is readily described in Martin Heidegger's *Being and Time* ([1927] 2010, 69). For Heidegger, tools are handy (*zuhanden*) because they "withdraw" from my awareness. This lets me focus not on the tools, but on the work. While I am fixing the porch railings with my father-in-law, I do not contemplate the hammer as an object. Instead I use it actively, as means to an end. Of course, this withdrawal is possible only when a tool can be trusted—in Gibsonian terms, when its affordances are invariant—and when its use is habitual.[29] In this sense, habit hides the hammer.

But as habit conceals, it also reveals. When the tool changes my abilities, it also changes the way I perceive the world. For example, objects beyond my normal reach appear closer when I plan to reach them with a tool (Witt and Riley 2014, 1356–57). As such, Merleau-Ponty argues that *motor habits are also perceptual habits*. To illustrate, he discusses navigation with a cane. Once the cane

27. For a philosophical discussion of keyboard fingering indications as a supplement to staff notation, see Szendy (2016, 47–68).

28. As Palmer and Meyer note, the expert performers might show greater motor learning if the task were more challenging (2000, 67).

29. If the hammer breaks or is missing, Heidegger adds, it demands conscious attention. Suddenly it is no longer handy but "present-to-hand" (*vorhanden*). When practicing a new piece of music, for example, I stop to work out fingerings only when a passage is especially difficult or unusual. This kind of breakdown will be explored in Chapter 4.

becomes familiar, it withdraws. The person using it feels things *through* the cane's tip. Merleau-Ponty emphasizes that this does not involve explicit reasoning about the pressure of the cane in the hand, the position of the tip, the position of things in the environment, and so forth. Instead, habit "relieves" the navigator of this work. As Merleau-Ponty writes, "The pressures on the hand and the cane are no longer given, the cane is no longer an object that the blind man would perceive, it has become an instrument *with* which he perceives" (2012, 154).[30]

My eyeglasses withdraw from my awareness in a similar way. I usually look *through* them rather than perceive them directly. Why is this, given that the glasses significantly modify my vision? According to the philosopher Don Ihde, they can withdraw because they are *transparent*. Though they modify perception, they isomorphically reflect invariants in the world. In this sense, the stick is "transparent" too. Yet the transformation of perceptual experience by the glasses or the stick is not neutral: "*for every revealing transformation there is a simultaneously concealing transformation of the world, which is given through a technological mediation*" (Ihde 1990, 49, emphasis in original). Ihde's studies of technoscience suggest that scientific instruments often create knowledge by modifying vision, making the invisible visible. With a telescope, I can see objects that are extremely distant; with a microscope, objects that are extremely small. Learning to focus a telescope or microscope again combines action and perception. As scientists learn to adjust these instruments, they also learn how to see through them. Ultrasound technicians, for example, view the images they produce in a different way than expectant parents, because they have acquired particular perceptual habits. As Hubert Dreyfus puts it, "What one has learned appears in the way the world shows up" (2002, 373).

Cultural or symbolic invariance can also facilitate a kind of transparency (Ihde 1990, 82). As you read this book, do you consciously identify each individual letter? Hopefully not. Instead, thanks to habits of literacy, familiar shapes on the page withdraw, revealing a world of discourse. (Of course, these same habits can easily conceal typographic errors!) Musical notation works in a similar manner. For literate musicians, the lines, clefs, note-heads, beams, flags, and dots on the page may coalesce into melodies and chords. In such moments, a score is less an object of perception than a medium for perception. And something similar can happen with musical instruments. As Merleau-Ponty writes, "Musical notation would not be a language and the organ would not be an instrument if the manner in which one writes and in which one plays a note did not comprise a systematic principle and did not as a consequence include the manner in which one writes and in which one plays the other notes" (1963, 121). The section on habit in his *Phenomenology of Perception* culminates in a discussion of the organ. It is a key passage, worth quoting at length:

30. The results of an experiment by Serino and colleagues (2007) are consistent with Merleau-Ponty's claims. Learning to navigate with a stick expanded participants' sense of personal space, and this effect was well established with blind participants who regularly used a cane in this manner. (I will return to this study in Chapter 2.) Incidentally, navigating with a stick is a classic philosopher's example, appearing as early as Descartes's *Optics* ([1637] 2001, 67–68).

> An experienced organist is capable of playing an unfamiliar organ, whose keyboards are more or less numerous, whose stops are differently arranged than those on his customary instrument. He needs but an hour of practice to be ready to perform his program…. He sits on the bench, engages the pedals, and pulls out the stops, he sizes up the instrument with his body, he incorporates its directions and dimensions, and he settles into the organ as one settles into a house. He does not learn positions in objective space for each stop and each pedal, nor does he entrust such positions to "memory." During the rehearsal—just as during the performance—the stops, the pedals, and the keyboards are only presented to him as powers of such and such an emotional or musical value, and their position as those places through which this value appears in the world. Between the musical essence of the piece such as it is indicated in the score and the music that actually resonates around the organ, such a direct relationship is established that the body of the organist and the instrument are nothing other than the place of passage of this relation. (2012, 146–47, translation altered)

During this brief rehearsal, the organist does not measure the distance between stops in centimeters or contemplate it in a disinterested manner. It is in this sense that the space of the organ is not an "objective space" but a lived space, an expressive space, a space in which the skilled body feels at home. Because of the organist's habits, the keys and stops show up as musical possibilities and, in a successful performance, the body and instrument seem to withdraw into the music. "From then on," Merleau-Ponty concludes, "the music exists for itself, and everything else exists through it" (2012, 147).

Likewise, for the expert pianists in Palmer and Meyer's study, the keyboard is less an object of perception than a medium for perception. They access melodies *in* or *through* the instrument. Beginning pianists gaze at their hands on the keys, working hard to find the right notes in this field of black and white. But for expert pianists, familiar patterns stand out at a glance. This allowed Beethoven to continue giving lessons, even after he had trouble hearing conversation. According to Carl Friedrich Hirsch, who studied with Beethoven from 1816 to 1817, the composer would catch students' mistakes by closely watching their hands on the keys (Thayer 1967, 664).[31] Like the Heideggerian handyman, Beethoven focused not on the piano, but on the music.

Later chapters will revise this initial account of habit, particularly Chapter 4. For now, I will note that withdrawal is never complete, and this is partly because habit is never complete. I am using two senses of the word "complete" here, meaning both "full" and "finalized." First, habits have limits. They apply only within a

31. Stories of Beethoven's teaching resonate with an fMRI study by Hasegawa et al. (2004). In it, pianists watched silent videos of hands pressing piano keys. Expert pianists were able to identify familiar pieces by sight. While watching the videos, they displayed increased activation in the left planum temporale, a part of the brain that is involved in lip-reading, which integrates auditory and visual information. In a similar study by Giacomo Novembre and Peter Keller (2011), pianists watched silent videos of a hand playing chord sequences and copied the sequences on a muted keyboard. They were slower to imitate chords that were harmonically unexpected. But even slower were responses to harmonically expected chords that were fingered in an unusual way. On visual expertise in guitarists, see Crump, Logan, and Kimbrough (2012).

certain genre of action. For example, chord shapes that are second nature to a jazz pianist may be foreign to a classical pianist. Second, habits, unlike innate reflexes, are acquired and more or less flexible. A habit can stagnate, of course. But since it has been learned in the first place, it can also be unlearned, relearned. Habit, in other words, is not fixed but dynamic, just like the patterns of brain activation discussed by Barsalou.

Note also that these examples of habit involve things—hammers, canes, eyeglasses, microscopes, books, organs, pianos. These objects are not neutral. They afford particular kinds of motor and perceptual habits; they reveal certain possibilities, while concealing others. Like the body, then, each of these things can be understood as a medium for having a world.

Prosthesis and Poiesis

If the keyboard enhanced Beethoven's auditory imagination, the piano might be described as a kind of hearing aid. Indeed, just as Beethoven used ear trumpets to help him in conversation, he sought modified instruments that might prolong his aural access to music. In 1817, for example, he wrote to Andreas Streicher, "Be so kind as to adjust one of your pianos for me to suit my impaired hearing. It should be as loud as possible." Years later, Conrad Graf, the pianoforte-maker for the imperial court, would build Beethoven an amplifying "resonance plate" that attached to his grand piano (Ealy 1994, 271). In this view, the piano, like eyeglasses or a blind person's cane, would be a prosthesis.

And yet there is a key difference between the piano and the ear trumpet. The ear trumpet transforms sounds in the world, amplifying them for a listener. But the piano is used to *make* sounds that do not already exist. A musical instrument, in other words, is poietic. "Poietic"—like *poiēsis*, the Greek noun from which it is derived—refers to the domain of production, to all kinds of making.

For many musicologists, these terms will recall the musical semiotics of Jean-Jacques Nattiez (1990), whose "poietic level" examines the perspectives of music-makers—principally composers and performers. But my use of the word draws on Heidegger's "Die Frage nach der Technik."[32] In this essay, the philosopher famously claims that the essence of technology is nothing technological. That is, technology is not just about modern machines or industrialization. Seeking an older concept of technology, Heidegger turns to another Greek term: *technē*. "*Technē*," he explains, "is the name not only for the activities and skills of the craftsman, but also for the arts of the mind and the fine arts. *Technē* belongs to bringing-forth, to *poiēsis*; it is something poietic" (1977, 12–13). At its core, technology is about making, about revealing a world.

Technē, though, does not refer to the *act* of making (Heidegger 2008, 184). Instead, *technē* is a mode of knowledge. Throughout antiquity, the term is

32. Heidegger's title is typically translated as "The Question Concerning Technology," though Samuel Weber (1989, 980–82) argues that a more accurate version would be "Questing after Technics."

persistently linked to music, even specifically with musical instruments. In dialogues by Plato and Xenophon, Socrates repeatedly says that *technē* is needed to play the flute and the lyre. A later Platonic work *The Sophist* similarly mentions a musician's *technē*, the art or craft of combining notes (Parry 2007). This active knowledge empowers a player to exploit an instrument's affordances, to bring forth a world of sonic relationships, to *make* music.[33]

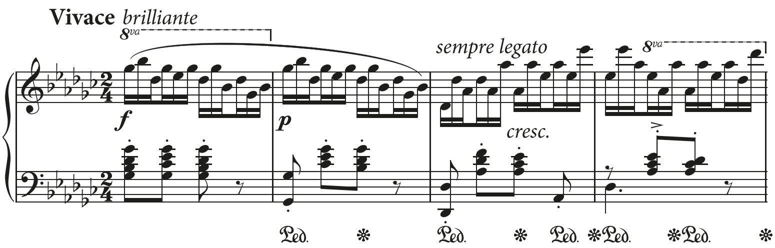
At the etymological and conceptual root of "techno-logy," then, is poietic know-how, a way of understanding based in making. From this perspective, technique and technology complement each other. The instrument, together with my action, reveals a world. That phrasing—with the artifact first, as the subject of the verb—might evoke questions about technical agency, which I will defer until Chapter 3. At present, I want to suggest that poietic know-how may belong not only to the tool user, but also to the tool itself.

This suggestion invokes research on distributed cognition, such as Edwin Hutchins's *Cognition in the Wild* (1995). The book presents an ethnographic case study of a vessel in the US Navy, an amphibious helicopter transport that he calls the *Palau*. Besides analyzing the ship's social organization, Hutchins examines many of the *Palau*'s navigational instruments. He concludes that these tools do not simply amplify the cognitive capacities of their users. Instead, they typically, and sometimes radically, change the task at hand. For example, sailors must often calculate interrelated quantities of distance, rate, and time (147–55). A pencil and paper may be used to record the numbers, holding them in a kind of external memory while the navigator focuses on algebraic and arithmetic operations. Alternatively, the calculations can be done with a three-scale nomogram, a kind of nautical slide rule. Since the appropriate mathematical relations are encoded in the slide rule, the navigator's task then involves lining up indices with numbers on scales. Computational constraints are built into the physical structure of the tool (96). It embodies cultural knowledge and strategies, and precludes certain kinds of mistakes. In this sense, instruments may know things for their users.

The piano, for example, "knows" a certain pitch-class collection: the notes of the equal-tempered chromatic scale. But it does not present twelve undifferentiated steps. Instead, it materially highlights particular tonal structures endemic to Western music. Its physical opposition of a diatonic white-note scale with intervening black-note semitones corresponds to the notational culture of natural and chromatically inflected pitches, and the resulting pattern of twos and threes functions as a visual and tactile reference point for the player. This means, of course, that white-note modes like C major are easy to play. But the keyboard's topology highlights other patterns too. No less than Frédéric Chopin suggested that B major fits the hand better than C, because it matches black keys—*les touches hautes* (literally, "the high keys")—with long fingers (1993, 66). In certain

33. Turning briefly to a philosophical technicality, this does not involve fixed, unchanging presence, but a presence with temporality, presence that is revealed and concealed. In an essay on Rilke, Heidegger describes this kind of presence using a musical metaphor: "our being is song, and indeed a song whose singing does not resound just anywhere but is truly a singing, a song whose sound does not cling to something that is eventually attained, but which has already shattered itself even in the sounding" (2008, 184).

Figure 1.8 Frédéric Chopin, Étude in G♭ major, "Black Keys," op. 10, no. 5, mm. 1–4.



respects, the black-note pentatonic collection might be even easier to play. The concert pianist Lang Lang demonstrates this in a parody of Chopin's Étude in G♭, op. 10, no. 5. Like all of Chopin's études, this piece is a virtuoso tour de force. Its melody flutters up and down the keyboard, always on the black keys that give the composition its nickname (see Figure 1.8). Lang Lang brings out this "black-keyness" when he plays the piece backstage—with an orange![34] As he realizes the accompaniment figure with his left hand, he holds the fruit in his right and, following the melodic contour, drags it over the raised black keys. The result is not, of course, a precise rendering of Chopin's original—but it is remarkably close, instantly recognizable to listeners who are familiar with the piece. The trick is possible because the étude exploits some of the keyboard's distinctive tonal and physical affordances. It works because the piano "knows" the pentatonic scale and because it takes care of tuning.

Piano tuning, in fact, is an excellent example of distributed cognition. As Chopin himself observed, intonation is "the tuner's task," and consequently "the piano is free of one of the greatest difficulties encountered in the study of an instrument" (quoted in Eigeldinger 1986, 23). Pianists rely on specialist technicians to put their instruments in order. From there, tuning is a fact of the instrument. The player cannot change it in performance. With a poorly maintained piano, this can be a problem. Otherwise, it is quite useful. This is why Beethoven's late improvisations on violin or viola were "the most painful," while his piano playing might still be praised. For example, Clara Schumann's father, Friedrich Wieck, heard Beethoven improvise at the keyboard in 1826. "He played in a flowing, genial manner," Wieck reported, "… weaving in the clearest and most charming melodies" (quoted in Ealy 1994, 272). As Hutchins observed, the instrument fundamentally changes the task at hand. When I play a conventionally tuned piano, I might hit the wrong note—but I cannot produce a note between the steps of the chromatic scale, a note without a name. Even when played with an orange, the keyboard, as a space for action, brings forth a pitch world that is culturally and historically specific.

Given these ideas about poiesis and distributed cognition, it seems best to be careful about treating instruments as prostheses, as devices that extend the body's

34. This video can be accessed at http://youtu.be/oiziGLe1jBw.

"natural" sound-producing capacities.[35] Commonsense examples of prostheses, such as artificial limbs, may imply that prostheses replace some function that has been damaged. Marshall McLuhan takes this negative thinking to an extreme when he claims that extension involves a kind of "self-amputation" (1994, 45). I prefer a broader concept of prostheticity. According to the philosopher Bernard Stiegler, "A 'prosthesis' does not supplement something, does not replace what would have been there before it and would have been lost: it is added" (1998, 152). This definition goes back to an older, Greek sense of the word, which combines *thesis*—that is, putting or placing—with the prefix *pros*-, meaning in front of, in addition to, or close to. A pros-thesis is something placed in front. It is "what is outside" (193).

For Stiegler, the prosthesis can be outside in two ways. First, it is set in front of me *spatially*. The piano is an external thing, fairly solid and stable. Unlike my vocal cords, it is always located at a certain distance from my body. Second, the prosthesis might be set in advance of me *temporally*. The piano in my front room was built in the 1930s, which means that it is older than my parents. Yet even a new piano engages this temporal dimension, since the piano as an instrument preexists me. Here Stiegler's understanding of prosthesis is tied up in a phenomenological understanding of historicality. "Prostheticity," he writes, "is the being-already-there of the world, and also, consequently, the being-already-there of the past" (235). This draws on Heidegger's concept of "thrownness" (*Geworfenheit*), an essential part of human existence (2010, 127–28). I cannot choose when or where I am born. Instead I find myself "thrown" into a world, a history, and a culture that is already there, over which I have had no control. One of Stiegler's main tasks in *Technics and Time* is to show how technical objects contribute to this already-there, forming a kind of durable, external memory that makes human culture possible. The piano, as part of the already-there, offers a certain access to a past through which I have not lived. It makes it possible for me to play the "Pathétique," remaking music from long before my birth, long after Beethoven's death.

When Beethoven improvised, then, he was bringing forth a world made possible by instruments. That is not to deny the composer's agency or his musical innovations but to note how instrumentality is inevitably historical. To borrow an image from Theodor Adorno, the improviser is like a child at the piano, who feels around for a chord that has never been touched, never been heard. "This chord, however, was always already there," Adorno writes, "the possible combinations are limited, and actually everything is already stuck inside the keyboard" (2002, 32, translation modified). The interaction of body and instrument—with all its cognitive consequences—is an interaction of individual and culture, present and past. Instruments ground modes of music cognition that are embodied, technically conditioned, and historically situated.

35. Taking instruments as prostheses is common in writings on musical evolution—see, e.g., Cross (2007). (I discuss this trend more extensively in De Souza 2014.)

Conclusions

"The music which he thus produced was frightful, though in his mind it was pure and harmonious." In a sense, Schindler was right. When the deaf composer improvised, there was a gap between the sounds he made and the sounds he "heard." But to explain this situation, I have argued that Beethoven's mind was integrated with his hands, his tools, and a broader musical world. This means that Beethoven's imagination, which might have been understood as an instance of purest interiority, instead shows how interiority and exteriority are irreducibly entangled.

Interiority and exteriority, mind and body, self-control and habit… As the chapter wraps up, consider one more dichotomy: cognition and perception. For proponents of grounded cognition, there can be no clean break between the two (e.g., Goldstone and Barsalou 1998). On the one hand, higher-level cognition engages the brain's sensorimotor systems, and it is affected by bodily activity.[36] On the other, when an animal perceives a predator—even when a bacterium prefers one form of sugar to another—its behavior is already imbued with a kind of sense-making that, for some thinkers, represents a minimal form of cognition.[37] This is not to ignore useful distinctions between cognition and perception but to emphasize, once again, how they are entwined. It suggests that the essence of cognition is nothing "cognitive," meaning that thinking is just not about calculation or symbolic logic but is, more generally, about making sense of the world. Moreover, this implies that it is possible to think with one's body. In Heidegger's words, "All the work of the hand is rooted in thinking" (1968, 16).

Beethoven at the keyboard, then, would be thinking with his hands and thinking with his instrument. Instrumental practice would offer not only a way of making music, but also ways of perceiving, imagining, inventing, and reflecting on it. Of course, this argument is not specifically about Beethoven. His example evinces body-instrument interactions and cognitive processes that are widespread—forms of grounding that constitute instrumentalists as such. Still, some implications of this argument are more or less specific to expert instrumentalists. For amateur players, action-sound integration may develop to a lesser degree, and singers, dancers, and listeners who do not play musical instruments would exhibit different patterns of multisensory coactivation.[38] Yet this framework also predicts differences among skilled instrumentalists. Insofar as a keyboard differs from a fretboard, a pianist's habits will differ from a guitarist's habits. This should affect performative action, sound, and experience. To address these distinctions, though, the investigation must go beyond general principles to analyze the affordances of particular instruments.

36. Psychological studies of gesture offer evidence for bodily influences on thought (Goldin-Meadow and Beilock 2010). For example, problem-solving strategies change when participants' hand movement is restricted (Alibali et al. 2011).

37. The biologists Humberto Maturana and Francisco Varela advance this view in *Autopoiesis and Cognition*. For them, "*living systems are cognitive systems, and living as a process is a process of cognition*" (1980, 13, emphasis in original).

38. For example, extensive vocal practice leads to structural changes in the brain, which differentiate expert singers from instrumentalists (Halwani et al. 2010).

CHAPTER Two

Sounding Actions

According to Leonard Meyer, listening to music is like riding a bike (1973, 15–16). An experienced listener may safely ignore music theory and history, just as a cyclist may ignore the bicycle's engineering or physics. Riding a bicycle, of course, is a standard example of *know-how*.[1] That is to say, knowing how the bike works is not the same as knowing how to work it, and I cannot acquire this skill merely by reading a book or watching others ride. Instead I learn how to do it by doing it. I become a competent cyclist by pedaling and breaking, balancing or falling, again and again. Meyer's analogy usefully frames musical listening as habit and skill, as procedural rather than declarative knowledge. Yet there is also a significant difference between these activities: cycling is a form of human-machine interaction. And on this level, riding a bicycle seems less like listening than like playing a musical instrument.

A phenomenological description of cycling can help flesh out the comparison, and such a description might begin with the rider's body. On the bicycle my feet alternate, much as they do while I walk. Right and left, up and down, forward and backward. But cycling feet, unlike walking feet, never strike the ground. Instead they stay in contact with the pedals and move with them, while my hands do the same with the handlebars. As the handlebars swivel to the left or right, as I turn them with my hands, the bike tilts; my whole body leans. Steering, like riding in general, thus involves a play of balance and instability. In all of this, my body is integrated with the bicycle. Together we form a system. After all, the bike cannot ride itself without me.

In a sense, I am the bicycle's engine. My legs power the wheels, and when I pedal harder, they go faster. Still, there is a gap between my action and the bicycle's movement. It continues to roll after I have stopped pedaling. The bicycle, then, does not simply absorb my energy; it amplifies it. Of course, this process is mediated by the terrain, which is why cycling can reveal subtle declines and inclines in an otherwise familiar path. While coasting downhill with the wind in my face, riding faster than I can run, I need not pedal—even if I do, the pedals may spin freely. But while I am climbing uphill, those pedals feel stiff, and I become aware of my own heaviness and that of the bicycle. In both cases, I may shift gears, trying to maintain a satisfying resistance in the pedals, a sense of grip. Here I feel the bicycle but also the ground *through* the bicycle. I can feel, for example, when the path

1. This example is famously discussed by the scientist and philosopher Michael Polanyi (1958, 50), who is cited later in Meyer's essay.

changes from asphalt to gravel. Riding a bicycle, in the end, can be understood as a way of being in the world. As it alters my capacity for movement, the bicycle transforms my experience of space, of speed, and of my own body.

Both riding and playing instruments involve a complementarity of technology and technique. Both involve habit and withdrawal. But where the bicycle converts action into momentum, musical instruments convert action into sound. This chapter's first task is to theorize that conversion. How do various instruments transmit a player's actions? How do they transform a player's energy? Which sonic parameters reflect bodily action? Which reflect instrumental affordances? Though it starts by investigating sound production, this line of thinking ultimately reveals how a musical instrument, like a bicycle, can mediate experiences of the body itself.

Sounding Objects

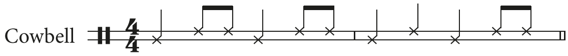
Strike a cowbell with a stick, and it rings. A momentary touch has initiated vibrations that stretch out in time and space. Of course, just as terrain affects the bicycle's momentum, performance environment can modify the bell's sound. For example, its ringing lasts longer in a reverberant concert hall. Nonetheless, the sound emanates from the cowbell itself, from this quivering piece of metal. And its sonic texture reflects that origin.

This relation between sound and source is central to ecological acoustics, a branch of Gibsonian psychology that considers how animals tune in to sonic aspects of their environments. People can *hear* the size of an object dropped into water and the hardness of a mallet hitting a pan; they can *hear* the difference between running upstairs and downstairs, between clapping with cupped or flat hands (Gaver 1988; Freed 1990; Repp 1987). For ecological acoustics, sounds are rich in information about the material forces that create them. Of course, such information does not determine perception. Attending to sources represents only one possible mode of listening, and the source of a given sound may be ambiguous, unfamiliar, or misidentified.[2] Still, this seems more likely with listeners who are distanced from a sound source than with players who can hear, touch, and see their instruments. Here different senses interact without fully converging. Insofar as sound indexes objects, hearing communicates with other sensory modalities. "I hear the hardness and the unevenness of the cobblestones in the sound of a car," writes Merleau-Ponty, "and we are right to speak of a 'soft,' 'dull,' or 'dry' sound" (2012, 239).

Or, with the cowbell, a metallic sound. In other words, the instrument's timbre can reveal aspects of its material. As William Gaver explains, "The damping of

2. Such misidentification may be fostered, though, by instruments that imitate other instruments—for example, the lute clavier (which I discuss in Chapter 5) or synthesizers (see De Souza, forthcoming). Chapter 6 examines modes of listening in greater detail. For a critique of deterministic applications of ecological acoustics (in discourse on electronic music), see Demers (2010, 36–37).

Figure 2.1 A standard cowbell pattern from salsa music (used with a 3:2 clave pattern). The bottom line corresponds to the mouth of the bell, the higher line to the body.



wood tends to be much greater than that of metal, which is why wood 'thunks' and metal 'rings'" (1993, 11).[3] Meanwhile, the bell's frequency reflects its size and shape—aspects of the instrument's configuration. Bigger bells, obviously, are pitched lower. And parts of a single cowbell afford distinct tones: the mouth sounds lower and fuller; the body, higher. This contrast is central to cowbell playing, for example, in salsa music (see Figure 2.1). In all of this, the sound of the instrument is predicated on its physical structure.

Yet ecological acoustics also considers the physical interactions that give rise to sound—in this case, how the cowbell is struck. Gaver specifically distinguishes between the sonic effects of interaction, material, and configuration (see Table 2.1) and describes how interaction principally affects dynamic and temporal features of the sound.[4] Tapped gently, the bell is quiet; whacked, it yelps. The loudness communicates the force of my attack. Note, too, the temporal difference between striking the bell and scraping it. And the timing of the attacks corresponds exactly to the sounding rhythm. From this perspective, sounds express ecological relationships. Recall the example of looking at a chair as I walk toward it (in Chapter 1), where visual invariants give information about the chair and changes give information about my movement. Likewise, in the cowbell pattern in Figure 2.1, sonic invariants reflect the instrument, while changes reveal the player's movement. This doubling—this intertwining of action and effect—underlies instrumentalists' auditory-motor coupling. Like a bicycle wheel, the instrument converts and amplifies an aspect of my action. As I make the bell speak, it makes my energy audible.

So hitting a cowbell may not be as simple as it seems. But how well does this percussive model generalize to other instruments? Consider an instrumental continuum proposed by Arnie Cox, which starts from a similar understanding of sound production.[5] Cox's continuum ranges from instruments with "no mediating device between the hands or mouth," to instruments played via implements (like mallets, bows, or keys), to electronic instruments, to mixers and computers (2011, 16).[6] By this point, musicians no longer provide the

3. Damping reduces the amplitude of oscillations (for example, through resistance, friction, or absorption of energy).
4. The stick's material again affects timbre: obviously, the attack of a wooden drumstick differs from that of a soft-tipped mallet.
5. For Cox, the relation between embodied action and sonic patterns fits into broader ideas about listening and mimetic motor imagery, already mentioned in Chapter 1.
6. Cox's continuum also extends to "music not performed primarily or solely by performers," such as birdsong or the "music" of a noisy factory (2011, 16). Since this category involves neither instruments nor players, I will set it aside here.

Table 2.1 Acoustic effects of source attributes (Gaver 1993, 11)

Source	**Effects on the sound wave**
Interaction	
Type	Amplitude function, spectrum
Force	Amplitude, bandwidth
Material	
Restoring force	Frequency
Density	Frequency
Damping	Amplitude functions; also frequency
Homogeneity	Complex effects on amplitude; also frequency
Configuration	
Shape	Frequency, spectral pattern
Size	Frequency, bandwidth
Resonating cavities	Spectral pattern
Support	Amplitude functions, frequency, spectrum

energy that produces sound. This is a continuum of increasing mediation, then, in which the player gradually loses touch with the site of sound production. On one side, action and sound correlate; on the other, they dissociate. This difference, however, cannot be reduced to an opposition between analog and digital instruments. Though digital technologies sometimes obscure a performer's movement, they may also amplify it. For example, the sensors in Tod Machover's "hyperbow" modify sonic output through gestural control.[7] Insofar as they afford continuous sonification of my movements, such technologies arguably give *more* information about the body than the pointed sound of a cowbell. And this is to say that the coupling of action and sound is not just natural but often engineered. On an electronic piano with touch-sensitive keys, the dynamics reflect the force with which I press the keys. A seventeenth-century harpsichord, by contrast, does not convey this aspect of my action. Whether it is played roughly or softly, the harpsichord's volume stays the same. Action and sound, then, do not necessarily diverge as instruments become more complex or as the number of mediators between my body and the vibrating medium increases.

Besides ranking different *degrees* of mediation, then, it is important to identify different *kinds* of mediation. The challenge is to tease apart various aspects of the sound, various functions of the instrument, to make sense of the diverse ways that musical instruments transform energy into sound. To that end, I turn to a distinctive scholar in the field of organology—whose work has surprising affinities with contemporary music theory.

7. For more on Machover's "hyperinstruments" see http://opera.media.mit.edu/projects/hyperinstruments.html.

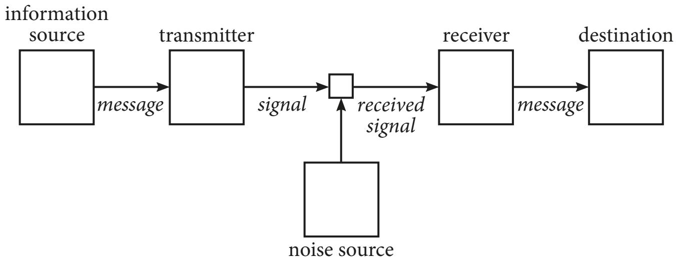
Instrumental Systems

Organology, the study of musical instruments, is inherently interdisciplinary, covering the science and engineering of instruments as well as their historical and cultural aspects. Modern organology typically classifies instruments in terms of the physics of sound production. For example, the widely used system of Erich von Hornbostel and Curt Sachs divides instruments into four categories: idiophones ("self-sounding" instruments, such as bells and woodblocks); membranophones (instruments with a stretched, vibrating membrane, such as drums and kazoos); chordophones (instruments with vibrating strings, such as guitars and pianos); and aerophones (instruments with vibrating air columns, such as flutes and pipe organs). This scheme aims to include "the whole range of ancient and modern, European and extra-European instruments"—and even instruments that have yet to be invented (Hornbostel and Sachs 1961, 7).[8] Its claims to universality are founded on the science of acoustics. Yet somewhat paradoxically, this foundation also reveals modern organology's historical origins in nineteenth-century Europe, where acoustical research enjoyed great prestige and influence.[9] By contrast, Herbert Heyde's *Grundlagen des natürlichen Systems der Musikinstrumente* (1975) develops an organology that is grounded in a scientific trend of the mid-twentieth century: cybernetics.[10]

Cybernetics is popularly associated with virtual reality (as in the terms "cyberspace," "cyberattack," and "cybersex") and human-technology hybrids (as in the "cyborg" or "cybernetic organism"). But the field of cybernetics, as developed in the 1940s and 1950s, investigates systems in general, whether technological, biological, psychological, or social. Cybernetics is concerned not with a system's material properties but with its abstract structure and behavior. As Ross Ashby puts it, "Cybernetics stands to the real machine—electronic, mechanical, neural, or economic—much as geometry stands to a real object" (1956, 2). For example, consider Claude Shannon's model of a general communication system, first published in 1948 (see Figure 2.2).[11] In this system, a message from some information source is fed into a transmitter. The transmitter encodes this message and passes it

8. In practice, electrical and electronic instruments pose problems for Hornbostel and Sachs's scheme (Kartomi 1990, 172–74). Also, some scholars have criticized organology for prioritizing a kind of scientism over social context (e.g., Bates 2012), in an argument that parallels attacks on music-theoretical formalism.
9. More broadly, nineteenth-century organology emerged at the intersections of acoustics, industrialized instrument-making, museum culture, and colonial encounters with non-Western music (see De Souza 2013, 7–14).
10. My discussion here responds only to the central section of Heyde's 1975 treatise, titled "Systemklasse" (Kartomi gives a brief overview of the book [1990, 189–90]). Moreover, cybernetic thinking does not characterize Heyde's later scholarship, which explores diverse topics in the history and science of musical instruments and organological methodology (e.g., Heyde 2001). He has also had a distinguished curatorial career, at the Metropolitan Museum of Art and other institutions, and received the Curt Sachs Award from the American Musical Instrument Society in 1991.
11. Incidentally, Shannon—one of the founders of information theory—collected musical instruments (Gallager 2001, 2683).

Figure 2.2 Claude Shannon's general communication system (after Shannon 1964, 34).



to a receiver, though not without interference from an external noise source. The receiver then decodes the signal, hopefully reproducing the original message. For Shannon's purposes, it does not matter whether the signal is sent via telephone wires, radio waves, or light beams. For a mathematical theory of communication, each element in the system may be treated as a "black box," reduced to a particular function. This generalizing move—a strategy of dematerialization—has provoked philosophical critiques of cybernetics (and the computationalist cognitive science that still bears its influence), though it also facilitates the application of cybernetic ideas in diverse domains.[12]

To approach musical instruments as cybernetic systems, Heyde starts by black-boxing instrumental components (1975, 22). The difference between Heyde's and Hornbostel and Sach's approach is striking. For Heyde, a string, a reed, and a drumhead belong to the same basic category (27). Each is a *transducer*, which takes energy from some *activator*—for example, a percussionist's hand or an organ's windchest—and changes it to sound. Every instrument couples an activator with a transducer. Instruments may optionally include further functional components, which are listed in Table 2.2, with Heyde's abbreviations and original German terms. The signal may pass through a *mediator* (like a violin bow) on its way to the transducer or through a *channel* at any stage. *Controllers, resonators,* and *couplers* may modify the signal. The remaining categories—*intermediate transducer, modulator*, and *amplifier*—are specific to electric and electronic instruments. After describing these categories (and subcategories within them), Heyde combines them in a general musical instrument system (*Ganzsystem der Musikinstrument*) (62). Any musical instrument, he claims, can be constructed as a subset of elements from the *Ganzsystem*. Like Shannon's communication system, a musical instrument system is a system of inputs and outputs, which transmits and transforms a signal.

For music theorists, Heyde's functional categories—arranged in a particular order, with some essential and some optional elements—may resemble a common

12. Hayles (1999) and Pickering (2009) offer critical histories of cybernetics, while Meyer (1967) combines music theory with information theory.

Table 2.2 Instrumental elements from Heyde (1975)

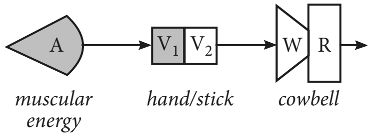
Label	German term	English term	Examples
A	*Anreger*	Activator	Muscles, lungs, bellows
V	*Vermittler*	Mediator	Violin bow, guitar pick, piano keys
W	*Wandler*	Transducer	Strings, membranes, reeds
ZW	*Zwischenwandler*	Intermediate transducer	Electric guitar pickup
M	*Modulator*	Modulator	Distortion pedal, electronic organ tone filter
Ampl	*Amplifikator*	Amplifier	Electric guitar amp, loudspeaker
R	*Resonator*	Resonator	Violin body, piano soundboard
K	*Kopulator*	Coupler	Flute tube
[circle]	*Kanal*	Channel	Violin bridge, flutist's throat
St	*Steuerelement*	Controller	Fingers, keys, switches

model of harmonic functions.[13] Just as a tonal phrase starts with tonic function (*T*) and leads to dominant function (*D*), instrumental sound production must start with some activating energy (*A*) and lead to a transducer (*W*, for *Wandler*); and just as predominant function (*P*) may intervene between *T* and *D*, a mediator (*V*, for *Vermittler*) may intervene between *A* and *W*. Of course, Heyde's ten instrumental functions are more numerous than the three harmonic functions, and they do not return to their starting point. Still, the comparison is useful. The interesting thing about a particular tonal phrase is not *that* it uses harmonic functions, but *how* it deploys them. Likewise, what is distinctive about an instrumental system is not just the functional components involved, but the structure of connections between components, what Heyde calls their "energetic, material, and informational couplings" (22).[14]

To analyze such structures in particular instruments, Heyde draws schematic circuit diagrams, diagrams of signal flow. For convenience, I will call these "Heyde diagrams." This graphic technique again recalls music-theoretical methods, since these schematics—like Schenkerian voice-leading graphs—are more than mere illustrations. Instead they supplement the written text, as a form of visual, symbolic argumentation. Heyde often presents the diagrams with minimal commentary, leaving it to his readers to investigate them independently. As a preliminary example, I offer a simple Heyde diagram for the cowbell in Figure 2.3. In this case, my body is the activator (*A*) and the bell itself is the transducer (*W*). These two functions, which appear in every Heyde diagram, have distinctive shapes: a "cone" for *A* and a trapezoid for *W*. Other components are represented as labeled rectangles. So one initial strategy for interpreting a Heyde diagram is to find the cone and follow the arrows to the trapezoid. In Figure 2.3, they are not immediately

13. For a critical interpretation of harmonic function, see Hyer (2011).
14. All translations from Heyde are mine.

Figure 2.3 Heyde diagram for cowbell sound production.



connected. Instead, mediators—the stick (V_2) in my hand (V_1)—direct energy to the bell. Note also that the bell itself performs a double function: it is a transducer but also a resonator. The distinction in shading is also meaningful here. In Heyde diagrams, human elements are shaded, while nonhuman elements have a blank background. Therefore, another strategy involves looking for boundaries between shaded and nonshaded zones. With the cowbell, that boundary comes between my hand and the stick. "Reading" such diagrams involves comparing interrelated levels, tracing various pathways through them—a practice that is not unfamiliar to music theorists. This type of analysis simply looks at the organization of an instrument rather than a piece of music.

Of course, most of Heyde's analyses are far more intricate than this preliminary example. Figure 2.4 reproduces and annotates his schematic for a Boehm flute. Boxes on the right side of the diagram represent parts of the instrument: sixteen keys (k_1–k_{16}) and a mouthpiece (W), joined to the cylinder that constitutes the flute's body (coupler, K). Fingers of both hands are connected to the keys, though the diagram indicates differences between the hands. Each right-hand finger operates multiple keys, while the right thumb is connected with none. Meanwhile, each finger of the left hand is associated with a single key, and the left thumb operates two. The activating energy here originates in the player's respiratory system. Air passes from the lungs (A), through the windpipe (a small circle, representing a channel), to the mouth (a switch symbol). Lips and mouthpiece together form the transducer (W)—and this symbol combines human (shaded) and nonhuman (nonshaded) elements. On the whole, then, this diagram shows the integration of flute and flutist. To paraphrase Heyde, the flute itself is only a subsystem (26).

Heyde diagrams present systems of linked nodes. In mathematical terms, these are a kind of graph.[15] A mathematical graph is a collection of points connected by lines. Formally a graph is defined by two sets: a set of vertices V (the points) and a set of edges E that pair vertices from V. For example, imagine a graph where $V = \{A, B, C\}$ and $E = \{\{A, B\}, \{B, C\}\}$. This simple graph would have three points and two lines. It might be drawn in various ways (as demonstrated in Figure 2.5), but such visual representations are, strictly speaking, not a constitutive feature of the graph.

15. Heyde's main source on cybernetics—a book by the neo-Marxist economist Oskar Lange (1965)—is effectively a mathematical treatise on transformations, networks, and graph theory.

Figure 2.4 Circuit diagram for a Boehm flute (adapted from Heyde 1975, 63).

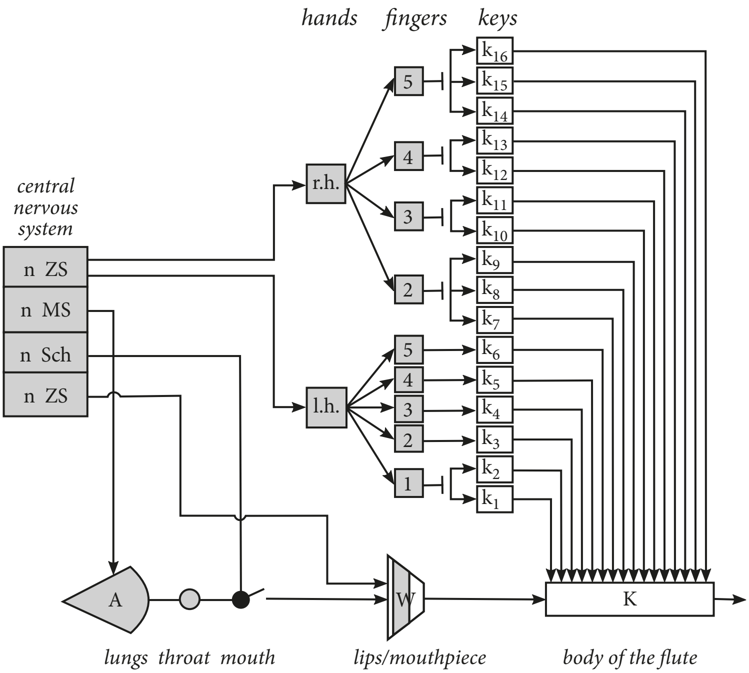
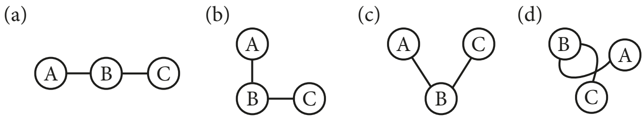


Figure 2.5 Four ways of drawing the same mathematical graph.



Graphs and networks are used in many diverse fields.[16] In music theory, they are central to transformational theory. Pioneered by David Lewin (1987), transformational theory uses mathematical group theory to model musical spaces, which may include but are not limited to pitch.[17] (For example, later chapters of this book will use transformational graphs and networks to explore various instrumental spaces.) The similarities go beyond the underlying mathematics to include conceptual attitudes: cybernetics is interested in systemic behavior, just as Lewin

16. Sporns (2010), for example, examines the importance of graph theory for neuroscience.
17. Rings discusses graph theory as part of a broader introduction to transformational theory (2011, 110–16). Readers who are familiar with transformational theory might note that whereas the "contents" of a transformation network are discrete elements from a mathematical group, Heyde's schematics model a more or less continuous flow of energy. However, cybernetics often models continuous variables in terms of a "discrete machine," using the framework of transformations, graphs, and networks as a more general conceptual resource (Ashby 1956, 28).

is interested in "musical behavior" (1986, 377). For example, Ashby's statement that cybernetics "does not ask 'what *is* this thing?' but '*what does it do*?' " (1956, 1, emphasis in original) resembles Lewin's "transformational attitude," which prioritizes subjective musical actions over objectified intervallic measurements.[18] More practically, this means that aspects of graph-theoretical thinking exercised in transformational theory—for example, ways of thinking about a graph's connectivity or directedness—can reveal interesting properties of particular Heyde diagrams.

From four source nodes representing the energy source, the graph in Figure 2.4 proceeds through a greater number of intermediate nodes before the arrows converge on a single "root" node, what Lewin calls an "output node" (1987, 207–8). Beyond that, its structure meets the conditions for an oriented digraph, employed in the study of tonal music by Steven Rings (2011, 111). Shared aspects of graphic structure suggest a surprising analogy here: just as independent voices in a tonal composition may start and finish in harmony, independent functional chains in flute playing unite in the final sound. Except for their final convergence at *K*, the two pathways in Figure 2.4 are indeed separate: there is an *activation pathway* involving the player's respiratory system and the mouthpiece, and a *control pathway* involving hands, fingers, and keys.

The energy that passes through this system originates in the performer's nervous system (*n*), represented by the four stacked, shaded rectangles on the left side of the diagram. Yet this energy is not undifferentiated. Heyde distinguishes between "energy-state control" (*Energiezustandssteuerung*, labeled *ZS*) and "energy-volume control" (*Energiemengensteuerung*, labeled *MS*). The former involves qualitative distinctions (for example, on or off), while the latter is quantitative (58).[19] This roughly corresponds to Shannon's distinction between discrete and continuous signals (1964, 34–35). Flute playing involves both forms of energy: the fingers set the keys' state (open or closed), corresponding to discrete pitch changes, while the breath involves variable amounts of energy (more or less), which create continuous fluctuations in volume.

In a way, Heyde's diagram shows relatively little about the flute's sound. Figure 2.4 does not specify what notes are produced by the various holes or key combinations on the flute. It represents a generalized Boehm flute rather than any particular flute or type of flute. For the moment, this abstraction, by usefully bracketing out pitch and rhythmic patterns, can focus attention on the process of sound production.

By bracketing off materiality, Heyde's organology, like cybernetics in general, posits a continuity between the mechanical and the organic. This theme is developed in Gregory Bateson's *Steps to an Ecology of Mind*:

> Some of these pathways happen to be located outside the physical individual, others inside; but the characteristics of the system are in no way dependent upon any

18. Here it seems worth mentioning that David Lewin, like Shannon, worked at Bell Laboratories, and Lewin is cited as a contributor to Jasia Reichardt's computer art exhibition *Cybernetic Serendipity* (1968, 7).

19. The opening and closing of the mouth corresponds to a third kind of control, what Heyde calls switch control (*Schaltsteuerung*, labeled *Sch*).

> boundary lines which we may superpose upon the communicational map. It is not communicationally meaningful to ask whether the blind man's stick or the scientist's microscope are "parts" of the man who uses them. Both stick and microscope are important pathways of communication and, as such, are parts of the network in which we are interested; but no boundary line—e.g., halfway up the stick—can be relevant in a description of the topology of this net. (1972, 251)[20]

If player and instrument are integrated in a "control circuit" (Heyde 1975, 25), aspects of technique can be distributed to the technology, and ultimately the player can be replaced by a nonhuman substitute.[21] For example, the human flutist can be replaced by a mechanical one, as in a celebrated eighteenth-century automaton created by Jacques de Vaucanson. One of Heyde's diagrams for the machine appears in Figure 2.6. Vaucanson's automaton plays the flute with mechanical fingers and a mechanical mouth, powered by a system of nine bellows. This translation from the human to the technical already implies an analysis of the human as part of a mechanical system, and indeed Vaucanson had studied the mechanics of human flute playing while designing his android (Riskin 2003, 613–16).[22] This means that not only the flute but also the flutist is a subsystem. The flutist who can be replaced by an android is already a cyborg.

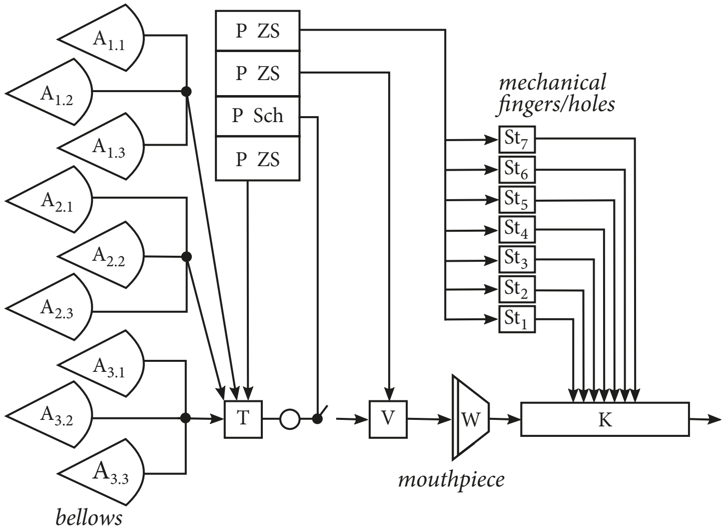
Activation versus Control

And yet cybernetics misses something important. The flute-playing automaton might reproduce certain musical behaviors, but it cannot re-create the flutist's lived experience.[23] Heyde's distinctions, then, demand phenomenological interpretation. I am particularly interested in the distinction between activation and control, as represented in the two converging pathways in the flute system. Returning to my bicycle analogy, this resembles the gap between feet that pedal and hands that steer. In fact, the German word that Heyde uses, *Steuerung*, can be translated as either "control" or "steering."[24]

When I strike the cowbell, I use the stick to relay my energy to the instrument. But at the same time, I aim the stick at a particular part of the bell. Something

20. Focusing on the topology of the net is part of Bateson's cybernetic refusal of Cartesian dualism, which denies the distinction between the internal and external.
21. More generally, Bruno Latour theorizes both *associations* among human (H) and nonhuman (NH) actors and their mutual *substitutions*. "Of course, an H-H-H assembly looks like social relations," he writes, "while a NH-NH-NH portion looks like a mechanism or a machine, but the point is that they are always integrated into longer chains" (1991, 110).
22. For reflections on the historical and philosophical significance of musical automata, with their mechanical doubling of human performers, see Abbate (1999) and Yearsley (2002, ch. 5).
23. Here I echo Merleau-Ponty's ambivalence about cybernetics, which he discussed in lectures during the 1950s (2003, 165–66).
24. Note also that Norbert Wiener (1948) derived the term "cybernetics" from the Greek *kybernao*, meaning "to steer."

Figure 2.6 Circuit diagram for Vaucanson's flute-playing android (adapted from Heyde 1975, 61). In this diagram, the box labeled *T* represents a "junction" (*Verteiler*).



similar happens with the piano: my fingers make the strings sound (via the key-and-hammer mechanism), but they also select the keys. With such instruments, activation and control functions are mixed. These doubled actions might be compared to vector quantities in physics, which combine magnitude and direction. In this analogy, magnitude might correspond to the strength of the attack (communicated in dynamics), and direction to its placement (communicated in pitch). Even with these percussive instruments, though, the functions may diverge to some degree. Cowbell players often use a finger on the nonsticking hand to damp the bell, adding some control over timbre and duration. And though pianists' feet do not typically produce tones, they can control aspects of duration or dynamics through the pedals.[25] Thus, activation and control—though they can be combined and must be coordinated—are mutually irreducible.

These functions are distributed throughout the body in various ways. With the piano accordion, for example, my fingers control the keys, but pushing and pulling arms supply the energy—and thereby control the volume—via the bellows. Because of this single power source, all simultaneous notes on the accordion share the same dynamic, and it is not possible for the accordionist to bring out a line in a polyphonic texture by playing it more loudly. Whereas playing a note on the piano

25. With certain kinds of piano, the player's feet do produce sound: "pedal pianos" include a keyboard for the feet, and pianos with Janissary stops, popular in late-eighteenth- and early-nineteenth-century Vienna, have pedals that activate percussive effects inspired by Turkish military bands. Such pianos, however, are rare today.

is a percussive act, on the accordion I can hold a chord with my fingers and work the bellows to sustain it, "breathing" in and out with my arms. In this situation, I would be focused on activation and not control. As with other wind instruments, I may seem to be maintaining and manipulating a stream of energy rather than percussing an object.

With the violin, my right hand typically activates the sound, either through the bow or through plucking fingers, while my left hand stops the strings.[26] That is to say, my left hand cannot make the notes louder or longer. Usually both hands collaborate to produce pitches and rhythms, since the bow hand selects the string or strings to be played, and the left-hand fingers may rhythmically change notes during a sustained bow.[27] When I combine active bowing with an unchanging left hand, the violin has the feel of a percussion instrument. When long, sustained bows support rapid finger changes, I am more likely to feel as though I am manipulating a flow of energy. Either way, violin hands are more highly differentiated than piano hands or accordion hands, but also less independent.

The opposition of activation and control becomes clearer as functions are distributed between the player and the instrument. Figure 2.7 plots these possibilities on a semiotic square.[28] Each combination of terms creates a category, illustrated with musical instruments in Figure 2.7a and with vehicles in Figure 2.7b.

If the piano is like a bicycle, the pipe organ seems closer to a Harley-Davidson. When I play the organ, I guide the instrument without providing its energy. Slamming or caressing the keys does not affect the organ's volume, which is set by an expression pedal. The gentlest touch can create a thunderous tone. Though I have surely initiated this sound, the instrument's response may seem disproportionate. And the breath filling the pipes is not like my breath. This wind instrument has an endless air supply, sustaining tone indefinitely. The organ, then, combines two kinds of superhuman power—in its endurance and in its strength—and puts them at my disposal. These possibilities are, of course, central to the idiomatic technique of the pedal point. For example, consider the fourteen-measure pedal near the opening of J. S. Bach's Prelude and Fugue in A minor, BWV 543, an unstoppable sonic force grounding the passage work above (see Figure 2.8). The excess of instrumental energy in such gestures engineers a sense of transcendence, as powerful as any hidden orchestra or choir.[29]

The organ's nonhuman breath is thematized even more clearly in György Ligeti's *Volumina* (1962), a piece that explores overwhelming sustained clusters, shifting in color. At the end of the piece, Ligeti instructs the organist to switch off the organ blower. The organist continues to hold down the keys, and the sound

26. An exception to this is left-hand pizzicato, a technique found, for example, in the ninth variation from Niccolò Paganini's Caprice in A minor, op. 1, no. 24.

27. Note that the bow offers continuous control over rhythm and dynamics, but discrete control over pitch. And though the left hand can produce continuous pitch variation (in vibrato or glissandi), its fingers often seek to reproduce a discrete system of pitches.

28. The semiotic square is a tool for exploring structural oppositions, introduced by Greimas and Rastier (1968).

29. On the transcendental effects of concealed orchestras (a technique particularly associated with Richard Wagner), see Dolan (2013, 258–64) and Kane (2014, ch. 4).

Figure 2.7 Semiotic squares exploring activation and control (a) with musical instruments and (b) with vehicles. (Note that the handcar is a crank-powered railway vehicle, popularly associated with Wile E. Coyote.)

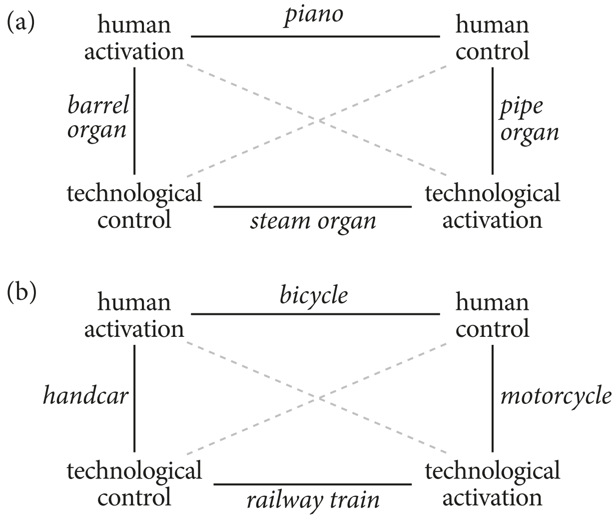


Figure 2.8 Johann Sebastian Bach, Prelude and Fugue in A minor, BWV 543, mm. 10–15. The pedal tone in the bass continues to m. 24.

gradually falters as the instrument runs out of air. Here Ligeti reveals the limit of a seemingly limitless energy source, highlighting an aspect of the organ that can easily be taken for granted.

So far, I have focused on human-controlled instruments. Yet as the square in Figure 2.7a shows, other possibilities are latent in the opposition of activation and control. Whereas the pipe organ combines mechanical energy with human control, the barrel organ inverts this pattern, combining human energy with mechanical control. With this inversion, however, some may question whether it is truly a musical instrument at all.

In the eighteenth and nineteenth centuries, the barrel organ was commonly used as a street instrument and in churches alongside "finger organs."[30] To play the instrument, an organ grinder turns a crank. This crank performs two functions, both hidden inside the instrument: it pumps the bellows, filling an air reservoir; and at the same time, it rotates a cylindrical barrel that is covered with a pattern of pins and staples. Each pin and staple opens a pipe to pressurized air from the reservoir, releasing a note in a programmed sequence. (Most barrels have multiple settings, to play multiple tunes.) Despite their popularity, barrel organs were widely denigrated (Hicks 2014). This is perhaps not only because of their contributions to urban noise or their populist repertoire, but also because of the organ grinder's ambiguous status as a musician. Some might view organ grinding as a purely mechanical activity, in which the player is automatized or instrumentalized. But playing the barrel organ does involve some skill. At the very least, the crank must be turned in the correct direction, since reversing it can damage the instrument. The organ grinder also controls the tempo, keeping it steady or varying it for expressive effect. And barrel organs, like pipe organs, often have multiple stops. Finally, many organ grinders obviously treat their work as a kind of performance. They often wear distinctive costumes, and gesture, dance, or sing along with the music. In this regard, they resemble the DJs studied by Mark Butler (2014, 95–105). Because their music-making obviously involves technological mediation, both organ grinders and DJs "perform performance." They work to convey personality and agency, to engage audiences, to emphasize "liveness." Despite the barrel organ's commonalties with musical automata and later recording technologies, then, it is still actively played.

Devices on the bottom edge of Figure 2.7a, in which both components are nonhuman, might seem even more liminal as instruments. Again, these are not necessarily digital or mechanical. A prime example here might be the aeolian harp, whose strings are activated by wind (an instrument that was discussed by Athanasius Kircher in the seventeenth century). But what of instruments that have to be *started* by a human? For example, a steam organ, which matches the pipe organ's mechanical power source with the barrel organ's programming? Is pressing an on/off button the minimal form of instrumental technique?

30. As a sample performance, I recommend the following YouTube video: https://youtu.be/ZClrDGnqd1Y. The earliest description of a barrel organ, however, appears in a ninth-century treatise by the Banū Mūsā brothers of Baghdad (Langwill and Ord-Hume 2001).

Of course, such questions are not uniquely related to musical instruments. Instead they engage broader issues in the history of technology, which are discussed in Jean Baudrillard's *The System of Objects*. For Baudrillard, older objects rely on human energy and ability, and are therefore shaped for the body. A hammer's handle—or a piano's keyboard—presupposes a strong, skilled hand. Yet, he continues, as technical objects have become more intricate, the related gestures have grown simpler, ultimately creating technologies that are more complex than the techniques required to operate them: "Buttons, levers, handles, pedals (even nothing at all—as when one passes in front of a photo-electric cell) have … replaced pressure, percussion, impact or balance achieved by means of the body, the intensity and distribution of force, and the abilities of the hand" (1996, 51). Buttons, in this account, demand neither effort nor dexterity. They reflect an increasingly abstract—but also increasingly free—connection between body and object.

The Monome 64, developed by Brian Crabtree and Kelli Cain, presents an 8 × 8 grid of identical square buttons.[31] The buttons can light up, but they are not pressure-sensitive and have no predetermined function. In Crabtree's words, "The wonderful thing about this device is that it doesn't do anything really" (quoted in Emsley 2011, 43). A button takes on an effect—triggering a sound, an audiovisual clip, or an action in a video game—only when the Monome is coupled with some software. The Monome, then, combines strict constraints with endless customizability. On this level, its buttons seem to embody the kind of abstraction theorized by Baudrillard.

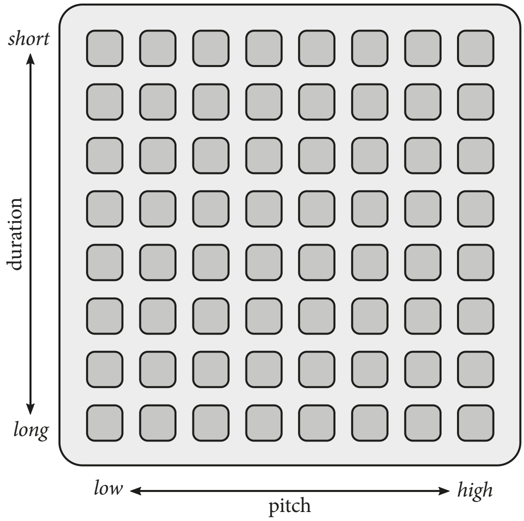
But although the Monome could easily be set up as a kind of jukebox (where the press of a button would play a complete prerecorded track), it is more commonly used to realize various musical spaces and processes. For example, Crabtree's "flin" app (released under his performance name, "tehn") creates an instrument with repeating notes.[32] Figure 2.9 models this arrangement. Each column of buttons corresponds to a single pitch, with lower pitches on the left and higher ones on the right. Similarly, the rows map onto duration, with higher rows producing shorter notes. Pushing a button, then, produces a looping note with a unique pitch and length. Each note is visually represented by a line of lights descending along the column like slow-motion raindrops. It is possible to press a few buttons and let the app run indefinitely, to watch and listen as the notes go in and out of phase. Here the Monome, like an automaton or aeolian harp, seems to play out a nonhuman musical process. Activation and control both come from the instrument itself. Yet it is also possible to intervene, to thicken or thin the texture, to change the notes or durations, to reintroduce human control.

Butler describes this mode of performance as "playing with something that runs" (2014, 106–8). His description draws on his performing experience with both classical music and electronic dance music (EDM). While playing piano, he must remain constantly involved in sound production. But while DJing, he can

31. The Monome grid is available in larger sizes too. Butler examines these controllers in the context of various technologies used in electronic dance music (2014, 87–89). As he notes, the Monome is not associated with any particular software. Instead, it works with a variety of programs, including open-source software developed by a community of users (88).

32. For a demonstration, see https://vimeo.com/418349.

Figure 2.9 Diagram showing pitch and duration layout for "flin" on a Monome 64.



step back and listen to a process unfold, taking time to plan his next move. "By shifting some of the responsibility for sound production from the performer to the machine," Butler concludes, "EDM technologies cultivate the emergence of a distinctively interpretive role *during performance*" (108, emphasis in original). A related difference between pianists and DJs might involve the habits of auditory-motor integration discussed in the preceding chapter. Though DJs might develop similar multisensory connections, they would likely be more flexible than those found in classical pianists. (Again, the abstraction of the Monome may engender a certain kind of freedom.)

In terms of the semiotic square in Figure 2.7a, "playing with something that runs" might involve an alternation between human and technical control. It is also possible to combine human and technical energy sources. With the electric guitar, for example, I directly activate the vibrating string—but the unplugged guitar responds in a whisper. When I connect it to an amplifier and hit the on switch, it feels like a different instrument. Simply tapping the string now produces a bold tone, especially if I have added a distortion pedal to this musical circuit. The force with which I pluck the string is still reflected in the guitar's volume, but magnified, supercharged. Here, again, technical and phenomenological aspects of instrumental sound production mingle with cultural values. For better or worse, the way that the electric guitar "empowers" its player is bound up with the ways that the instrument has been gendered in popular culture.[33] Instead of being pinned in a single place on the square, then, this

33. Robert Walser (1993) and Steve Waksman (1999) have both examined such aspects of electric guitar culture.

instrument offers experiences of sound production that are defined by dynamic tensions among the square's elements.

From Feedback to Incorporation

Sound production—conceived as the transmission and transformation of energy—might seem like a one-way process. After all, the arrows in the Heyde diagrams presented earlier always point forward. Yet for a performer, sound also provides a kind of *feedback*. Indeed, Heyde's first circuit diagram includes a feedback loop—an arrow that wraps around, going back to the nervous system through the ear (1975, 24). Such a loop, in a sense, is implicit in all later diagrams.[34] (That said, certain self-powering instruments let the player experiment with auditory feedback. Here I am particularly thinking of an electric guitar technique known as "volume swells," in which the guitarist activates the string with the volume off, then fades in with the volume knob or a volume pedal.)[35] Auditory feedback helps guide specific aspects of performance, particularly with continuous parameters. For example, auditory feedback is essential for intonation on bowed string instruments. When experienced cellists shift along the fingerboard but do not bow the string, their left hand drifts away from the correct position (Chen et al. 2013). In this case, the control pathway cannot properly function without the activation pathway. Despite years of practice, the cellist's motor performance depends on auditory feedback.[36]

Instrumental performance involves other forms of sensory feedback too. Many performers can *see* their hands on the instrument, and this visual information can be useful when they are executing certain actions (such as large leaps). Visual feedback is often important for beginners as well: for example, an experiment with beginning piano students indicated that "covering the hands of the learners so that they could not see the keyboard was to some extent detrimental to learning" (Brown 1934, 527). Still, not all instruments offer an equal amount of visual feedback. A flute can be seen only peripherally, and a diatonic harmonica is completely hidden in the player's hands.

Tactile feedback is also essential, particularly for timing.[37] Aschersleben, Gehrke, and Prinz (2001) found that anesthetizing participants' hands did not affect their ability to tap as rapidly as possible or to air-tap along with a beat. But their ability to synchronize key taps with a beat was significantly compromised.

34. Feedback is a central concept for cybernetics, because of its role in a system's self-regulation.
35. Eddie Van Halen's solo electric guitar track "Cathedral" from the 1982 album *Diver Down* uses volume swells to imitate an organ. For an analysis of "Cathedral," see De Souza (2016b).
36. Similarly, Hafke-Dys, Preis, and Trojan (2016) investigated the effects of altered pitch feedback on violinists' motor performance. In this experiment, violinists accurately compensated for the pitch shift, even when they could not consciously perceive the alteration.
37. Tactile feedback can be distinguished from kinesthetic or proprioceptive feedback, which involves bodily movement but not touch.

From this perspective, the hand is not just an output device. Rather, information flows in both directions. The hand touches and is touched.[38] Unlike its auditory or visual counterparts, tactile feedback allows for experiences of resistance. I feel my finger make contact with the piano key, and I feel it when the key hits bottom. This feedback, again, is important for temporal regulation. As the tempo becomes faster, pianists lift their fingers higher and strike the keys more forcefully, and increasing tactile information in this way improves temporal accuracy (Palmer and Dalla Bella 2004; Goebl and Palmer 2008). Clarinetists do the same, even though their fingers do not affect note onset or volume (Palmer et al. 2009). Tactile feedback can also pass through a mediating implement. For example, I feel the cowbell at the tip of the drumstick, not at the position of my hand.[39]

The key point here is that playing an instrument mixes multiple streams of feedback, involving what Merleau-Ponty calls "exchanges" between the visible, audible, and tangible (1968, 143). This multisensory integration underlies the action-effect binding discussed in Chapter 1, shaping players' perception and production of sound. Beyond that, though, such feedback may modulate the experience of one's own body.

Here, while recalling the Husserlian distinction between *Körper* and *Leib*, it is useful to invoke a related distinction *within* the category of the lived body—a distinction between body image and body schema.[40] The body image involves a conscious awareness of my body, the lived body as intentional object.[41] The body schema, on the other hand, is preconscious and supports automatic movements. Though the body schema involves reflexes and so on, note that this does *not* correspond to a distinction between a natural and a cultural body. Learned skills and habits register at both levels.

Though these two aspects of the body are typically mixed in lived experience, they may come apart. The classic example of a gap between body image and body schema is the phantom limb. Since the patient is aware that the limb

38. Both Husserl ([1929] 1960, 97) and Merleau-Ponty (2012, 94–95; 1968, 147–48) discuss this doubling in terms of one hand touching the other. For Merleau-Ponty, touching and being touched intertwine without fully coinciding. "When I press my two hands together," he writes, "it is not a question of two sensations that I could feel together, as when we perceive two objects juxtaposed, but rather of an ambiguous organization where the two hands can alternate between the functions of 'touching' and 'touched'" (2012, 95). This non-coincidence, to use a harmonic analogy, might be compared to a pivot chord: it functions in two keys, but I can hear it only in one key at a time. Wiskus (2013) approaches Merleau-Ponty's philosophy of non-coincidence via music, painting, and literature.

39. Yamamoto and Kitazawa (2001) use a temporal discrimination task with crossed hands to show that stimuli are not located at the position of the hand, but sensed at the drumstick's *tip*.

40. Merleau-Ponty discusses the body schema (*schema corporel*) in *The Phenomenology of Perception*, drawing on earlier work in neurology by Henry Head (1920). For terminological issues here, see Gallagher (1986) and Sheets-Johnstone (2005). In a review of neurophysiological and psychological research on the body schema, Graziano and Botvinick (2002) emphasize its reliance on interconnected sensory and motor areas in the parietal lobe and premotor cortex.

41. In phenomenology, intentionality refers to the "aboutness" or "directedness" of experience. That is, every experience is an experience of *something* (and that something is an "intentional object").

has been amputated, it is no longer part of the patient's body image. Yet it persists in the body schema.[42] As Merleau-Ponty writes, "To have a phantom limb is to remain open to all of the actions of which the arm alone is capable and to stay within the practical field that one had prior to the mutilation" (2012, 84).

More rarely, the body schema itself may be impaired, resulting in a loss of the sense of bodily position and movement (Cole and Paillard 1995). One patient suffering from this unusual neuropathy can verbally explain where her body has been touched or locate it on a diagram but, without visual information, cannot point to the place on her body. She knows the touch in terms of body image but not body schema (254). Such patients are able to move their bodies but must consciously regulate every move. Sitting on a chair, holding an egg without crushing it, gesturing while talking—these usually automatic actions, for them, require effort and attention. As another patient puts it, he cannot walk and daydream at the same time (262). Besides revealing the everyday reliance on automatic bodily habits, such cases demonstrate the nonidentity of body image and body schema.

Exploiting this gap can produce fascinating phenomena, such as the "rubber hand illusion" (Botvinick and Cohen 1998). While a participant is seated at a table, one of the participant's hands is hidden by a screen, and a rubber hand is put in its place. An experimenter uses paintbrushes to stroke the hidden real hand and the visible rubber hand at the same time. Through this coordination of visual and tactile feedback, participants come to feel that the rubber hand is part of their own body.[43] Surprisingly, such an illusion can take place in the absence of the artificial hand: if the experimenter systematically strokes an empty space while stroking the unseen hand, the participants may come to feel that they possess an invisible hand (Guterstam, Gentile, and Ehrsson 2013). And if the experimenter then "stabs" the invisible hand with a kitchen knife, this evokes increased skin conductance (a common physiological measure of arousal). The body schema, then, can incorporate even empty space, inducing a kind of phantom-limb experience.[44]

In a similar study, the experimenter gently taps a participant's hand with a small hammer (Senna et al. 2014). The participant wears headphones, in which the sound of the hammer against the participant's skin is gradually replaced by the sound of a hammer tapping marble. If the marble sounds are temporally coordinated with the felt taps, uncanny effects appear after five minutes: the hand begins to feel numb, stiff, heavy, and hard. It feels like a marble hand. In the rubber hand illusion, I come to feel what I see; in the marble hand

42. Phantom limbs are consistent with the phantasmal voices and other simulations discussed in perceptual symbol systems theory (see Chapter 1). Indeed, some commentators argue that phantom limbs provide strong evidence consistent with Barsalou's theory (Edelman and Breen 1999).

43. Neuroimaging research suggests that the premotor cortex is involved in the multisensory integration that produces a sense of bodily ownership (Ehrsson, Spence, and Passingham 2004).

44. It is, however, considerably more difficult to induce the sense of ownership with an object that does not resemble a hand, such as a wooden stick (Tsakiris and Haggard 2005). This suggests that such illusions require a mix of bottom-up and top-down processes.

illusion, what I hear. Multisensory feedback reconstructs the sense of one's own body.

These experiments indicate conditions under which the body may incorporate tools or other objects. Navigating with a stick alters the body schema because it provides multisensory feedback. When blind people regularly use a cane, their sense of personal space expands. Tactile and auditory awareness focuses on the area at the tip of the cane. For experts, the perceptual changes are more or less permanent, but they can be temporarily induced in sighted people who have been trained to use a cane (Serino et al. 2007). Like riding a bicycle, navigating with a stick involves practical know-how, which, despite its conscious aspects, must be grounded at the level of the body schema. "If I want to become habituated to a cane," writes Merleau-Ponty, "I try it out, I touch some objects and, after some time, I have it 'in hand'" (2012, 144).[45]

All of this, finally, can help explain why musicians sometimes claim that an instrument feels like part of the body. I would hypothesize that such experiences are more common when multisensory feedback is maximized—that is, when an instrument's sound reflects multiple aspects of the player's action and when tactile and visual feedback match the auditory image. In other words, the illusion of instrumental incorporation seems more likely with human activation and control than with a self-propelling instrument like the Monome. Mediators like bows or drumsticks (which, like the cane, can be felt *through*) might also enhance the illusion. Gibson's distinction between "detached objects" (which I can pick up and move) and "attached objects" (which are fixed) seems relevant too (1979, 133). But this might simply be because detached instruments like the violin or flute stay in continuous contact with the body.

Some players actively seek a sense of bodily extension. The trumpet virtuoso Jens Lindemann, for example, tries to foster it in his students. "It's a lifelong pursuit trying to get to that point of comfort," he says, "but when you do arrive there you realize that you're just taking a piece of metal and you're blowing through it. It's that simple and that complicated at the same time."[46] Of course, the feeling of incorporation, like any form of withdrawal, will be fleeting. The experience, surely, differs in notable ways from the experience of having a rubber hand, and musicians may not intend that their statements about such experiences be taken literally. Still, these psychological and philosophical perspectives suggest that playing an instrument can change the experience of one's own body, that in music as in other domains the boundaries of the lived body can be reshaped by technics.

45. Another study by colleagues of Serino showed that tool use can alter perceptions of one's own body. After participants used a mechanical grabbing arm, their reaching behavior changed, and their estimates of their own arm length slightly increased. Briefly put, they acted as though they had longer arms (Cardinali et al. 2009).

46. See http://www.artistshousemusic.org/videos/your+instrument+as+an+extension+of+your+body.

Conclusions

Instrumental sound production, generally speaking, involves a certain reciprocity: actions are converted into sounds, and sounds give feedback about actions. As such, player and instrument together can be understood as a system that generates and transforms musical energy. Yet because this coupling is realized in countless ways, analyses of particular instruments must untangle the contributions of bodily technique and instrumental technology, considering their phenomenological and sonic effects.

Physical traces, of course, are also audible in voices. This is central to Roland Barthes's reflections on the "grain of the voice." The "grain" refers not just to vocal timbre but to contributions of "the tongue, the glottis, the teeth, the mucous membranes, the nose" (1977, 183). "The 'grain,'" Barthes explains, "is the body in the voice as it sings, the hand as it writes, the limb as it performs" (188).[47] Additionally, the sense of vocal ownership, like bodily ownership in general, can be influenced by multisensory feedback. In one notable experiment, the participants spoke words while simultaneously hearing a voice in headphones say the same words (Zheng et al. 2011). With this congruence between auditory information and vocal motor activity, the participants came to feel that the other voice was their own.[48] This "rubber voice" illusion is possible because vocal production is both felt and heard.

As my voice resounds outside of me, it may sometimes be experienced as a kind of object. Whereas instrumental incorporation brings a tool into the body schema, this objectification exteriorizes voice, projecting corporeal activity outward. But a voice is a slippery thing.[49] After all, my voice originates *inside* my body. I can neither grasp nor see it, and I hear it "from within" (Merleau-Ponty 1968, 144; Vitale 2008). In the end, then, this chapter differentiates instrumental and vocal sound production. Singing is like running rather than cycling. Though running and singing are undeniably technical, they do not require a prosthesis—something set before me—that transforms my energy and grounds my actions.[50] Variations in vocal tension, for example, are not tethered to tangible spots in the world. I can point to a middle C on the piano or violin but not in my voice. Voices, that is, do not spatialize pitch in the same way that many instruments do.

47. Barthes explicitly extends the grain to instrumental music, with a brief discussion of keyboard performance (1977, 188–89).
48. I would hypothesize that the voice can incorporate other sounds as well. This could be tested by modifying the procedure of Zheng et al. (2011), replacing spoken words with sung notes and the stranger's voice with instrumental tones.
49. For a discussion of the ambiguities surrounding voice—and a concise overview of the extensive scholarly literature on voice—see Feldman (2015). I discuss voice-instrument relations in De Souza 2014.
50. Of course, this presumes a "naked" voice. Various musical technologies—from kazoos to vocoders to microphones—*do* transform vocal energy. These instruments, it might be said, are "played" with the voice.

The question of instrumental space, however, goes beyond sound production. Heyde diagrams may outline an interface's topology, but they do not show how it affords specific sets of pitches. Yet this will be crucial for understanding how instrumental organization relates to tonal organization and how an instrumental space, with its boundaries and privileged zones, might affect players' creative actions.

CHAPTER Three

Idiomaticity; or, Three Ways to Play Harmonica

In an experiment at the Max Planck Institute for Human Cognitive and Brain Sciences, guitarists were asked to finger a chord in response to an on-screen cue (Drost, Rieger, and Prinz 2007). The chords were not difficult, either A major or A minor. But as each visual prompt appeared, the participants heard a chord that might—or might not—match the one they were supposed to play. That is, sometimes they heard A major when they had to play A minor (and vice versa). The mismatched chords slowed reaction time *but only when they had the timbre of a guitar*. If the distractor sounded like a piano, an organ, flutes, or voices, it had no significant effect on the guitarists' performance. When pianists did this same task, though, they were influenced by piano sounds *and* organ sounds. The researchers explained this result in terms of affordances: because piano and organ are both keyboard instruments, they afford similar actions and musical textures. Despite differences in action-sound coupling, expert pianists may hear organ music kinesthetically, sensing movement on the keys.

A subtle difference between the guitarists' and pianists' tasks raises further questions. Guitarists played A major and minor, but pianists played C major and minor. Why would the designers of the experiment choose one key for the piano, another for the guitar? The answer, for a guitarist, is obvious. The chord voicings used in the experiment involve open strings, and they are particularly easy to play. The corresponding hand shapes for C major and minor, though, are barre chords—that is, chords where the index finger stops multiple strings at the same fret. Similarly, C has a special relationship to the piano, since the key of C major entails only white notes. Such contrasts have less to do with the instruments' modes of sound production than with the way they organize pitch materials. With other instruments, the experimental task would have to be further modified. The diatonic harmonica, for example, cannot play a major and minor triad over the same root. How, then, do particular instruments realize pitch spaces in physical space? How are instrumental interfaces structured? And how might they structure players' actions?

These questions evoke broader debates about technology and agency, which are often framed around two theoretical poles.[1] On one side, voluntarism and social reductionism suggest that tools are merely vehicles for human intentions. The most common expression of this view might be the National Rifle

1. For further discussion of such debates, see Ihde (1990, 4–5) and, in a musical context, Taylor (2001, 25–31).

Association's slogan, "Guns don't kill people. People do." On the other, technological determinism claims that tools shape or control their users. This is conveyed by Marshall McLuhan's famous claim that "the medium is the message" (1994, 7). Both extremes are problematic. Clearly we make choices when using instruments, and yet it sometimes feels as though they have a hold on us.

Ecological perceptual theory avoids deterministic oppositions here. As emphasized in Chapter 1, affordances and abilities are always codefined. But Gibson also insists that a thing's affordances exist independently of an agent's needs or skills. As he puts it, "The object offers what it does because it is what it is" (1979, 139). This realism distinguishes Gibson's "affordance" from Gestalt psychology's earlier term, "valence" (*Aufforderungscharakter*). Though both concepts suggest that objects invite particular actions, the Gestalt theorist Kurt Koffka argues that valences belong to a perceived "phenomenal object," not the physical object itself. Gibson rejects this dualism. Noticing or ignoring affordances does not change them. They are "always there." Note how this invariance unsettles voluntarism and social reductionism. Affordances are not produced by agents' intentions, nor are they merely projected onto an object. That is why my attempt to use an object might fail, why the object might resist certain uses, why it might do things that I do not want it to do.

Given those real constraints, though, an object's affordances are potentially endless. A chair never forces me to sit in it. I could stand on the chair instead. I could hide behind it. I could use it as a doorstop, an end table, a clothes horse, or a music stand. It is impossible to list all of the chair's uses or features. This openness subverts technological determinism. A tool can always be put to some unexpected use.

This nondeterministic reciprocity between agent and thing challenges both sides of the dialectic. But it also raises new problems. If affordances are theoretically innumerable, why are certain uses of an object preferred over others? Why does it seem that a tool should be used in a certain way? Extending ecological psychology here requires an account of artifact-based skills that are learned, culturally and technically situated, and directed toward goals. To this end, David Kirsh offers the idea of the "enactive landscape," a set of affordances that are activated for an agent. In other words, an enactive landscape is a space of possibilities, in which technology and technique coevolve. As Kirsh puts it, "Music teaches us that these … landscapes multiply furiously" (2013, §2.6). Musical instruments, specifically, "provide musicians the physical landscape necessary to change their possibilities—to create a perfect niche for making music" (§2.6).

This chapter investigates enactive landscapes associated with a specific instrument: the diatonic harmonica, colloquially known as the "blues harp." Though the harmonica's origins are poorly documented, it was likely invented in Germany around the 1820s as part of a vogue for free-reed instruments that also produced the accordion, the concertina, and various forgotten cousins (like Christian Buschmann's "aura" and Charles Wheatstone's "symphonium").[2] In the second half

2. These free-reed instruments were directly or indirectly inspired by traditional Asian mouth organs such as the Chinese *sheng*, which had been known in Europe since the seventeenth century (for example, Marin Mersenne described such an instrument in his 1636 *Harmonie universelle*). On the origins of the diatonic harmonica, see Missin (n.d.) and Field (2000, 23–24).

Figure 3.1 A ten-hole diatonic harmonica, or "blues harp."

of the nineteenth century, the diatonic harmonica would be industrially mass-produced and exported globally (Wenzel and Häffner 2006). It was portable, fairly durable, and inexpensive—and these features contributed to its widespread popularity. The harmonica's use in folk music, blues, and jazz shows how this seemingly simple instrument supports multiple enactive landscapes. Such landscapes call for a mode of analysis that investigates performers' moves through instrumental space, an approach that may be informed by statements from expert players and by Lewinian transformational models. At the same time, this analysis motivates theoretical reflections on instrumental spaces and idioms—and ultimately an argument about technical agency.

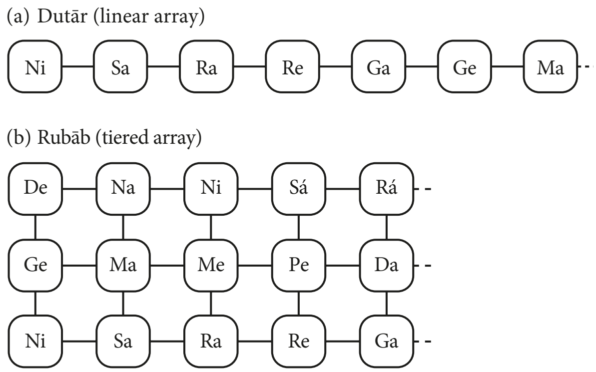
Instrumental Spaces

The harmonica fits in my palm, but my hands cannot make it sound. The harmonica, after all, is a particular sort of wind instrument, a "mouth organ."[3] It has ten square holes, lined up on a comb (Figure 3.1). Breathing through these holes activates tuned reeds hidden beneath the instrument's metal cover plates. Here air and sound are immediately joined, in their timing and their strength. The instrument is louder when I blow harder; it stops resonating when I stop moving air through it. Briefly put, the harmonica converts my breath into music.

This action-sound coupling differentiates the harmonica from free-reed instruments that have bellows. With the accordion, squeezing and pulling arms activate sound while fingers control pitch. With the harmonica, breathing provides both power and steering. Breath strength controls dynamics, while breath placement and breath direction control pitch. Because of its two sets of reeds, inhaling and exhaling through the same hole give different notes. Moreover, the "draw" notes (produced by inhaling) and the "blow" notes (produced by exhaling) form two tonally distinct collections. Each of the harmonica styles analyzed here somehow

3. This is reflected in its original German name, *Mundharmonika* (mouth harmonica). Note, however, that it affords breathing-through for other animals too: for example, the Smithsonian's National Zoo has a harmonica-playing elephant that holds the instrument in her trunk (Fazeli Fard 2012).

Figure 3.2 Two instrumental "arrays" (after Baily 2006, 116): (a) with the *dutār*'s linear array, the player moves *along* a single string (for example, the pitch "Ma" is five "steps" to the right of "Sa"); (b) with the *rubāb*'s tiered array, the player can also move *across* strings (finding "Ma" at the same fret as "Sa," on the adjacent string).



responds to this complementarity between the instrument's pitch affordances and human physiology. In a sense, the harmonica musicalizes respiration.

At the same time, the ten holes on the comb set out a pitch continuum much like a keyboard. Low notes are on one end (typically held on the left); high notes, on the other. Such linearity is common among instruments, though not universal. (Instruments that set out pitch space in a nonlinear way include mbira, steel drums, and bandoneon.) As I play, I coordinate my lips and the holes, moving the harmonica left or right with my hands and sliding my mouth along the comb. Since I can also change pitch by reversing the direction of my breath, harmonica space offers two basic ways of moving—side to side and in and out. It has two "dimensions."

The ethnomusicologist John Baily explores this multidimensional aspect of instrumental interfaces in his study of two Afghan lutes, the *dutār* and the *rubāb* (1977, 2006). Though their repertoires overlap, their instrumental spaces are quite different.[4] With the *dutār*, melodies are usually played on one string, shifting along a single dimension. With the *rubāb*, melodies are usually played across three strings. Baily calls the former a "linear array" and the latter a "tiered array."[5] He illustrates their difference with a diagram resembling Figure 3.2.

Thinking in terms of "arrays" highlights different kinds of *proximity* in instrumental space. I imagine their dimensions in terms of intersecting instrumental "scales" (using Dmitri Tymoczko's [2011, 116] expansive definition of "scale" as "a kind of musical ruler"). If I am blowing through the harmonica's third hole, I can move "one step" along the comb to the fourth-hole blow *or* I can move "one step"

4. In fact, musicians in the city of Herat devised the fourteen-stringed *dutār* in the 1960s so they could play classical music associated with the *rubāb*.
5. Baily and Driver (1992) extend this thinking to folk-blues guitar playing.

with my breath, changing to the third-hole draw. In both cases, I sense a kind of adjacency, although neither move would sound a diatonic "step."[6] Before investigating the harmonica's pitch affordances, however, I want to formalize this idea of instrumental spaces with particular dimensions.

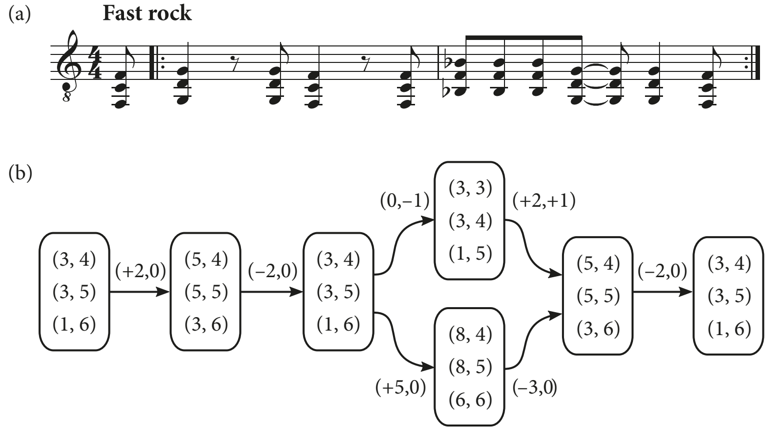
Instrumental arrays—instruments with dimensions that are divided into steps—can be represented via Lewinian transformational theory. As mentioned in the preceding chapter, this approach uses mathematical groups to model various kinds of musical spaces and actions, involving pitch, rhythm, texture, or other domains. Joti Rockwell (2009), for example, has used transformational techniques to analyze picking patterns on the five-string banjo. Since transformational theory deals with grouplike structures involving discrete quantities, it may not apply to instrumental spaces that lack countable steps (such as the timbral space of a drumhead). Nonetheless, it offers a productive way to model many kinds of instrumental patterns.

Tiered-array instruments like *rubāb*s and guitars involve two dimensions—across and along the strings. In other words, any spot on the fingerboard can be modeled as a combination of fret position and string position. I write this as an ordered pair of the form (f, s), with both variables represented by integers.[7] Elements can then be transposed in either dimension: across-string operations would take the form (0, $+x$) or (0, $-x$), where x is any nonzero integer; along-string operations, ($+x$, 0) or ($-x$, 0). Note that the numbers in my operation labels are marked with a plus or minus sign. This emphasizes that they indicate movement and also differentiates them from the notation for elements. That is, (+1, +1) represents an action (going up one string and up one fret), whereas (1, 1) represents a place (the first fret on the first string). Such transformations can be applied either to individual elements in the space (that is, notes) or to sets (melodies or chords). The network in Figure 3.3, for example, models such moves in a passage from the Kinks' 1964 song, "All Day and All of the Night." This sequence moves a single fretboard shape around the fretboard. There is, however, more than one way to realize this: moving along and across the strings or staying on the lowest three strings throughout (see Video 3.1▶).[8] As with Heyde diagrams, transformational graphs and networks can be read in various ways. It is generally useful, however, to trace the pathways formed by the arrows.[9]

By comparison, elements in harmonica space can be modeled as ordered pairs of the form (h, σ), where h is the hole (represented by an integer) and σ is a sign (+ or –) that corresponds to blow or draw. For example, (3, +) is the third-hole blow. (This labeling method resembles common forms of harmonica tablature.) In

6. The first move, from third-hole blow to fourth-hole blow, creates a perfect fourth; the second, from third-hole blow to third-hole draw, produces a major third.
7. For a more technical treatment of fretboard transformations, see De Souza (2016b).
8. Timothy Koozin analyzes this passage in a network that combines "fret-interval types" with neo-Riemannian operations and pitch-class transposition (2011, ex. 2). I analyze more complex along-string transformations in Chapter 4 and more complex cross-string transformations in Chapter 5.
9. The layout of Lewin's graphs and networks was partially inspired by Jeanne Bamberger's use of Montessori bells in cognitive research (see Lewin 1993, 45–53). These bells can be arranged in diverse ways, effectively enabling children and adults to design their own instrumental spaces.

Figure 3.3 Introduction/verse riff from the Kinks, "All Day and All of the Night" (1964): (a) notation; (b) transformation network, showing two ways of realizing the riff in fretboard space. The riff uses a single fretboard shape. The upper route in the network includes cross-string transformations, whereas the lower route includes only along-string transformations. Note that guitar strings are conventionally labeled 1–6, with 1 as the string with the smallest diameter (typically the highest string) and 6 as the string with the largest diameter.



the ordered pairs that label harmonica transformations, though, the signs + and – represent preservation or change in blowing direction.[10] This is illustrated by the spatial network in Figure 3.4. In the nodes, the signs refer to breath direction; on the arrows, they refer to preservation or change. To get from the third-hole blow (3, +) to the fourth-hole draw (4, –), for example, I move one step up the comb and reverse my breath (+1, –). Again, this works for individual elements or sets.

Readers who are familiar with transformational theory may note that the group structures underlying these two models reflect different kinds of dimensionality. The tiered array is based on a group that is isomorphic with $\mathbb{Z} \times \mathbb{Z}$, while harmonica space is based on a group that is isomorphic to $\mathbb{Z} \times \mathbb{Z}_2$. Neither is modular like pitch-class space—that is, the top never flips around to the bottom. This also means that they must be theoretically infinite, that an actual instrument partakes of only a selected range of the abstract space.[11]

10. Julian Hook's uniform triadic transformations use these same signs for modes and modal changes. As Hook explains, "The set {+, –} forms a multiplicative group isomorphic to the additive group $\mathbb{Z}_2$ of integers mod 2" (2002, 62). Multiplying a sign by itself gives +; multiplying the two signs together gives –. This group can model other instrumental features too: for example, bowing or picking direction readily maps onto $\mathbb{Z}_2$, and trumpet valve positions can be represented as ordered triples of the form (σ, σ, σ).
11. Imposing boundaries here would cause formal problems, since it would no longer be possible to define intervals or transformations that hold for any element in the space (see Lewin 1987, §2.3.1; Rings 2011, 19). This is why the models of Rockwell (2009) and Koozin (2011), which specify finite sets of strings, cannot define cross-string transformations (see De Souza 2016b).

Figure 3.4 Spatial network for three adjacent harmonica holes. Reversing breath on the same hole is represented by the operation (0, –); moving along the comb, by operations of the form (+*x*, +) or (–*x*, +). These are combined in (+1, –), which moves up one hole and changes breath. Note that many operations in this space are not shown on this network. These include inverses—for example, (−1, +) is the opposite of (+1, +)—and compound moves, such as the (+2, –) action that would take (3, +) to (5, –).

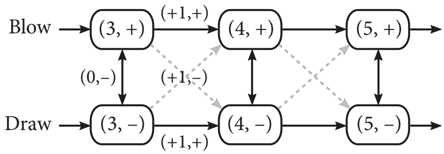


Figure 3.5 Stevie Wonder, electric-piano introduction from "I Wish" (1976). The head of this riff starts on E♭ and moves up through black-key space. Its tail starts on C and moves up chromatically to E♭. Though each measure repeats the same sequence of key and pitch classes, they have distinct pitch contours.

Some instruments, though, can be modeled as modular spaces. For example, it is possible to imagine the twelve "key classes" on a piano in terms of the integers mod 12 ($\mathbb{Z}_{12}$)—that is, the mathematical group that corresponds to the numbers on a clock face. This keyboard space, unlike fretboard or harmonica space, has a single dimension. Yet it, too, involves more than one kind of adjacency. I can move chromatically to the next key, or I can move to the next key *of the same color*, as in various "white-note" or "black-note" pieces (like the Chopin étude in Figure 1.8).[12] Mark Spicer (2011) cites the electric-piano riff from Stevie Wonder's 1976 hit "I Wish" as an example of a black-note figure (see Figure 3.5).[13] In fact, this riff involves *both* types of adjacency in keyboard space. Though it initially climbs through a black-note pentatonic scale, the riff later drops to C and ascends chromatically to its starting note. While chromatic movement would be represented

12. In a presentation at the Society for Music Theory's mathematics interest group, Hook (2014) discussed key-color invariance and pitch-class transformations, an issue with interesting consequences for fingering choices. James Bungert (2015) also considers key color in his analysis of performance gestures in a Bach corrente, though his approach eschews mathematical formalism.
13. Noting that Wonder's keyboard riffs often highlight black keys, Spicer (2011) speculates that the blind musician might use these raised keys to orient himself at the instrument. Will Fulton confirms the tactile significance of the black keys, showing a distinctive hand position in which "Wonder keeps the thumb of his right hand at or below the ridge of the keys' surface, allowing him to gauge his position, with his remaining digits on the black keys" (2015, 275).

Figure 3.6 (a) "Key-class" space and (b) a transformation network that shows the mapping for an operation Key. Key takes each key class "up" to the adjacent key class while preserving key color, creating a white-key cycle and a black-key cycle.

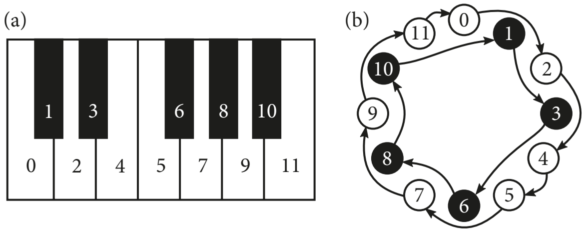
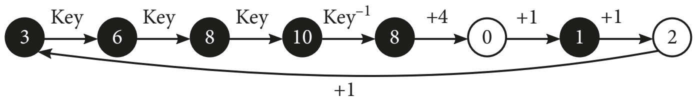


Figure 3.7 Transformation network for Wonder, "I Wish" riff. Node shading indicates key color.



via mod-12 addition, same-color movement can be modeled by an operation that I will call Key. As shown in Figure 3.6, this function neatly partitions the key classes into discrete white-note and black-note families. Note also that it can be compounded and inverted: for example, Key^2 moves up two same-color key classes, and Key^{-2} reverses that. With this new theoretical tool, it is easy to create a transformation network for the "I Wish" riff, which highlights these two kinds of movement at the keyboard (see Figure 3.7).

This model of key-class space conveniently replicates numerical note labels from pitch-class set theory. However, my networks represent locations on the instrument, not notes themselves.[14] In other words, *the topography of an instrumental interface is theoretically independent of any particular tuning*. Before particular melodies or harmonies can be derived from these networks, the space must be connected with some set of notes. I call this an instrument's *place-to-pitch mapping*.

The piano has a *one-to-one* mapping: each pitch has a single location on the keyboard. Yet other instrumental spaces—such as the guitar's tiered array or the organ's multiple manuals—have a *many-to-one* mapping, in which the same pitch might be found in more than one place.[15] This kind of many-to-one place-to-pitch mapping is also common to woodwinds like the clarinet, whose side keys permit a range of alternative fingerings. Still others have a *one-to-many* mapping. On the

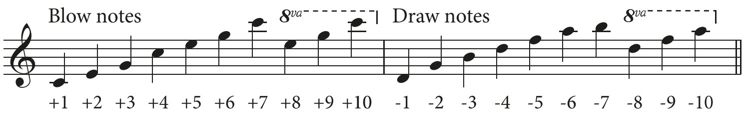
14. In this regard, my approach aligns with Joti Rockwell's transformational model of five-string banjo music. Rockwell defines a function called PITCH that maps fret/string locations on the banjo to pitches (2007, 205).
15. In mathematical terms, such mappings are "onto" or "surjective" (see Rockwell 2009, 140).

Figure 3.8 Pitch layout for a ten-hole diatonic harmonica in C: (a) chart of pitch layout for a harmonica in C, opposing blow and draw notes on each hole; (b) pitches of a harmonica in C in notation (with tablature). Note that pitch references follow the nomenclature established by the Acoustical Society of America, where C4 is middle C.

(a)

Blow	C4	E4	G4	C5	E5	G5	C6	E6	G6	C7
Hole	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
Draw	D4	G4	B4	D5	F5	A5	B5	D6	F6	A6

(b)



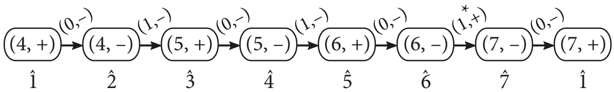
trumpet or tuba, for example, a particular set of valve positions affords not one note but a series of harmonics. The harmonica's mapping is, in a sense, both many-to-one and one-to-many. One pitch appears in two distinct places, and certain hole–breath direction combinations offer multiple notes.

Blowing through a standard ten-hole harmonica gives a major triad spanning three octaves; inhaling gives the remaining notes of a diatonic scale (see Figure 3.8 and Video 3.2). This tuning pattern—known as "Richter tuning"—has several idiosyncrasies.[16] It repeats $\hat{5}$ among the drawn notes (in an isolated many-to-one mapping), so the in-breath and out-breath give tonic and dominant chords. The bottom octave (holes 1–4) opposes these triads, skipping $\hat{4}$ and $\hat{6}$. The other end of the instrument omits the leading tone. That is, the harmonica does not just lack nondiatonic "chromatic" notes: depending on register, certain diatonic scale steps are absent too. (In its middle register, for example, the harmonica affords "Oh! Susanna" but not "Amazing Grace.") This might be understood in terms of a distinction, made by Tymoczko (2011, 11), between "scale" (again, a musical ruler) and "macroharmony" (the total collection of pitches actually appearing). The notes on the harmonica can be reckoned in terms of a diatonic scale, but its macroharmony is a pattern of nineteen pitches where no two octaves are identical.

Register also affects the relation between blow and draw notes. On holes 1–6, draw notes are higher than blow notes; this is reversed for holes 7–10. In the words of one player, above the sixth hole "is where the harmonica flip flops" (Holmes 2002). This spot stands out when one is learning to play a major scale on the instrument. As the network in Figure 3.9 shows, movement along the comb is consistent throughout the scale: after every second note, I move up one hole. (Note the regular alternation of 0 and +1 in the first part of the ordered-pair labels on the network's arrows.) But I must change my breathing pattern above hole 6: when

16. As Pat Missin (n.d.) shows, we do not know exactly who "Richter" was or when he developed this tuning.

Figure 3.9 Network for a harmonica's central major scale. The asterisk between scale degrees 6 and 7 marks a deviation in breathing pattern: this is the only place where the player preserves breath direction, inhaling twice in a row.



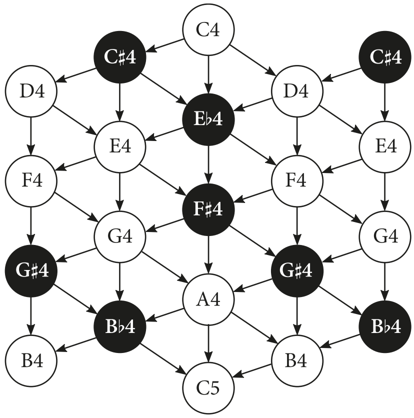
I move to the seventh hole, I keep my breath direction the same and inhale for two notes in a row. This (+1, +) transformation, marked with an asterisk, is the only one in Figure 3.9 that involves a + sign for breathing direction. More generally, this "flip-flop" means that any tune that combines blowing and drawing will have a different breathing pattern for each octave. Note, in fact, that only one pair of holes has the same pitch-class affordances. (Holes 1 and 4 both offer $\hat{1}$ on the blow and $\hat{2}$ on the draw.)

Many harmonica players explore the instrument's two dimensions without explicitly thinking about individual notes from Figure 3.8. Picking up the instrument as a child, I simply felt the consonant stability of the blown major triad. Draw notes, from this perspective, could fill in the gaps in this triad. This shows how an instrument's place-to-pitch mapping may involve hierarchical levels, somewhat like the nested pitch spaces theorized by Fred Lerdahl (2001, 49–50). Here the harmonica's major triad—the piano's white keys, the five-string banjo's open G chord, perhaps even the diatonic notes of the saxophone's finger keys—functions as a *referential pitch framework*, whose steps can be subdivided. In the cases just mentioned, the referential structure is essentially diatonic, which adds a certain asymmetry to the interposition of intermediate notes.

Because of its characteristic gaps, the harmonica's place-to-pitch mapping exhibits a certain *irregularity*. That is to say, consistent moves in harmonica space produce variable pitch intervals. The (+1, +) transformation, as highlighted in Figure 3.9, produces a major second when it starts from (6, –). But this move—going one step up the comb while maintaining breath direction—more commonly sounds a minor third, major third, or perfect fourth. There is a mismatch here between instrumental scale and pitch scale. By contrast, chromatic button accordions like the Russian *bayan* have a *uniform* place-to-pitch mapping. The evenness of its equal-tempered pitch collection is matched by its physical topography. The *bayan*'s regularly spaced melody buttons set out three maximally even interval cycles: as Figure 3.10 shows, the vertical axis moves by minor thirds, creating a diminished-seventh space; the major seconds of the northwest/southeast diagonal offer whole-tone scale segments; the minor seconds of the northeast/southwest diagonal, chromatic-scale segments.[17] This means that each pitch interval or melodic pattern has a consistent shape, which may theoretically start on any button. Furthermore, keyboard shapes transpose and invert just like pitch collections.

17. On symmetrical divisions of the octave in the English concertina, see Gawboy (2009). On the theory of maximally even sets more generally, see Clough and Douthett (1991).

Figure 3.10 Partial map of a *bayan*'s tuning pattern. Unlike the piano, the *bayan* offers the same pitches in multiple places. This network shows the octave between C4 (middle C) and C5. (Lower pitches are at the top of the network, reflecting the way that the instrument is held.) Each button, represented by a node, can be understood as the intersection of three consistent dimensions. Descending arrows move +3 semitones in pitch space; rightward arrows, +2 semitones; leftward arrows, +1 semitone.



Because of the *bayan*'s many-to-one place-to-pitch mapping, there are also many opportunities for alternative fingerings. These features, of course, differ in significant ways from the nonrepeating breathing patterns of the harmonica and the one-to-one mapping of the piano.

For emphasis, let me briefly present another variation on irregularity/uniformity with strings instead of free-reed instruments. The standard tunings for violin and double bass involve consistent intervals between adjacent strings, moving by perfect fifths or perfect fourths, respectively. This means that a fingering pattern generally creates the same sounding intervals, starting on any string.[18] The five-string banjo, though, is tuned to a G-major chord. Its place-to-pitch mapping is irregular, much like the harmonica's. Because each pair of adjacent banjo strings forms a different pitch interval, melodic fingerings change depending on their position in cross-string space.

If uniform mappings facilitate transposition, irregular ones may foster the sense of a privileged "home key." Players of instruments with irregular mappings, then, often change their instrument when they want to change keys. I put a capo on the banjo to create open strings that fit a new key, or I get another harmonica from the case.[19] Such adjustments can help preserve connections between locations in

18. To be precise, this works only for fingering patterns that do not involve the open strings—a boundary of the instrumental space.
19. A capo is a small device that clamps onto the neck of a guitar or banjo, stopping all the strings at the same fret. By transposing the open strings, it allows a player to use familiar chord voicings in any key. For example, I might use a capo to play in A♭ major: playing in "G major" with a capo on the first fret, in "E major" with a capo on the fourth fret, and so on.

an instrumental space and particular tonal qualia. It is easy to switch from one harmonica to the next because their physical interface is identical and their instrumental scales are related by exact pitch transposition.[20] (A similar situation applies to the various members of the saxophone family—and is reflected in their transposing notation, which specifies the note on the instrument, not the concert pitch.) That said, there are subtle differences in the feel and timbre of harmonicas that are tuned in different keys. In terms of ecological acoustics, these distinctions between high and low harmonicas are related to differences in material, specifically the reeds' restoring force (see Gaver 1993, 10). Lower-pitched harmonicas—for example, in A or G—speak easily and have a more mellow sound. Their reeds are more flexible. Higher-pitched harmonicas, like E, require stronger, supported breathing and have a brighter tone. The reeds' flexibility also affords one of the harmonica's most characteristic gestures: bending.

Once again, my breath not only initiates but also sustains the harmonica's sound. I can use breath, then, to add accents or vibrato. By changing breath pressure, along with mouth and tongue position, I can temporarily shift the pitch. This adds a degree of *mobility*, a term that I borrow from the Renaissance theorist Gioseffo Zarlino (1588, 218–20). The concept emerges from Zarlino's disputes with Vincenzo Galilei about tuning.[21] "Mobile" instruments can bend notes. This means that, like voices, they can make music in just intonation (which Zarlino believed to be numerically perfect). By contrast, "stable" instruments have fixed pitches and, therefore, require tempering. Violin, trombone, and theremin are mobile instruments, while piano and xylophone are stable ones. The former group can slide through the pitch continuum, whereas the latter divides it discretely. Since the intonation for mobile instruments is not strictly governed by holes or keys, playing them in tune relies on physical and auditory feedback. Players of these instruments, in other words, have to worry about tuning in a way that pianists do not. That said, they also have greater flexibility in the pitch discriminations they can employ, which makes it possible to more precisely match their pitch to that of other players. Zarlino includes a subcategory for stable instruments with some measure of mobility, since performers of certain instruments can alter pitches through blowing or fingering. The harmonica belongs here, combining stability and mobility.

The harmonica affords bending only in particular places (see Figure 3.11). This depends on the physics of the paired reeds.[22] Only the higher note on a hole can be

20. This suggests that canonic music-theoretical relations may be relevant to instrumental pitch mapping. Open strings on the violin and mandolin share the same pitches, while those of the viola and cello share pitch *classes*. Viola and violin have the same pitch intervals between strings, but with different pitches. Ukulele strings share unordered pitch-class intervals with the highest four strings of a guitar (but neither pitch classes nor pitch intervals). This is far from abstract for a guitarist picking up the ukulele for the first time: recognizing it allows a guitarist to use familiar fretboard shapes on the unfamiliar instrument.
21. For a discussion of Zarlino and Galilei's relationship and its historical context, see Palisca (1961). Note that Zarlino's distinction—in terms of Heyde's organology—would roughly correspond to a distinction between "continuous volume control" and "discrete state control" for pitch.
22. For an experimental investigation of harmonica pitch bending, see Johnston (1987).

Figure 3.11 Bending chart for a diatonic harmonica in C.

										B♭6
Blow bend								E♭6	G♭6	B6
Blow	C4	E4	G4	C5	E5	G5	C6	E6	G6	C7
Hole	1	2	3	4	5	6	7	8	9	10
Draw	D4	G4	B4	D5	F5	A5	B5	D6	F6	A6
Draw bend	D♭4	G♭4	B♭4	D♭5		A♭5				
		F4	A4							
			A♭4							

bent, meaning that the breathing direction for bends again "flip-flops" around hole 6. The bent note is always pulled down, and notes can be bent only into the space between the blow and draw. That is why there are the most possibilities on hole 3, where the blow and draw are a major third apart, and why bending is impractical on holes 5 and 7, where they are only a semitone apart. In general, the draw bends on the bottom half of the instrument are the easiest to play, because the reeds are lower-pitched and therefore more flexible. And this difference is important for various styles of harmonica performance.

Idiomatic Multistability: Folk, Blues, and Jazz Harmonica

Mapping an instrumental space only begins to reveal how players inhabit it, for the enactive landscapes that an instrument supports appear most fully in performance. Here the investigation proceeds on two levels. It examines individual performances, using transcription and close analysis. Yet these details also inform broader comparison. Like a set of phenomenological variations, interlinked analytical vignettes bring out broader patterns of variance and invariance. They show how an instrument's affordances ground its styles without fixing them. Analyzing harmonica performance thus drives a music-theoretical argument against technological determinism. It demonstrates how instrumental idioms are negotiated, emerging from the interaction of player and instrument.

Bob Dylan, "Queen Jane Approximately"

Such negotiation is particularly clear when a melody needs one of the harmonica's "missing notes." My grandfather played this way at family sing-alongs, either substituting a nearby pitch for the missing note or breaking away from the melody

Table 3.1 Harmonica tablature symbols used in transcriptions (numbers refer to holes on the instrument)

+	Blow
–	Draw
′	Semitone bend
″	Whole-tone bend
″′	Minor-third bend
°	Overblow
s.	Tongue slap
vib.	Throat (not hand) vibrato

to add an accompanying line. This is required less frequently, though, when one is playing major-key folk tunes that emphasize the tonic triad. Figure 3.12a, for example, presents basic harmonica tablature for Bob Dylan's "Queen Jane Approximately" from his 1965 album *Highway 61 Revisited*. In this notation, numbers correspond to the holes of the instrument: a number on its own represents a blown note; one with a minus symbol represents a drawn note. Figure 3.12b presents the tune in notation. (For an explanation of symbols used in this and following transcriptions, see Table 3.1.) The melody is quite easy to play, despite its demand for nearly constant exhalation. Only seven of its forty-eight notes are drawn. (It is also easy because it mostly involves staying on the same hole or moving to an adjacent one.)

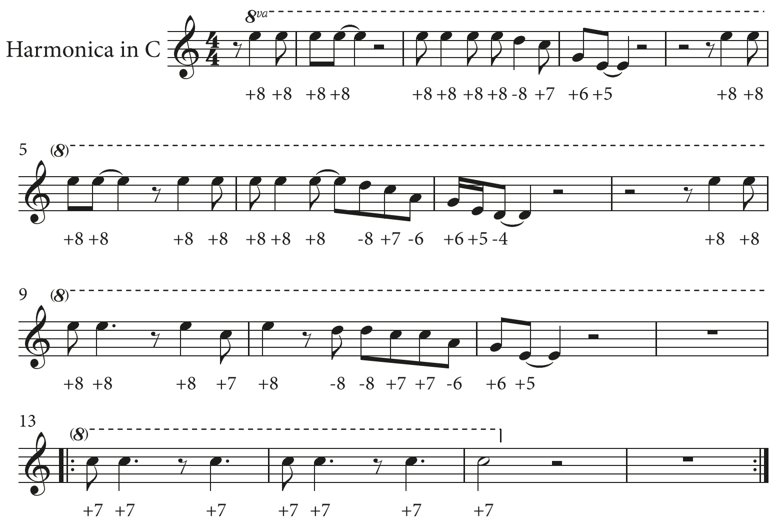
Since the basic tablature of Figure 3.12a gives single numbers, it might seem that only one hole is played at a time. But the harmonica readily affords chords—within specific limits. It is easy to play I and V triads, and V^7, ii, and $vii^{ø7}$ chords are also possible in particular spots. (Other chords, of course, are not available.) Harmonica players often use chords as a kind of melodic thickening, with the player's mouth taking in more of the comb.

This approach is central to a folk-harmonica style that is particularly associated with Dylan. His solo on the studio recording of "Queen Jane Approximately" begins in the middle register: a two-note pickup leads to a held single tone (at 3:13 on the original track), which Dylan gets by pursing his lips (see Figure 3.13). As he repeats the pickup gesture, however, Dylan takes in more notes (m. 5). He starts the third phrase with a similar pickup but shoots to the top of the instrument, repeating the held G/C dyad on holes 9 and 10. Dylan then ends the phrase by jumping down to a tonic chord (end of m. 10). The final phrase—the eight-bar group where the song repeats "Won't you come see me, Queen Jane?"—stays with this open-mouth chord, rhythmically huffing and puffing, gradually returning to hole 6 (3:41–3:58). This short solo shows off several of the harmonica's affordances, exploring its possibilities for single notes and full chords, the tonal opposition of blow and draw, and all three octaves. Dylan explores the instrument's side-to-side dimension in m. 9, while the end of the solo privileges its in-and-out dimension.

Figure 3.12 Bob Dylan, melody from “Queen Jane Approximately” (1965).

```
 8    8       8    8    8    8    8   -8  7  6  5
When your mother sends back all your invitations

 8   8    8  8  8   8    8  8  8 -8 7 -6 6 5 -4
And your father to your sister he-- ex---plains

 8     8    8  8  8   7   8    -8 -8  7   7   -6  6  5
That you're tired of yourself and all of your creations

  7    7   7    7   7    7    7
Won't you come see me, Queen Jane?

  7    7   7    7   7    7    7
Won't you come see me, Queen Jane?
```

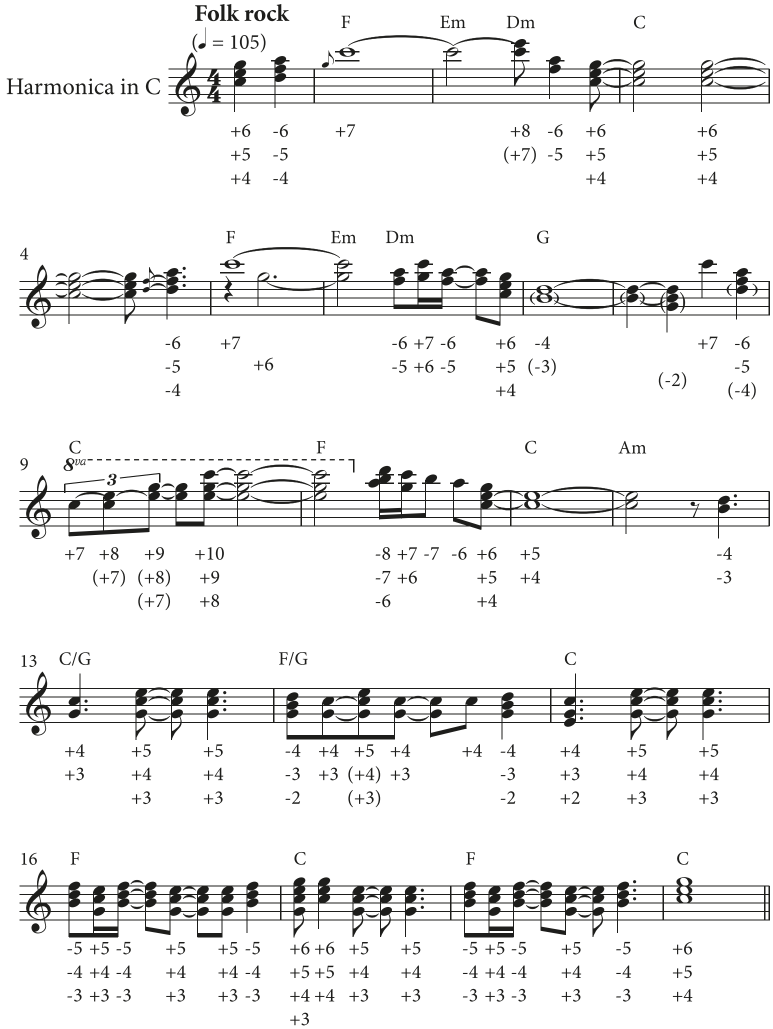
(a) Tablature from harptabs.com, posted by “chibluesteve”



(b) Notation (annotated with harmonica tablature)

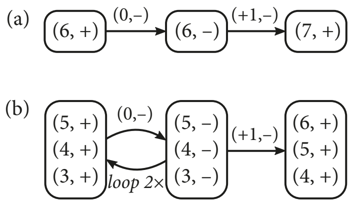
The transformational networks set out in Figure 3.14 reveal a correspondence between the solo’s beginning and its end, which is demonstrated in Video 3.3. The repeated “pickup gesture” and the cadential “huffing and puffing” are rhythmically and melodically distinct. Yet they involve the *same operations in harmonica space*. (Recall that I model elements in this space as the combination of hole and breath direction, written as an ordered pair of the form (*h*, σ [sign]).) Dylan’s pickup melody, represented as a single line in Figure 3.14a, reverses breath on the same hole (0, –) and then reverses breath again while moving up one hole (+1, –). The closing realizes these actions on lower holes (first in mm. 15–17, then in mm. 17–19; see Figure 3.14b). Here Dylan realizes the gesture with full chords throughout, cycling the initial (0, –) before the final (+1, –).

Figure 3.13 Bob Dylan, harmonica solo from “Queen Jane Approximately” (1965).



This ((0, –), (+1, –)) motion is characteristic of the major-scale pattern presented earlier in Figure 3.9. Yet the opening of Dylan’s solo places this gesture on holes 6 and 7, the spot where the harmonica switches between drawing-to-move-up and drawing-to-move-down. (Recall that this is where the scale in Figure 3.9 deviated from this characteristic pattern.) This strategy produces the pentatonic-tinged G–A–C that is prominent throughout the solo: Dylan moves directly between (6, –) and (7, +) seven times, adding the intervening (7, –) only once. The instrumental placement of $\hat{6}$, then, shapes the sound of this solo and, more generally, Dylan’s style of playing harmonica.

Figure 3.14 Transformational networks for Dylan's solo on "Queen Jane Approximately": (a) network for melodic pickup from mm. 1–2 and mm. 4–6 of Dylan's solo on "Queen Jane Approximately"; (b) network for end of Dylan's solo on "Queen Jane Approximately" (mm. 15–17, then repeated immediately in mm. 17–19).



It bears mention that this style has often been criticized. One player describes it as follows: "Almost no bends, lots of chords, lots of go-forth-and-back-notes. No harp teacher I know will teach his students to play like that" (Shikida 2007). In this view, Dylan's harmonica playing lacks skill; it reflects the technology's raw affordances. Dylan himself acknowledges that this technique is not considered to be "proper," but says it defines his "harmonica and guitar sound." "Most of the time, I would blow out of the harmonica," he explains, "because everybody sucks in. The proper way to play is like Little Walter or Sonny Boy Williamson would play—which would be to cross it—and I found myself blowing out more because nobody was doing it in that area" (quoted in Appleby 1992, 20).

Sonny Boy Williamson II, "Born Blind"

Dylan's reference here is to the "cross-harp" or "second-position" style of playing associated with blues harmonica.[23] Cross-harp playing interprets the instrument's tonal affordances in a way that its nineteenth-century designers never expected. Where first position takes the blow chord as the tonic triad of a major scale, second position takes the *draw chord as the tonic* of a Mixolydian mode. A C harmonica, for example, can be used to play blues in G, affording both bending and a flat seventh scale degree. While folk-harmonica players, like most other wind players, inhale between phrases, blues players usually use such moments to expel air.[24] (This works well for blues-harmonica players who are also vocalists: they can breathe out while singing and breathe back in during short harmonica breaks between phrases.) This reflects the phenomenon that Don Ihde calls "multistability," which

23. Dylan also plays this style, though it is less closely associated with him. His cross-harp playing often ends up in a high register that blues players typically avoid (for example, see "Pledging My Time" from *Blonde on Blonde* [1966]).
24. Blues-harmonica tablature reverses the marked/unmarked categories represented by Figure 3.12. In blues-harmonica tablature, that is, an unsigned number denotes drawing, and blowing requires a plus symbol.

he finds in both visual illusions and technological variation (1986, 67–79). Like a figure/ground reversal, cross-harp playing flips the hierarchical relation between the harmonica's two chords, remapping the link between breath and tonal qualia while preserving the inhalation/exhalation pair.

Demonstrating G blues with a C harp, the noted harmonica player John Sebastian discusses one tonal consequence of this position: "What you don't have really is what they call the dominant or the D chord. All you have is your D note [on the first- and fourth-hole draw]." Sebastian, however, thinks of that challenge as an *opportunity*. "And so that's where your creativity is really going to come into play here because it's during that V chord, dominant chord, whatever you want to call it, the D-seventh or D chord that the harmonica has to play around to get the sound" (1992, 3:08).

Cross-harp playing also exploits the relatively easy draw bends on the bottom half of the instrument. This adds bluesy inflections and the chromatic notes that define the blues scale ($\flat\hat{3}$, $\sharp\hat{4}$, and $\flat\hat{7}$). Referring to a chart that resembles Figure 3.11, David Barrett (1995, 32) explains that the draw notes include twice as many bendable notes and three times as many "blue notes" as their blown counterparts. The draw bends, then, complement the flat Mixolydian seventh, and in this sense, the style is overdetermined.

Cross-harp position defines the dominant blues-harmonica idiom.[25] For example, consider Sonny Boy Williamson II's "Born Blind" (1957).[26] "Born Blind" is a blues in F played on a B♭ harmonica (see Figure 3.15). His solo features a repeated gesture that, in many ways, resembles Dylan's opening on "Queen Jane Approximately": a short pickup, a sustained note, then falling off (1:07 on the track). Williamson, however, mainly inhales, going between non-bent and bent notes. It is possible to hear the reeds' resistance in bent-down notes that rise up to their straight counterparts: for example, note the bending on hole 4 in m. 2 or the slow release of G up to A in m. 9.[27] (The latter also shows one way to "play around" the dominant in Sebastian's sense.)

While most of the solo is inhaled, in mm. 5–6 Williamson combines blowing and drawing in a characteristic triplet riff over the subdominant (1:16). This riff—which appears on other tracks by Williamson, such as "Help Me" (1963)—is demonstrated in Video 3.4 ▶. His tongue-slapping articulation thickens the texture here, subtly bringing out the I and IV chords that underlie cross-harp.[28]

25. The relatively rare examples of straight-harp blues—by Jimmy Reed or the Harmonicats—stick to the top register to exploit blow bends. Their sound is marked by the major-sounding sixth and seventh scale degrees.
26. "Born Blind" was a new version of 1951's "Sight to the Blind," which Williamson had recorded in Mississippi.
27. This bending can be understood in terms of ecological acoustics: here it is possible to hear deformation and return, as discussed by Gaver (1993, 10).
28. Barrett explains tongue slapping as follows: "When in the tongue blocking embouchure your lips are over three holes and two of those holes are blocked by your tongue. If you breathe in first and then quickly slap your tongue into position, all the air that it took to vibrate three holes is then punched through the one hole left over. The effect is a thicker sound because of the initial vibration of the three holes, and a wicked attack on the hole left over" (1995, 92).

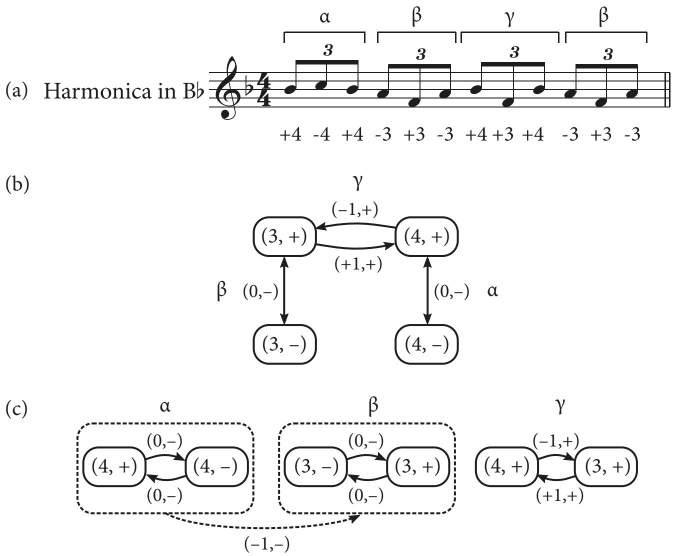
Figure 3.15 Sonny Boy Williamson II, harmonica solo from "Born Blind" (1957). (A slightly different transcription appears in Weiser 2001, 55–56.)

Figure 3.16a presents a schematic version of the riff and labels its three distinct segments α, β, and γ. Locating them on a spatial network derived from Figure 3.4 shows how each segment involves a kind of "neighboring" motion in harmonica space: γ moves along the comb, while α and β alternate breathing on the same hole (see Figure 3.16b). Figure 3.16c frames each of these as a loop. This clarifies some relationships between α and β. First, they grow out of the same basic (0, –) transformation. Moreover, α actually becomes β when it is transposed down one hole with inverted breathing (–1, –). The flipped breath pattern that takes α to β is physically immediate when one is learning this riff, as is their dimensional difference from γ.[29] One player visualizes this as a kind of "knot" in harmonica space (Graham, n.d.).

The emphasis on drawing repeats with the return of tonic harmony in m. 8, when Williamson returns to a variation on his opening gesture. The remainder of the solo stays with the bottom three holes of the harmonica. With the final return of tonic harmony (m. 11), though, a moment sticks out: at the bottom of a falling

29. In *Mel Bay's Complete Classic Chicago Blues Harp*, Barrett (1995, 59) presents an exercise that systematically takes the γ triplets from one end of the harmonica to the other, both blowing and drawing.

Figure 3.16 Williamson's triplet riff from "Born Blind," mm. 5–6: (a) notation with tablature; (b) spatial network, placing riff segments in harmonica space; (c) network showing (−1, −) relationship between segments α and β.



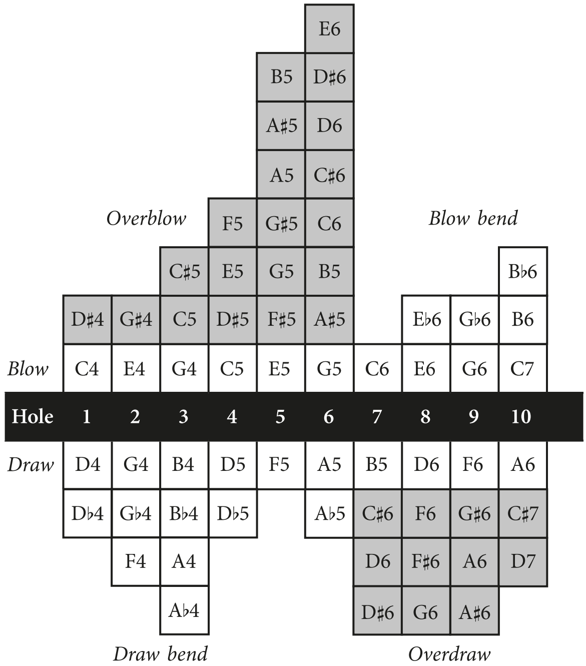
line, Williamson briefly blows the first hole, sounding a B♭ ($\hat{4}$), which is the bottom boundary of the instrument but which does not fit the chord. For a knowledgeable listener, this example of what David Temperley (2007) calls "melodic-harmonic divorce" briefly reveals the instrument's underlying pitch collection.

Where Dylan effectively uses the harmonica's full range on "Queen Jane Approximately," Williamson's solo stays on the bottom four holes. In other words, his high point is around Dylan's midregister home base. This registral preference responds principally to the possibilities for drawn bending in holes 1–4. This is not to say that Williamson never exceeds this range, only that it is less common in blues-harmonica playing. It does not seem coincidental that a solo in which he ventures into a higher register—during an extended jam on "Take Your Hand Out of My Pocket" (1958)—was not released until fifteen years after Williamson's death. When he uses the pentatonic subset around holes 6 and 7 and slides to the top holes—gestures central to Dylan's solo—the unbent notes, particularly the unadorned major IV triad, sound very unusual (2:12–2:29 on the recording). They go to the edge of the instrument and the edge of the blues-harmonica idiom.

Howard Levy, "Blues in Six Keys" and "Sweet Georgia Brown"

Just as second-position playing involves a Mixolydian interpretation of the harmonica's diatonic affordances, higher positions may exploit other modes. Third

Figure 3.17 Overbending chart for a diatonic harmonica in C.



position (or "double-cross-harp") is Dorian, the fourth is Aeolian, and so on, moving through a diatonic cycle of fifths.[30] Dylan, for example, uses such positions on minor-key songs like "All Along the Watchtower." Yet this technique has been explored most thoroughly by the Grammy-winning jazz-harmonica player Howard Levy, who has developed the ability to play any diatonic harmonica in any key.

Of course, extended modal positions do not, by themselves, step outside of the instrument's diatonicism. Levy also uses a technique of "overbending" that provides a full chromatic scale. "I realized that there were some missing notes on the ten-hole diatonic harp that just weren't there," he explains. "Being a pianist, I thought that this was impossible. They had to be there somewhere. So by stubborn experimentation, I found the missing six notes that allowed me to get a three-octave chromatic scale" (Musicians Professional Resource, n.d.). Without going into the physics of the phenomenon, overbending is effectively the opposite of bending: overblown notes are on the bottom half of the instrument, opposite to the draw bends; overdrawn notes are on the top, opposite to the blow bends; and where bending gave lower notes, overblowing gives higher ones (Holmes 2002; see Figure 3.17).

30. For a detailed introduction to harmonica positions, see Holman (2000).

Levy says that he visualizes a piano keyboard when he improvises on the harmonica (Paulson 2009). His extended technique, then, overcomes the harmonica's conceptual constraints by simulating another instrumental space.[31] By his account, he always thinks in C major, mapping the harmonica's open notes onto the keyboard's white notes and the bends and overbends onto the black notes (Levy 1992). This natural/chromatic opposition reveals a similarity between the conventional piano keyboard and Levy's overbending harmonica.

Levy demonstrates this approach in "Blues in Six Keys," the introductory performance from his instructional video *New Directions for Harmonica* (1992). With each twelve-bar chorus the tune moves up a semitone, starting in F major and ending in B♭. With the Dylan and Williamson examples, tonal patterns make it clear—to a harmonica player, at least—which key the instrument is in. Here this is less obvious. Overbending, after all, lends itself to single-note melodies, which Levy plays in a fully chromatic bebop style. Yet he also supplements this approach with gestures that are particularly idiomatic to the harmonica. These characteristic gestures reveal that Levy is playing a B♭ harmonica, which means that he begins the track in cross-harp position and finishes in straight-harp.

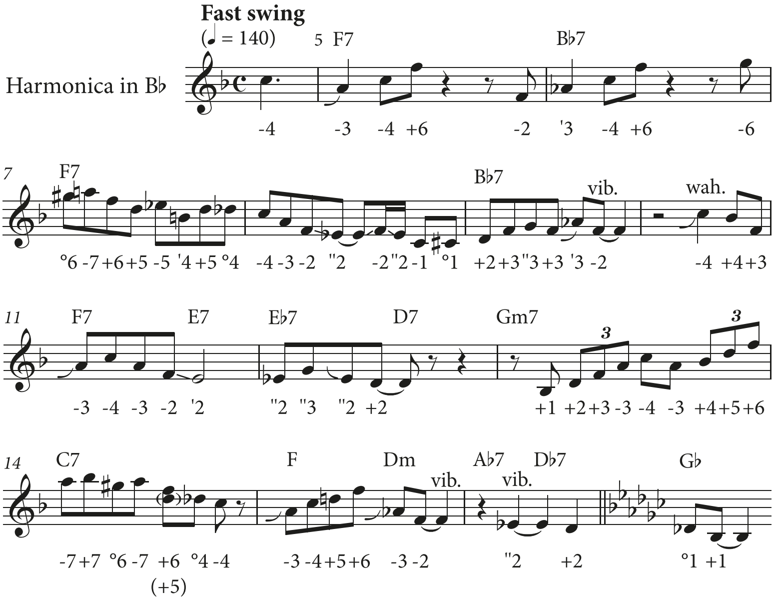
Several aspects of Levy's cross-harp section echo the blues style I illustrated with "Born Blind." Near the beginning, for example, he alternates between the $\hat{3}$ and the lowered $\flat\hat{3}$ that are both available on the third hole (mm. 5–6 in Figure 3.18). At the end of the first line (m. 8), Levy slides down to $\flat\hat{7}$ with a whole-step bend on the second hole—a gesture that Williamson explores in the corresponding measure of his solo from "Born Blind" (see Figure 3.15, m. 4).

The instrumental space may be even clearer when Levy plays on more than one hole at the same time. As Figure 3.19 shows, he repeats an A/C dyad in the fifth chorus, a blues in A (mm. 57–58). This gesture adapts part of the B♭ harp's drawn F dominant chord to the key of A major.[32] The start of the final chorus (in B♭) brings another trick typical of the harmonica: the shake. Shaking involves the sustained, rapid alternation between two adjacent holes; it is particularly characteristic of blues harmonica. Levy holds sustained shakes throughout mm. 65–66, gradually moving up the comb. Unlike most of "Blues in Six Keys," these measures reflect simple movement in harmonica space: the network of Figure 3.20 illustrates this repeated (+1, +) shift up the comb. (The D♭/F♭ blow bends on holes 8 and 9 maintain the exhalation from m. 65, even though they require different breath pressure.) After the sophisticated tonal twisting of several intervening keys, Levy has returned to the harmonica's stylistic and tonal home, to one of its easiest and most characteristic tricks.

In a complementary demonstration, Levy plays the jazz standard "Sweet Georgia Brown" in F, using several harmonicas (see transcriptions in Figures 3.21–3.23). He describes the tune's opening progression (D^7–G^7–C^7–F) as a series of modal positions and then uses the four harmonicas that place one of those chords in cross-harp (that is, harmonicas in F, B♭, C, and G).[33] The different positions

31. Levy, in fact, sometimes plays both instruments at once—holding the harmonica in one hand, using the other to comp or play piano melodies in unison with the harmonica.
32. This chorus, in other words, is a rare instance of the Locrian sixth position.
33. Since Levy does not play the main tune on the G harmonica, I have omitted it here.

Figure 3.18 Howard Levy, "Blues in Six Keys," mm. 5–17. The performance opens with a blues in F, played in cross-harp position.



are audible here in contrasts between bent and straight, drawn and blown notes. Straight-harp and cross-harp are also the positions where he uses chords and more arpeggios. These differences are perhaps clearest in Figure 3.23. Its second phrase, in cross-harp position, involves nearly constant inhalation and bluesy bending (mm. 6–9). In the following straight-harp phrase (mm. 10–13), by contrast, there are no bent notes. Here Levy moves up and down the comb, outlining a C-major triad (m. 12). When he reaches the more unusual "first flat position" in m. 14, though, Levy abandons the composed melody and improvises a flowing bebop-style line.

In Levy's own words, his improvisations respond to the instrument's "sweet spots."

> Every time you play a different mode on the harmonica the bends and the sweet spots on the harmonica change. For example the first note of the scale when you play in the Lydian mode is a bend in this [low] octave. It's a straight note when you play in this [middle] octave. And you get all sorts of juicy bends like around the sixth and the third over here…. So when you play in these positions, there's all sorts of expressive possibilities that start happening on the instrument that are totally different from when you're playing in cross-harp. (Levy 1992, ch. 9)

In ecological terms, a "sweet spot" would be a place where the object's affordances converge with the agent's abilities in a particularly strong way. The sweet

Figure 3.19 Howard Levy, "Blues in Six Keys," mm. 53–73. Blues in A and then B♭ close the piece.

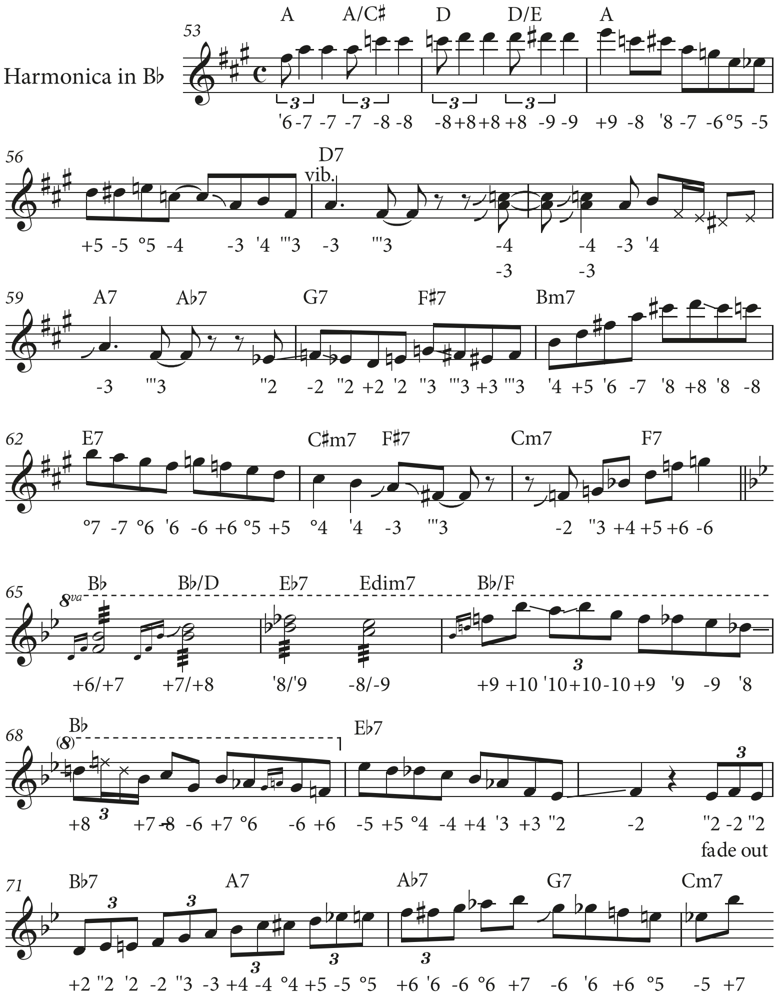


Figure 3.20 Transformational network for Levy, "Blues in Six Keys," mm. 65–66.

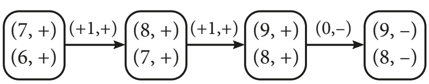


Figure 3.21 Howard Levy, "Sweet Georgia Brown" (straight-harp).

Figure 3.22 Howard, Levy, "Sweet Georgia Brown" (cross-harp).

spot offers less resistance, more possibilities. Unlike the difficult and unstable overblown notes, for example, draw bends are fairly easy to play and can be colored with throat vibrato. They are unique—unique in the sense that they appear only at certain places on the instrument and also in the sense that they are particularly characteristic of that instrument. Levy's "new directions for harmonica," then, build on the same sweet spots—the same privileged affordances—that drive harp's glissandi—in these moments, instruments do not seem neutral or transparent. Their individuality, their materiality, their presence as mediators is sounded.

Idiomatic music reflects what an instrument can and cannot do, what it does willingly and what it does reluctantly. Yet as David Huron and Jonathon Berec emphasize, "What makes something idiomatic is not that it is easy to play, but that it is easier to play given the specific prescribed circumstances compared with other possible performance circumstances" (2009, 119). Huron and Berec develop a computational model that shows how idiomatic compositions for trumpet become more difficult when they are transposed up or down and when the tempo is changed. In my terms, their "transposition idiomaticism" has to do with instrumental space and place-to-pitch mapping. Their "tempo idiomaticism," on the other hand, involves action-sound coupling: if a trumpet piece's tempo becomes too slow, the player may run out of breath; if it speeds up too much, tonguing may become impossible. With both, idiomatic trumpet music plays to the instrument's sweet spots—not too slow, not too fast, in a key that fits just right.

Instrumental idiomaticity seems distinct from tonal idiomaticity. Though they obviously overlap, an instrument may win out in moments of melodic-harmonic divorce. But like the linguistic and tonal idioms discussed by Robert Gjerdingen (2007b, 121–24), instrumental idioms involve characteristic patterns that cannot be predicted by grammatical rules alone. When speaking a foreign language or composing for an instrument I do not play, I may easily construct utterances that are grammatically correct but stylistically nonsensical, and such mistakes may be identified only with reference to standard practice. (A francophone learning English, for example, might say, "Let's call a cat a cat." This literal translation of a French idiom contains no syntactic errors. Nonetheless, anglophones call a spade a spade.) Corpus analysis suggests that about half of spoken and written language involves conventional word combinations (Erman and Warren 2000). To address this, teachers of English as a second language often use special dictionaries of collocations, whose closest musical equivalents would come from improvisational pedagogy—books of jazz licks, eighteenth-century *partimenti*, or the Persian *Radif*.[35] In idiomatic performance, then, speakers or players do not select every word or note individually; they also draw on larger, ready-made sequences.

Gjerdingen brings up this aspect of idiomaticity in a brief response to Huron and Berec, arguing that difficulty depends not only on "particular fingering or registers" but also on a performer's "musical upbringing" (2009, 124). Indeed, from an ecological standpoint, idiom must involve *both* instrumental affordances and players' habits. Overemphasizing one or the other risks a return to technological or social determinism. As the multistable opposition of straight- and cross-harp demonstrates, the instrument itself does not give rise to an idiom. The idiom is realized in players' overlearned actions, in the ways they typically move through an instrumental space, revealing some affordances and concealing others.

35. *Partimenti* are figured or unfigured basses to be completed in keyboard performance (see Gjerdingen 2007a). The *Radif* is a collection of melodies in each of the Persian modes (*dastgāh*s), whose motifs are used in improvisation (see Nettl 1992).

Beyond that, the linguistic analogy can help clarify how musical idioms reflect *social habits*. Idioms are produced, maintained, and negotiated in communities. My individual case studies, then, also stand in for particular traditions. Dylan's harmonica playing, however idiosyncratic, is linked to Woody Guthrie's folk style, Jimmy Reed's straight-harp blues, and so on.

Here it seems productive to consider the ecological understanding of sociality offered by the anthropologist Tim Ingold. "Sociality," he writes, "does not depend upon the organization of sensory data, initially private to each perceiver, in terms of an objective system of collective representations. Rather, sociality is given from the start … in the direct, perceptual involvement of fellow participants in a shared environment" (2000, 167). Sociality, from this perspective, is about shared perception and action, shared abilities and affordances, about inhabiting an enactive landscape together. For Ingold, an object becomes a tool only when it is joined to a technique (319). In other words, to see something as a musical instrument is already to have an idea, however rough, of how it might be played.

The communal perception of affordances is important to Bernard Stiegler too. Recall Stiegler's general argument (outlined in Chapter 1): tools reveal traces of their users' actions, forming a kind of external memory that makes human culture possible. Idiomaticity, for Stiegler, coordinates individuals, communities, and technical objects (2009, 67). While individuals develop distinctive personal styles, idioms are rooted in social groups (157). And this localization creates a certain untranslatability, even as idioms inevitably overlap (84). Stiegler illustrates his argument with the common Latin origins of French, Italian, and Spanish, yet the musical elements shared by different instruments also facilitate idiomatic crossover. Levy's harmonica playing, for example, shares something with his piano playing; Williamson's playing, with his singing. Ultimately, Stiegler thinks that idioms show how the relation between humanity and technology—between speakers and their languages or musicians and their instruments—is socially conditioned, though not socially determined. With a characteristic ontological twist, he even claims that this kind of idiomaticity marks all human existence (157).

Technical Agency and Motor Agency

A theory of idiomaticity helps explain how instruments shape players' actions, how coordinated affordances and habits give rise to distinctive musical dialects made of seemingly prefabricated patterns. Yet this can also shed light on ambiguities related to technology and agency. Why might I sometimes feel that my body is improvising on its own? Or that I am being played *by* the instrument? As with questions about instrumental incorporation, the answers here are related to the prereflective body schema, for the body schema supports both the perception of affordances and the sense of agency.

A series of experiments by Mike Tucker and Rob Ellis shows that objects prime the actions they afford (1998, 2001, 2004). Seeing a graspable object—or even reading its name—elicits unconscious simulations of hand action.[36] These simulations are particular to the thing's affordances: for example, grapes and hammers evoke different kinds of gripping. Merleau-Ponty seems to anticipate these results in *The Phenomenology of Perception*: "The gesture of reaching one's hand out toward an object contains a reference to the object, not as a representation, but as this highly determinate thing toward which we are thrown, next to which we are through anticipation, and which we haunt" (2012, 140). He refers to this as a mode of "being-toward-the-thing," in which the body is aimed at objects and responds to their call. Embodied responses to affordances go beyond simulation for people with anarchic hand syndrome (Marcel 2003, 76–81). Such patients, who typically have brain damage involving the supplementary motor area, respond involuntarily to objects in their environment. They might pick up a pen and start writing, without any conscious intention to do so.

These responses instead involve what Merleau-Ponty calls "motor intentionality" (2012, 113). Motor intentions drive automatic movements. They are phenomenologically recessive, difficult to describe in words. Elisabeth Pacherie (2008) gathers evidence to show that motor intentions have a separate neural substrate from conscious intentions and a different timescale. For example, when skilled drivers encounter an unexpected obstacle in the road, they may avoid it a split second before consciously recognizing it. Quick responses like this can outpace conscious thought, creating a momentary dissociation between action and subjective awareness (Jeannerod 2006, 46–49). Note, also, that motor intentions or automatic movements are not limited to biological reflexes; they equally involve learned, technical skills (like driving a car). All of this complicates common notions of agency, demonstrating that actions are not always "caused" by self-conscious decision-making.

Psychologists and philosophers, then, distinguish between action, a *sense of ownership* (the experience of my body being mine), and a *sense of agency* (the experience of causing or controlling action). These elements, though usually integrated, can come apart in delusions of control, whether pathological or experimentally induced. Patients with schizophrenia typically have no problem with motor control or the sense of ownership. They can complete physical tasks following an experimenter's instructions, and they feel their moving bodies as their own. But for some of these patients the sense of agency is severely impaired. Their bodies seem to be controlled by alien forces. Neurologically this is related to problems with bodily representation and self-monitoring, to a breakdown in the unconscious correspondences among predicted action and visual, proprioceptive, and kinesthetic feedback (C. Frith 2005, 754–56; Graham et al. 2014). Disruptions to perceived agency and disruptions to the body schema often go together.[37]

36. Simulation is key to many theories of grounded cognition (Barsalou 1999, 2008). For a review of other relevant experiments, see Kirsh (2013, §2).

37. For a discussion of the distinction between ownership and agency, see Gallagher (2012). In general, problems with the sense of ownership relate to disorders of the body image, whereas problems with

So it is perhaps unsurprising that instrumentalists' sense of agency can be reduced by altered auditory feedback (Couchman, Beasley, and Pfordresher 2012). They feel less control when pitch or timing changes unexpectedly, upsetting the multisensory integration that subtends experiences of instrumental withdrawal and incorporation.

But I would further argue that idiomatic fluency, paradoxically, might either enhance or reduce a player's sense of agency. Both effects are likely most common with music that is idiomatic and also difficult. At fast tempos, I sometimes react musically before I know exactly what I am doing, like the driver dodging an unexpected obstacle. On the one hand, this mix of skill and challenge is characteristic of "flow," a psychological state that combines an increased feeling of control with decreased self-consciousness (Csikszentmihalyi 1990, 52–66). On the other hand, because objects prime motor intentions for actions they afford, the overlearned patterns of idiomatic performance may seem to be inevitable responses to some external imperative.[38] For a fleeting moment, it may feel as though my body or the instrument or the music itself is in charge. Examining this paradox, the philosopher Eddy Nahmias argues that musicians and athletes do not make detailed, self-conscious decisions in the course of play. This kind of overthinking, in fact, would hinder performance. Instead, Nahmias suggests, the player has "a general intention or plan to play well" and then lets the details unfold (2005, 774).[39] I monitor my playing as if from a distance, watching in wonder my own fingers move.

Let me elaborate by describing a performance at a late-night gig in a Chicagoland café. During an up-tempo blues, I switch from mandolin comping to a harmonica solo. I step up to the microphone, but there is no time to plan, no time to select a particular starting note. So I start by drawing air through the bottom half of the instrument, orienting myself as I play. I glance at the guitarist, the bass player, the small audience. In this moment, I do not explicitly think of chord changes, breathing patterns, or licks I have learned. Instead, I feel that I am listening to the harmonica's suggestions, following pathways that seem both familiar and new. I respond to possibilities as they present themselves: here I can bend and here I can shake; here I reach a boundary and must turn around. I manage a flow of energy that passes through the harmonica—leaving space at first, then building to a climax. As my solo finishes, I hardly know what I have played. But I know that it would have been very different had I chosen to solo with the mandolin or another instrumental partner. My sense of technical agency here relies on motor agency, on my schematic responses to the harmonica's affordances. The instrument might not be an autonomous agent—but, in a

the sense of agency relate to disorders of the body schema (Gallagher and Vaever 2004, 121). As a side note, patients with schizophrenia tend to be especially susceptible to the rubber hand illusion discussed in Chapter 2 (Peled et al. 2003; Thakkar et al. 2011).

38. For the phenomenologist Alphonso Lingis, things themselves are experienced as imperatives that "order the diagrams and variations of our postural schema and exploratory manipulations" (1998, 64).

39. In such cases, Nahmias claims that general intentions may support a sense of authorship (an experience of being the source of action), even without a robust sense of agency.

sense, neither am I. My own embodied agency is distributed; my actions respond to the instrument's call.

Conclusions

Movement around an instrument—like all movement—involves a certain spatiality. In fact, instrumental interfaces coordinate different varieties of space.[40] Place-to-pitch mapping links technological and tonal spaces, each with particular dimensions and scales of measurement, and this doubled space is inhabited by a performing body.[41] As Merleau-Ponty put it in his description of the organ rehearsal, the player may settle into the instrument "as one settles into a house" (2012, 146). Instrumental space, then, is not simply a homogeneous geometric field, but the correlate of a lived body, an affordance space, an enactive landscape. Here the player is both constrained and free, since the interface conditions performance without determining it. The idioms that emerge from this negotiation show people and instruments truly making music together. These idioms make the fit between space and action audible, in music that sounds like it feels good to play.

By focusing on variations of technique, this chapter has more or less treated the instrument—in this case, the diatonic harmonica—as a given. Yet expert players are highly aware of differences among harmonica models. Levy favors Hohner Golden Melody harmonicas, which have plastic combs and equal-tempered tuning, whereas many blues players prefer Marine Band harmonicas, with wooden combs and a tuning that is closer to just intonation. On this level, there is no such thing as "the" ten-hole diatonic harmonica. The instrument does not correspond to a single technological object.[42] Moreover, though some durability is essential for instrumental prostheticity, instrumental technology is not immutable. Its stabilization requires active maintenance, and though the social actors that reproduce musical instruments and idioms often act in predictable ways, they do not always do so.[43] In other words, instrument and idiom may be transformed as well as preserved.

A more complete study of harmonica playing would also have to consider variations in technology. While Levy uses overblowing to get the equivalent of "black notes," for example, others have done so by using redesigned instruments. Chromatic harmonicas are typically equipped with a button that raises the note being played by a semitone. While their form is less standardized than a ten-hole blues harp, one common model is a sixteen-hole instrument developed for the

40. In the context of painting and dance, Merleau-Ponty argues that aesthetic experience opens up new forms of spatiality (1964, 159–90; 2008, 39–42; 2012, 546n86). A painting, for example, can be experienced as having depth, despite the canvas's flatness.

41. Of course, instrumental performance may involve other kinds of space as well, such as the visual space of notation or the architectural space in which the music is played.

42. Timothy Taylor (2001, 7) elaborates this idea with reference to clarinets; De Souza (2016a, 148–58), with reference to guitars.

43. For a theoretical discussion of stabilization in technology and society, see Latour (1991, 123).

classical harmonica player Larry Adler. This essentially offers a C-major harmonica and a C♯-major harmonica, played through a single comb.[44] To play it in various keys requires the kind of pervasive natural/accidental (or white-note/black-note) thinking reflected in Levy's pianistic visualizations. (Indeed, Stevie Wonder, whose sensitivity to keyboard topography was mentioned earlier, is a master of the chromatic harmonica.) This shows how Levy's technique and Adler's technology end up in the same place conceptually, loosening the consistent association between instrumental space and tonal qualia.

Other harmonicas, however, specifically avoid this kind of reconceptualization. Some preserve straight-harp relationships between hole and scale degree but afford the minor mode. Harmonic-minor harps flatten the thirds in the blown triad, while keeping the same dominant-function draw notes; natural-minor harmonicas also have a minor draw chord (to permit minor cross-harp playing). "Melody-maker" or "country-tuning" models similarly shift to a Lydian mode, so that cross-harp position offers a major scale. This allows blues players to play their habitual licks—but with a leading tone in place of the Mixolydian subtonic. Other ten-hole models like Brendan Power's "PowerBender" maximize bends: placing every drawn note above its blown counterpart permits draw bends on every hole.

These alternative harmonica tunings already show how *modifications of the technology presuppose certain techniques*. Melody-makers or PowerBenders are of little value to first-position players; harmonic-minor models are similarly ineffective for dedicated cross-harp players. This suggests that instrumental alteration can provide insights about how players' habits can be adapted or disrupted. And this can help refine my account of auditory-motor integration, complicating the connections between instrument, action, intention, and sound.

44. The sixteen-hole chromatic harmonica also regularizes pitch and breathing patterns, repeating the complete major-scale pattern from the blues harp's middle register in all octaves.

CHAPTER Four

Voluntary Self-Sabotage

My wife and I are playing violin-piano duets at a wedding reception. And as soon as I start the accompaniment to Jules Massenet's "Meditation" (see Figure 4.1), the rickety baby grand starts to give me trouble. The F♯ below middle C sticks. It refuses to bounce back into position. I reset the key without stopping the piece, but the problem persists. Every time I hit the note, it has to be manually fixed, and for the rest of the gig I remain acutely aware of this single, previously unremarkable black key.

This experience recalls Martin Heidegger's discussion of handiness (*Zuhandenheit*) in the "tool analysis" of *Being and Time* (2010, 72–74). While I am busy hammering, Heidegger says, I hardly notice the tool. I am more focused on the work, on whatever I am doing with the hammer. Likewise, while playing piano, I rarely think about the keys; usually I am more focused on the music. But sometimes my hammer breaks. I stop. I look at the tool. Suddenly this *thing* demands my attention. Instead of being handy (*zuhanden*), the broken hammer is "present-to-hand" (*vorhanden*).

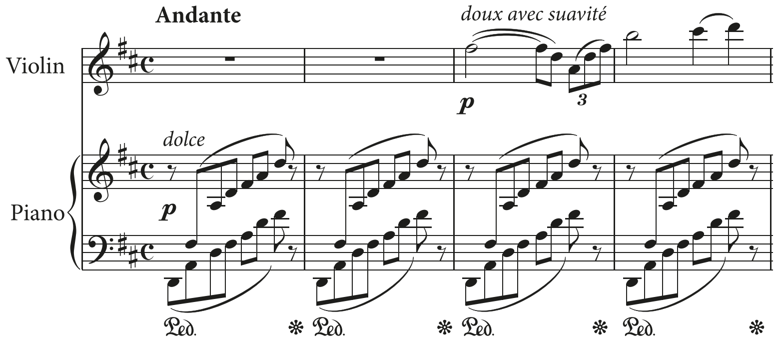
Musicians are familiar with such moments of "presence-to-hand" (*Vorhandenheit*), moments when an instrument's affordances change unexpectedly. A sticky key, a broken string, or a tuning problem can disrupt my integration with an instrument. Here I am made aware of its materiality, distracted by its "thingness." I become conscious of my equipment and my body, improvising around the problem, adjusting the instrument or my fingering in the course of play.

Some musicians create a similar kind of breakdown on purpose by altering their instruments. Like Heidegger's broken hammer, an instrument that has been retuned, prepared, or redesigned can "get in the way." It may surprise, resist, or provoke its player.

The guitar offers a rich set of case studies here. Like most stringed instruments, the guitar is easily retuned or prepared. But tinkering is also an essential part of guitar culture, especially with electric guitars. Players often customize instruments, pickups, effects pedals, or amplifiers. They personalize mass-produced gear. Historically this interplay appears alongside the development of jazz guitar, which depended on amplification technologies that were often homemade (Waksman 1999, 20).[1] Jazz and rock guitarists' practices of alteration show how

1. Of course, certain adaptations, like Les Paul's solid-body design, initiated lasting changes. Here instrumental alteration intersects with the history of instruments: individual experimentation may become stabilized in communal practice (see Pinch and Trocco 2002; Bijsterveld and Schulp 2004).

Figure 4.1 Jules Massenet, "Meditation" from *Thaïs*, mm. 1–4.



changes to an instrument relate to sonic organization and bodily technique. Yet statements by the players themselves—along with insights from psychology and philosophy—suggest that these changes also affect perceptual experience.

Auditory-Motor Disalignment

Instrumental modifications can interrupt learned connections between hand and ear. Does this disruption contradict my earlier emphasis on auditory-motor integration? Not exactly. As discussed in Chapter 1, sensorimotor integration in perception and memory relies on repeatable patterns of coactivation. Yet such associations are dynamic, not rigid. Since sensory modalities have distinct neural substrates, *they are always potentially separable*. Brain injuries can make this tragically clear. The possibility of dissociation, then, is built into the theory of grounded cognition. At the neural level, even a "single" sense is not holistic. Seeing, for instance, involves multiple neural pathways (Jeannerod 1997). An object's visual properties activate various groups of neurons, cuing perceptual schemas related to shape, color, and so on. Because these schemas are independent at the neural level, they can be transformed and combined in novel ways (Barsalou 1999, 593–94). Schemas may form a framework that is "filled in" with new content; other times, the structure of a schema itself may be altered. Such changes, additionally, might involve bottom-up or top-down processes.

Experiments with altered auditory feedback provide some insights into dynamic remapping in musical performance. Steven Finney (1997), for example, asked expert keyboard players to play two-part inventions by J. S. Bach—but manipulated the instrument's MIDI output to produce unexpected sonic results. The keyboard might be silent, or participants might hear their playing delayed by 250 milliseconds. During some trials, single notes would occasionally sound a tone or semitone off (producing a note outside of the current key). In others, key-to-pitch mapping was randomized. Another condition produced a wholly different piece, with each key press activating the next note in the *giga* from Bach's D-minor Sonata for Solo Violin.

These alterations affected participants in distinct ways. The silent keyboard did not impair performance. Like the deaf Beethoven's improvisations, this represents a situation where motor action and auditory simulation work together.[2] With delayed auditory feedback, however, participants played more wrong notes, their performances took longer (meaning that the tempo decreased), and their hands were less coordinated. The delay introduces a mismatch between production and perception.[3] It violates the binding of action and effect, which is not specific to music but basic to ecological acoustics.

Perhaps surprisingly, Finney's pitch alterations had no significant effect on performance. Why is that? Certainly, an instrument's pitch organization is arbitrary in a way that action-effect coupling is not.[4] Yet it also turns out that Finney's remappings—to random scales or even another piece by Bach—are so radical that players quickly learn to ignore the unpredictable pitches. As with a silent keyboard, they let their hands lead. Later experiments indicate that altered pitch feedback impairs performance only when the perceived music is structurally similar to the planned music (Pfordresher 2005).[5] Wrong notes from earlier or later in the melody I am trying to play are more confusing than wrong notes from outside of the key (Pfordresher and Palmer 2006). A kind of auditory-motor "disalignment," then, is generally more disruptive than dissociation. In disalignment, sound and action are connected but not identical. There is a gap or divergence between them.

Though the following analyses examine disalignment with altered instruments, it bears mention that a sense of disalignment may also arise with unaltered instruments. For example, the ethnomusicologist Steven Friedson discusses "a dialectic between what is heard and how it is played" in the *vimbuza* drumming of northern Malawian healing rites (1996, 132–58). This stems from the gap between a polymetric rhythmic surface and bimanual playing technique. The music within these rites seems to switch between twos and threes, creating multistable acoustic illusions like the optical illusions discussed by Ihde (1986, 67–79). Nonetheless, players' motor patterns *feel* fundamentally duple because *vimbuza* drumming technique maintains strict alternation between hands. Something comparable occurs in the music of the Shona mbira, whose sound is enhanced by the rich buzzing and overtones created by bottle-top vibrators and a gourd resonator. As Paul Berliner writes, "The music reflected back to [the mbira player] by his resonator as he plays

2. This matches the results of Repp (1999). Unsurprisingly, the absence of auditory feedback is a greater problem for ensemble performance (Goebl and Palmer 2009).
3. For a review and theoretical discussion, see Pfordresher (2006). Delayed auditory feedback is less disruptive if the delay can be perceived in terms of subdivisions of the beat (Pfordresher and Palmer 2002). This is because the player is able to synchronize action with sound via a larger metric structure.
4. This also differentiates instruments from voices. As discussed by Pfordresher and Mantell, musical instruments have a certain "susceptibility to disruption" (2012, 168; see also Howell, Powell, and Khan 1983, 773).
5. Playing a reversed keyboard—where high and low pitches are systematically inverted—is also more difficult than playing a keyboard that generates random pitches (Laeng and Park 1999).

seems to be more complex than that which his fingers alone produce" (1993, 130). Here the effect emerges both from rhythmic complexity and from the way that the mbira, as an instrumental system, amplifies and modifies a player's musical input.

"Extended techniques" in contemporary music can give rise to similar experiences. For example, Helmut Lachenmann's "Dal niente" for solo clarinet decomposes the clarinetist's usual technique. It unyokes action schemas—of fingering, breathing, and tonguing—that are usually integrated. Certain sections involve fingering or blowing alone; sometimes notes fade in and out, playing with the boundary between breath and tone (see Figure 4.2a). This demonstrates the separability of different motor schemas. But Lachenmann also plays with the clarinetist's habits. The rapid key clicking that opens the work often involves stepwise motion. (This means that it often involves sequences of individual finger movements.) Surprisingly, Lachenmann sometimes mixes this technique with familiar motor schemas. Line 28, for instance, has a descending D-major scale (see Figure 4.2b)! Such diatonic patterns might not be audible to the audience, but they can jump out at the player, since overlearned patterns like scales engage strong auditory-motor habits. Like the violinists tapping Mozart in the fMRI machine (discussed in Chapter 1), the clarinetist here may experience sonic simulations driven by physical action.

"Dal niente" belongs to a series of compositions from the late 1960s and 1970s that Lachenmann calls *musique concrète instrumentale*. He defines this as "a music in which the sound events are chosen and organized so that the manner of their production takes at least as much importance as the resulting acoustic properties" (Lachenmann 1996, 381). These pieces, then, try to sustain a kind of breakdown, to prevent the player's bodily exertions and the instrument itself from withdrawing into the music.

Another piece in the series, "Guero," treats "the piano as a six-manualed variant … of that Latin American instrument" which gives the piece its name (Lachenmann 1996, 384). The graphic notation, shown in Figure 4.3a, sets out the space of the keyboard and measures time in seconds. Then it specifies different

Figure 4.2 Helmut Lachenmann, excerpts from "Dal niente" for solo clarinet (1970): (a) opening, annotated with playing techniques; (b) line 28, highlighting an unexpected, silent D-major scale. © 1974 by Musikverlage Hans Gerig, Köln, 1980 assigned to Breitkopf & Härtel, Wiesbaden. Used with kind permission.

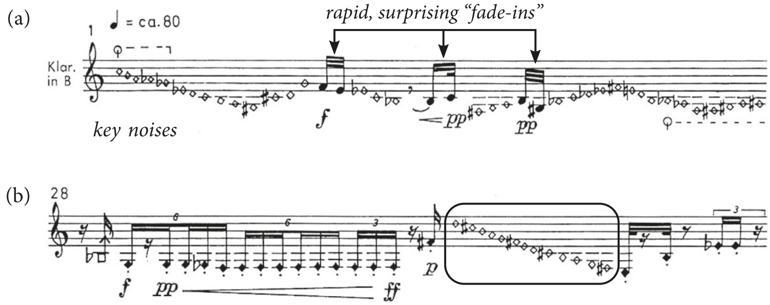
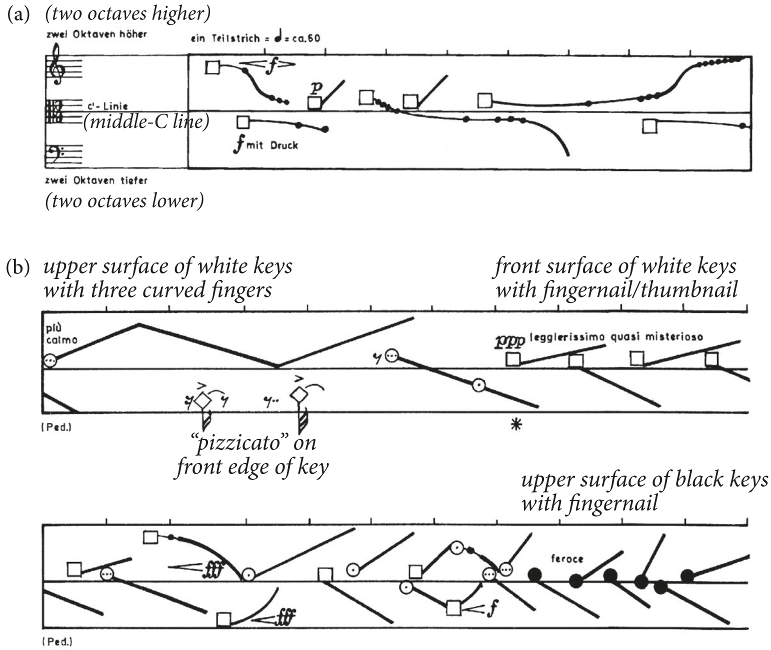


Figure 4.3 Helmut Lachenmann, excerpts from “Guero” for piano (1969): (a) opening, showing Lachenmann’s “instrumental clef” (with translation); (b) lines 12–13, with annotations explaining graphic notation and scraping technique. © 1972 by Musikverlage Hans Gerig, Köln, 1980 assigned to Breitkopf & Härtel, Wiesbaden. Used with kind permission.



surfaces to be scraped or struck—the upper surface of the white keys, their front edge, their top, and so on (see Figure 4.3b). It might seem that such pieces do not require preexisting instrumental techniques, that Czerny’s finger exercises or Chopin’s études will not prepare you to play “Guero.” In this view, anyone could learn these pieces, since they make everyone a beginner. Yet this would miss out on part of Lachenmann’s aesthetic goals. He is interested in subverting musical habits, in pushing against established auditory-motor associations. Hence the composer describes “Guero” as “a manual and also a psychological study for the pianist” (384). It aims to develop new performative and perceptual skills by disrupting a pianist’s technique. Lachenmann’s musical experiments with disalignment and dissociation thus parallel Finney’s and Pfordresher’s psychological experiments, using disalignment and dissociation for artistic rather than scientific ends.

All of this relates to the composer’s distinctive modernist understanding of “beauty.” Beauty, for Lachenmann (1980, 22), is found in moments of human potential—the potential to know oneself and the world, to change one’s actions, to change one’s mind. “By allowing oneself to experience this ‘non-music,’ ” says Lachenmann (1995, 101), “… listening becomes genuine perception. It is only now that one begins to listen differently, that one is reminded of the changeability of listening and of aesthetic behavior, reminded, in other words, of one’s own structure, one's own structural changeability." Lachenmann's music, then, can be understood as a kind of phenomenology, "deliberately incorporating, provoking and revealing perception."

The rest of the chapter shows how this can be achieved through altered instruments. With an altered instrument, realizing the simplest tune may become confusing: I no longer know what notes I am playing.

Retuned Instruments: Kurt Rosenwinkel, "Zhivago"

The jazz guitarist Kurt Rosenwinkel (b. 1970) describes creative development as a cycle of stability and instability, learning and unlearning. "You start off not knowing what you're doing," he says, "then you organize things so they become ordered. When that order becomes static, you have to break it up to create another state of instability, which, in turn, throws you back into chaos. That's what continuing on to the next step is all about" (Rosenwinkel 2007). On his 2001 album, *The Next Step*, this dynamic process is driven largely by instrumental modification: he uses alternate tunings for four of the record's eight tracks.[6]

Rosenwinkel had found success in the mid-1990s with a Composer's Award from the National Endowment for the Arts and a recording contract with the prominent jazz label Verve. But at the point when he started work on *The Next Step*, Rosenwinkel was dissatisfied with his playing. "My knowledge of the guitar was hindering my relationship to the music," he explains. "I felt like I knew too much about what I was doing and not hearing the music directly." This is not simply about practiced hands falling into predictable patterns. Rather, Rosenwinkel frames this as an inability to *hear* the music properly. It involves *perceptual or conceptual habits* as much as performative ones. In cognitive terms, Rosenwinkel is describing particularly tight auditory-motor connections. If he already knows what his actions will sound like, he may come to hear his playing as unsurprising, overly schematic. A description by Rosenwinkel's colleague Christian Rover (2006) evokes the instrumentalized simulations discussed in Chapter 1: "To have a certain collection of voicings for every harmony, and a sound you already internally hear before you actually play it, would eventually make it redundant to still play it."

Rosenwinkel's solution was to retune his guitar in a form of "voluntary self-sabotage." "Anyone who has ever tried this," Rover comments, "knows that one twist of a tuning peg can turn you into a beginner in an instant. Just like the first time you touched a guitar all you have is your ears to rely on—and that's exactly what Kurt's intention was." There is some sense to this metaphor. Beginners rely more on visual feedback and pay more attention to motor patterns than do expert performers (see Palmer and Meyer 2000, discussed in Chapter 1). Since their

6. While alternate tunings are uncommon in jazz, they are often used in other guitar traditions, from the widespread drop-D tuning (that lowers the lowest string a whole step) to various open tunings of folk and slide blues guitar.

mapping between hand and ear is still being formed, they lack the perceptual habits that Rosenwinkel found frustrating.

In other ways, though, this professional musician was quite different from a beginner. Rosenwinkel was able to adapt various motor skills to the altered instrument. His right-hand picking, for example, would be unaffected. This reflects a general principle: *retuned instruments change place-to-pitch mapping, while preserving the instrumental interface*. The experiments by Pfordresher and colleagues, cited in the preceding section, imply that new mappings might be most challenging when they preserve aspects of a familiar tuning too.

I analyze relationships between standard and altered tunings through transformational voice leading theory, an application suggested by a speculative "scordatura fantasy" by David Lewin (1998, 38–41). Figure 4.4 represents alternate tunings as mappings between two pitch sets. This shows each string's movement in pitch space and sums up the mapping as a whole with two metrics of transformational voice leading, "consistency" and "displacement." "Consistency" measures the mapping's uniformity: it counts the number of voices that move by the same pitch interval (Straus 2003, 315). Higher consistency values mean that the mapping is closer to transposition—and that it preserves more inter-string intervals from standard tuning. Rosenwinkel's favored retuning takes three strings down a semitone; it is semiconsistent. By comparison, the scordatura for Toru Takemitsu's "Equinox" keeps four strings consistent. "Displacement"—the total number of semitones traversed (Straus 2003, 320)—further quantifies distance from standard tuning. Where Takemitsu's tuning moves only two semitones overall, Rosenwinkel's tuning moves twelve.

Rosenwinkel's scordatura is further from standard tuning than Takemitsu's. Every string moves, and the tuning does not repeat pitch intervals between adjacent strings. Yet Rosenwinkel also maintains some familiar features. Because three strings transpose together, he can play standard fretboard patterns involving those strings. This is particularly notable with the perfect fourth between the highest

Figure 4.4 Tuning transformations for guitar scordatura by Kurt Rosenwinkel and Toru Takemitsu. "Consistency" counts the number of voices that move the same distance; "displacement," the total number of semitones shifted.

	Kurt Rosenwinkel "Zhivago" (2001)	Toru Takemitsu "Equinox" (1993)
	E4 $\xrightarrow{-1}$ E♭4	E4 $\xrightarrow{0}$ E4
	B4 $\xrightarrow{-1}$ B♭4	B4 $\xrightarrow{-1}$ B♭4
	G3 $\xrightarrow{+1}$ A♭3	G3 $\xrightarrow{0}$ G3
	D3 $\xrightarrow{-1}$ D♭3	D3 $\xrightarrow{0}$ D3
	A2 $\xrightarrow{-2}$ G2	A2 $\xrightarrow{0}$ A2
	E2 $\xrightarrow{-6}$ B♭1	E2 $\xrightarrow{-1}$ E♭2
Consistency:	3	4
Displacement:	12	2

Figure 3.23 Howard Levy, "Sweet Georgia Brown" (first flat position).

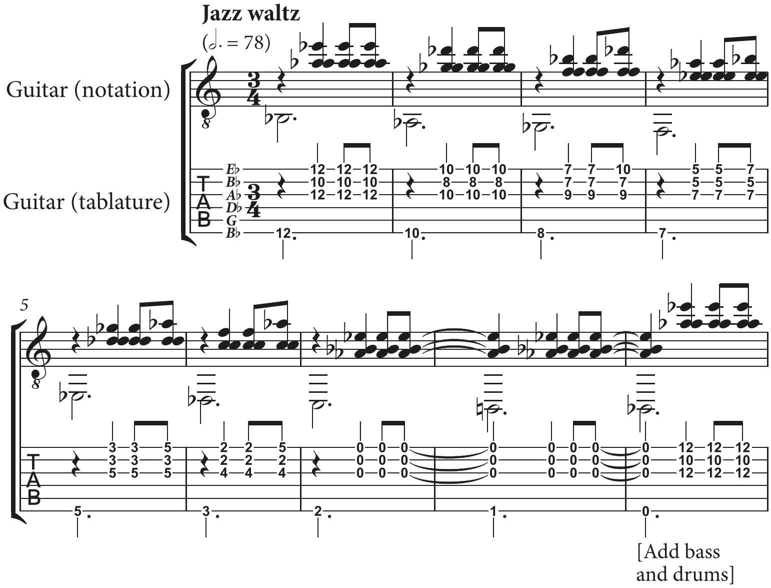
folk and blues harmonica. His innovation is not to leave them behind but to add to them, systematically multiplying the modal thinking of cross-harp, putting the sweet spots into new musical contexts.[34]

Idiomaticity

Instrumental "idioms" typically engage such "sweet spots." When Dylan goes back and forth between tonic and dominant-plus-$\hat{6}$ or when Williamson bends under $\hat{1}$, $\hat{3}$, and $\hat{5}$ (but never $\hat{7}$), their music seems to be organized around the harmonica's characteristic affordances, its physical and sonic possibilities. In other words, idiomatic playing makes it possible to hear aspects of action-sound coupling and instrumental space. In moments of instrumental idiomaticity—from the harmonica's bending to the horn's hunting calls, from the fiddle's string crossing to the

34. These technical variations, of course, are not comprehensive. The openness of affordance theory, mentioned earlier, means that they could not be. Rapper Doug E. Fresh, for instance, plays harmonica while beat-boxing. Since he is using his lips to articulate the beat, he cannot always have his mouth on the instrument. Instead, he holds the harmonica in front of his microphone and sends percussive blasts of air through it. With this technique, it is not possible to isolate single melody pitches. Instead, Fresh capitalizes on the *harmonic* affordances of the harmonica: he gets his audience to sing a melody while he accompanies them with harmonica chords and mouth percussion. The resulting tonic/dominant alternation—similar to the end of Dylan's solo on "Queen Jane Approximately"—demonstrates the pitch affordances of the ten-hole harmonica in a particularly clear way.

Figure 4.5 Kurt Rosenwinkel, "Zhivago," mm. 1–9. (This follows an improvised solo-guitar introduction.)



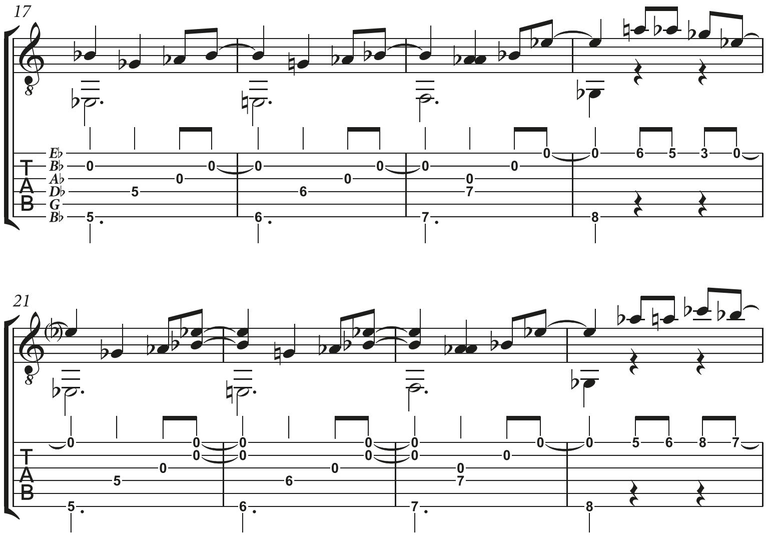
two strings. Such zones engage established performance habits. They allow the player to forget temporarily about the retuning, making other areas on the instrument more surprising by comparison. All of this involves cross-string intervals, of course; relative pitch relations along the strings, which are determined by acoustics, remain constant. It is perhaps unsurprising, then, that Rosenwinkel privileges motion along the strings in the opening track from *The Next Step*, "Zhivago."

"Zhivago" is a contemporary jazz waltz. After a free solo lead-in, Rosenwinkel establishes the driving triple-time feel of the composition proper. The guitar descends for eight measures, then repeats the progression with bass and drums (see transcription in Figure 4.5). Together they develop a new vamp, shown in Figure 4.6. At m. 33, the saxophone joins the guitar with a skipping theme that will return throughout the eighty-six-measure composition (see Figure 4.7).

The following analytical notes consider these opening sections, using the transformational model of guitar space introduced in the preceding chapter. As illustrated in my network for a riff by the Kinks in Figure 3.3, I represent fret/string positions as ordered pairs of the form (*f, s*). (Transformations in this space are represented by ordered pairs that show movement in these dimensions with integers marked by + or –.) This model makes it possible to show how "Zhivago" thematizes certain kinds of movement on the fretboard, even more than specific hand shapes or harmonic objects.[7]

7. For a similar approach, see Montague (2012) and Bungert (2015), who analyze thematic keyboard gestures in Chopin and Bach.

Figure 4.6 Kurt Rosenwinkel, “Zhivago,” mm. 17–24.



In the first section’s descent, the bass note begins at the twelfth fret of the bottom string (12, 6) and steadily works its way to the open string (0, 6). Here Rosenwinkel alternates between two basic hand positions, labeled α and β in Figure 4.8. I add subscript numbers to distinguish different instances of these chord shapes: the number refers to the position of the sixth-string fret (that is, the bass note). The move from α_{12} to α_{10} is a straightforward along-the-string transposition, (–2, 0). The shift between α and β, however, is also an along-the-string move. The two shapes hold frets on the same strings, and my fingers slide along the fretboard as I shift from one to the other.

Defining two contextual transformations will help us conceptualize the relationship between the two shapes. J formalizes a “pivoting” gesture. J holds the fret on the lowest string of the shape constant and moves the others up by one. A complementary perspective is provided by another transformation, K. K moves the lowest-string fret down one, while holding the others. This will prove to be a kind of “thematic move” throughout the piece. Figure 4.9 and Video 4.1▶ demonstrate these operations, applying each to α_{10}. These transformations, however, might apply to any fretboard shape and may appear in standard tuning. For example, K and J^{-1} can be used to toggle between two voicings in a common descending “ii–V” progression (see Figure 4.10 and Video 4.2▶).

Readers versed in transformational theory will note that J and K are operations (not simply transformations), since they are invertible. Their inverses—J^{-1} and K^{-1}—undo the move, taking β back to α. More specifically, I am describing groups of operations isomorphic to the integers under addition.[8] This means that

8. This means that the model incorporates negative fret numbers, which must be included for formal reasons (Rings 2011, 25–27; De Souza 2016b).

Figure 4.7 Kurt Rosenwinkel, “Zhivago,” mm. 33–46.

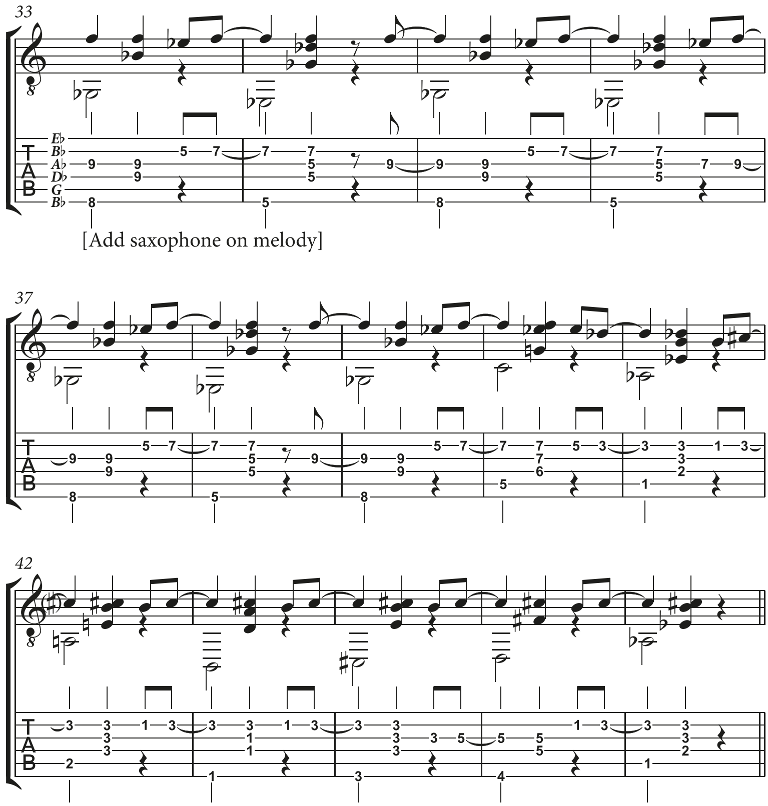


Figure 4.8 Kurt Rosenwinkel, “Zhivago,” mm. 1–6, labeling basic hand positions. Subscript numbers refer to the fret on the lowest string. For these hand positions, I include only the lower anchor note on the highest string (excluding the added melodic neighbor note). This underlying schematic shape for α—with the highest two strings sharing a fret—emerges clearly in mm. 4–5. Here the higher note on the first string is added at the end of the bar, whereas throughout mm. 1–2 this highest note covers the basic shape.

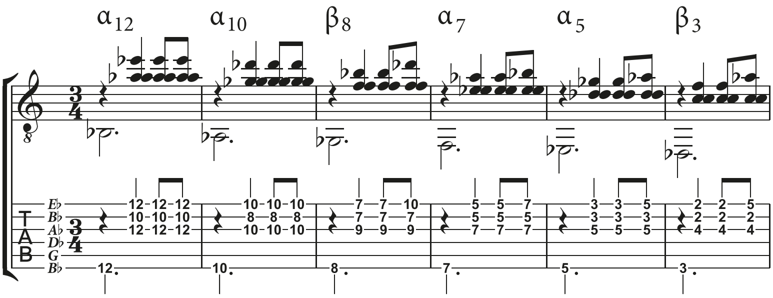


Figure 4.9 Two contextual operations for fretboard shapes in Rosenwinkel, "Zhivago." Both connect α and β. J holds the bottom-string fret and moves the others up one; K moves the bottom-string fret down one, holding the others. The inverses of these operations (J^{-1} and K^{-1}) take β back to α.

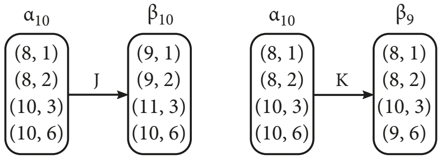
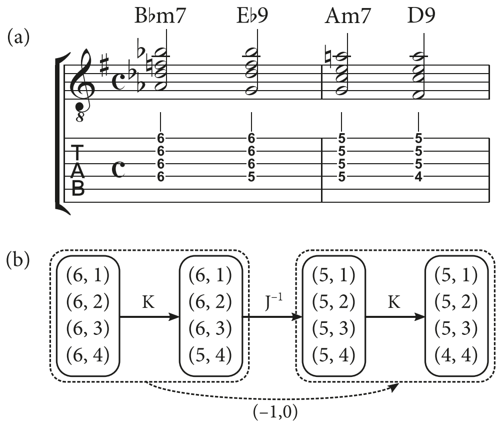


Figure 4.10 Contextual fretboard operations with a chromatically descending ii–V progression, which appears in many jazz standards (including Duke Ellington's "Satin Doll," Miles Davis's "Four," and John Coltrane's "Lazy Bird"): (a) an idiomatic voicing for this progression, using only the highest four strings on a guitar in standard tuning; (b) transformation network modeling these voicings via K and J^{-1} (the inverse of J).



the operations can also combine with themselves: for example, performing K twice in a row (K^2) moves the lowest-string position down two frets. Furthermore, these contextual operations commute with transpositions in fretboard space. The order in which these transformations are combined does not change their product: for example, $(-2, 0)J = J(-2, 0)$. Figure 4.11 demonstrates the combination of pivoting and shifting along the fretboard with the middle section of the Beatles' "Blackbird" (see Video 4.3▶).

Figure 4.12 represents the opening section of "Zhivago" in networks that combine J and K with transpositions along the string. (This section is performed in Video 4.4▶.) The first two networks show that Rosenwinkel repeats a sequence of hand shapes as he moves down. The interpretation that uses J highlights the bass line, showing that it always drops two frets after α forms. Thinking in terms of K obscures this somewhat. Yet as Figure 4.12c shows, K also accounts for the descending motion in mm. 7–9 and 15–16. Though these measures introduce new

Figure 4.11 John Lennon and Paul McCartney, "Blackbird" (1968), mm. 13–14: (a) notation; (b) a network that combines the pivoting gestures J and K with along-the-string transpositions on a guitar in standard tuning. (The interested reader can pursue such gestures throughout the rest of "Blackbird," starting with the characteristic (+8, 0)J leap in the song's first two measures.)

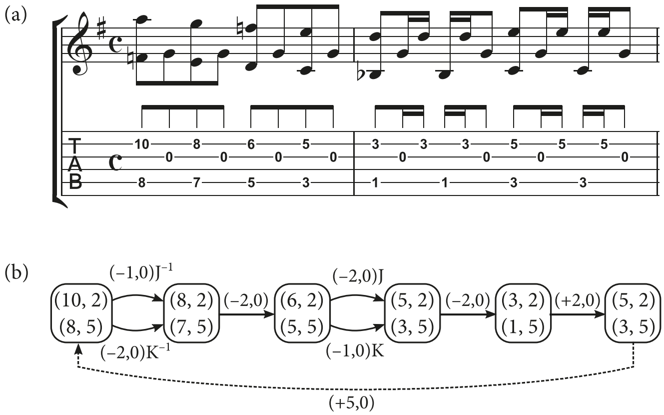


Figure 4.12 Transformation networks for Rosenwinkel, "Zhivago," mm. 1–16: (a) network for mm. 1–6, 9–14, using J to connect α and β; (b) network for mm. 1–6, 9–14, using K to connect α and β; (c) network for mm. 7–9, 15–16.

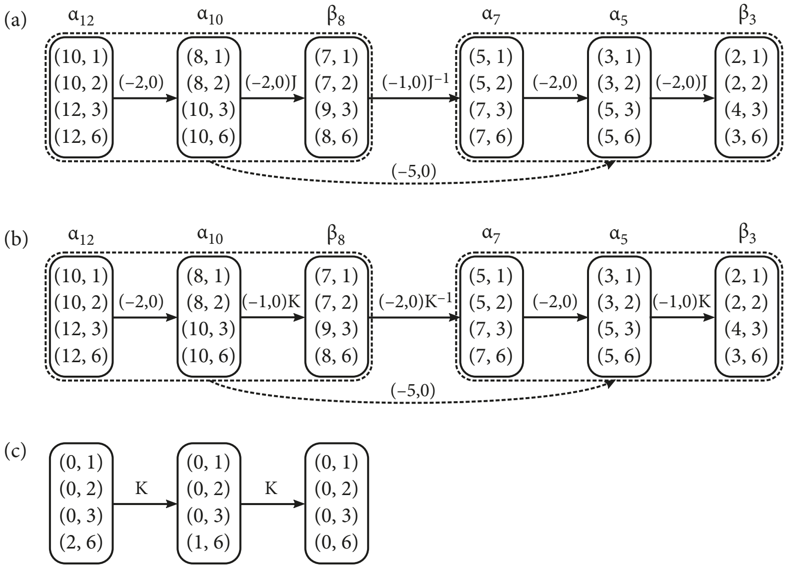
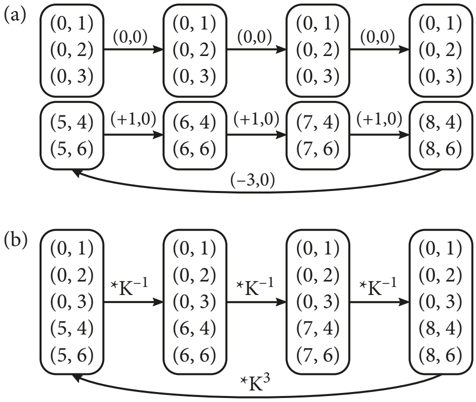


Figure 4.13 Transformation networks for looping schema from Rosenwinkel, “Zhivago,” mm. 17–32: (a) network with fretboard transpositions; (b) network with variant of K.



hand shapes—that is, new chord voicings—*they involve comparable movement along the fretboard.*

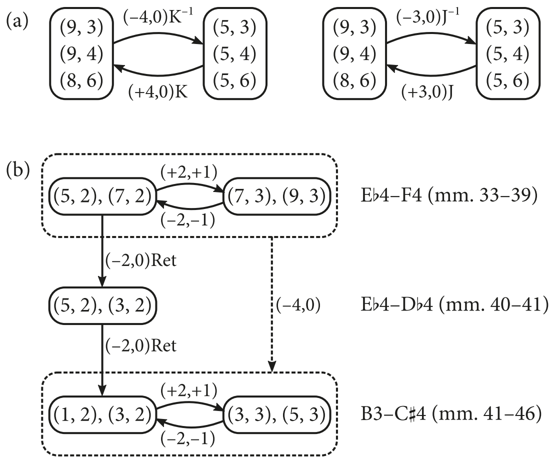
The second section reverses and extends the K motion from mm. 7–9. It takes a parallel shape up the neck, against stable higher strings (see Figure 4.13 and Video 4.5). Rosenwinkel loops the process four times, adding to the higher strings with each repetition. The step-by-step action on the lower strings can be modeled as the inverse of a K variant—call it *K—which would move the frets from a shape’s lowest *two* strings (instead of just the lowest).[9]

The new theme at m. 33 also involves cycling between hand positions (mm. 33–39, 47–52, 63–68). The chords that support it can again be modeled by J or K, alternately straightening the shape and offsetting the lowest-string note (see Figure 4.14a and Video 4.6). The melody itself, though, introduces the first cross-string movement as it explores the instrument’s many-to-one place-to-pitch mapping. The “same” melodic figure is alternately realized on different strings, related by the first transformations involving string crossing, (+2, +1) and its inverse (−2, −1). As shown in Figure 4.14b, this figure is also shifted along the fretboard by (−2, 0), outlining part of a whole-tone scale. In later sections (which are not shown here), this action loop forms an antecedent that is answered differently each time.

These analytical sketches highlight some characteristic physical positions and movements in “Zhivago.” Rosenwinkel privileges along-the-string movement and bass-pivoting or bass-displacing gestures (modeled by J and K). These sections can be further understood as a series of action cycles: an eight-measure loop, repeated

9. With the second pass through the cycle, Rosenwinkel adds the top string; with the third, a held note on the top string’s seventh fret. In the last place in the loop, the eighth fret is fingered on the fourth string—but this fret is *sounded* only after the final repetition of the cycle, shifted onto the *third* string (in m. 32).

Figure 4.14 Transformation networks for Rosenwinkel, "Zhivago," mm. 33–46: (a) chord pattern from mm. 33–39; (b) melodic transformations for mm. 33–46. In (b), "Ret" stands for retrograde.



twice (mm. 1–16); a four-measure loop, repeated four times (mm. 17–32); a two-measure loop, also repeated four times (mm. 33–39). Each loop is shorter, more focused, than the one that precedes it.

The way Rosenwinkel lingers in these grooves, which make up most of the composition, foregrounds a kind of haptic engagement with the music. By this I mean that physical shapes on the instrument take precedence over usual harmonic labels. Rosenwinkel discussed this in a 2010 master class:

> What was cool about it was that I didn't really know what this chord was. [Plays a chord.] What is that? I don't know. It seems like a major seventh. I wasn't sure, you know, and I didn't know what the notes were. So I had to take a tuner, to plug into a chromatic tuner to tell me what that note was, you know, so I could write it down. And then I kind of started to figure out what the harmony was. Slowly, very slowly. But it was really cool because no longer did I have this intellectual relationship with it. It was just pure sound and discovery.[10]

This suggests that Rosenwinkel's motor habits and auditory expectations readjust more quickly than his theoretical awareness. Even as his hands and ears become familiar with the altered fretboard used in "Zhivago," his "intellectual" perception of the music lags behind. Rosenwinkel's retuning temporarily disrupts his

10. A brief video from the event can be viewed at http://www.youtube.com/watch?v=QVSNccMNtJU. Of course, this master class is a performative and pedagogical situation, in which Rosenwinkel consciously models a certain type of musicianship. Still, his comments fit with my own experience of "Zhivago" and its unusual guitar tuning. I find it difficult to name the notes or chords as I play it, even though I have transcribed and analyzed the piece.

symbolic experience of the music and instead foregrounds its sensory, "aesthetic" qualities.

Prepared Instruments: Fred Frith, "Hello Music"

The English multi-instrumentalist Fred Frith (b. 1949) has more than four hundred items in his discography. He has played with experimental rock, folk, and jazz groups, written film scores and orchestral pieces, and taught composition at Mills College. One of his most acclaimed recordings, though, is a forty-minute set of unaccompanied improvisations, simply titled *Guitar Solos*. For this 1974 album, Frith modifies a 1936 Gibson K-11 archtop by adding a second pickup at the nut (that is, the end of the strings farthest from the bridge). He then taps the strings with his hands or with found objects, recording the results. This explores, Frith says, "the difference between the touch of stone, the touch of glass, the touch of wood, the touch of paper—those kinds of basic elements that you're using against the surface of the strings which produce different sounds" (Milkowski 1983, 24).[11] Clearly, like Rosenwinkel, Frith seeks to defamiliarize the guitar. But instead of retuning, his approach involves *instrumental preparation*.

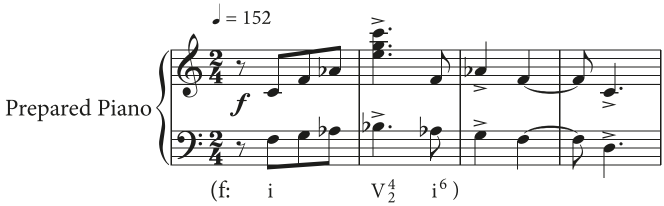
Where retuning changes an instrument's pitch mapping, preparation incorporates foreign objects *at the site of sound production*, and this often transforms pitches into complex inharmonic sounds. Preparation, in a sense, turns any instrument into a percussion instrument. It disrupts habitual associations by crossing categories. That is, a prepared instrument may not simply produce unexpected notes. It may instead produce unexpected *noises*—metallic or wooden, thudding, rattling, or ringing.

Preparing an instrument, then, suggests a certain openness to noise that Frith first encountered in John Cage. "Reading [Cage's] *Silence* when I was about eighteen changed my attitude completely, far more profoundly than listening to any music ever would have," says Frith. "That book brought very sharply into focus the idea that sound, in and of itself, can be as important as … melody and harmony and rhythm. The sound itself is just as important. And from that notion I started viewing the guitar itself from a different point of view altogether, just to see what I could get out of it" (quoted in Milkowski 1983, 23). Frith's exploration of the guitar, of course, parallels Cage's approach to the piano. The composer "invented" the prepared piano in the late 1930s, adding screws and bolts to the instrument's strings to make it sound like a percussion ensemble. Cage (1979, 8) describes this as a process of "continual discovery," full of delight and surprise.

That sense of surprise is central to Cage's concept of *experimental action*, "an act the outcome of which is unknown" (1961, 13). Experimental music for Cage disrupts the "straight line between anticipation of what should happen and what actually happens" (167–68). When the composer formulated this idea in the

11. For more details of Frith's performance techniques, see Dawe (2010, 78). They are also documented in the film *Step Across the Border* (Humbert and Penzel 1990).

Figure 4.15 John Cage, *Our Spring Will Come* (1943) for prepared piano, mm. 1–4. All the strings in this excerpt are prepared, so the apparent harmonic progression indicated by Roman numerals does not sound.



1950s, he explained "experimental action" in terms of chance composition and music with indeterminate performance (69). Yet Cage's work with the prepared piano—principally between 1938 and 1951—precedes these techniques: *here the altered instrument itself renders an action's result unpredictable*, transforming the habitual into the experimental.

In cognitive terms, this reshapes expected action-effect coupling, learned associations between hand and ear.[12] Playing prepared instruments might feel less disorienting than playing retuned ones, since their remapping is closer to the random auditory feedback that induced auditory-motor dissociation in Finney's studies. But a prepared instrument, like a silent or random keyboard, may suspend auditory expectations *while preserving motor schemas*. Cage's notation for prepared piano—which indicates the keys to be pressed, not the resulting sounds—presumes "normal" pianistic habits. (In this respect, it resembles notation for string music in scordatura.) *Our Spring Will Come* (1943), for example, even uses familiar tonal patterns (see Figure 4.15). On the page and under the hand, it projects a sense of F minor. An apparent V^4_2 chord even seems to "resolve" to a kind of i^6, more or less as it would in a tonal context (mm. 2 and 6). But since all of these strings are prepared with bamboo strips or screws, the resulting sounds are percussive, lacking clear pitches. Tonal schemas and motor schemas are pulled apart; the action's result becomes unpredictable.

The continuity of technique reflected in this example correlates with a continuity of technology: *preparation changes an instrument's sound production, not its interface*. The piano and the prepared piano both have keyboards, just as the guitar and prepared guitar both have fretboards. In other words, preparation does not obscure the basic instrumental space.

I will illustrate with some analytical comments on "Hello Music" from Frith's *Guitar Solos* (1974). "Hello Music" brims with jaunty energy. Frith starts with a jazzy, syncopated motive that recurs throughout the first third of the piece. After

12. For Cage this helps deconstruct the traditional separation of matter and spirit, life and art, action and sound—which results partially from the way that tones are rationalized, possessed, or made repeatable by music theory.

Table 4.1 Formal outline for Fred Frith, "Hello Music" (1974)

Letter	*Time*	*Gesture/texture*
A1	0:00	Chord/cross-string gesture (4×)
	0:05	Answer (cross-string)
A2	0:10	Opening chord/cross-string gesture (4×)
	0:14	Answer (along-string steps; vibrato at 0:16)
	0:21	Strumming (vibrato at 0:24)
A3	0:25	Opening chord/cross-string gesture (4×)
B1	0:31	Chords up and down along string
	0:38	Contrary motion
C1	0:46	Bimanual tapping triplets (parallel)
D	0:51	Slide/hammer-on counterpoint
E	1:00	Free transition
C2	1:06	Tapping triplets (wedge)
A4	1:15	Opening chord/cross-string gesture (3×)
B2	1:21	Chords along string
F	1:27	Ascending scale

contrasting middle sections, he comes back to this opening gesture for an upward-spinning codetta (for an overview, see Table 4.1).[13]

In the context of the album, "Hello Music" represents a balance between more atmospheric tracks (like "Glass C/W Steel") and more tonal ones (like "Not Forgotten" and "Hollow Music"). The pitches throughout this track are mostly indistinct, hovering around a threshold of inharmonicity. But its gestural qualities still reflect the space of the guitar's tiered array.

The additional pickup at the nut defines the overall sonority of "Hello Music." Like more common forms of preparation, this alters the way the instrument produces sound. It makes it possible to hear two sides of a stopped string—both the side between the finger stopping the string and the bridge, and the usually inaudible side between the finger and the nut. One tap of the string, in other words, produces two interlinked notes. Despite the pitches' fuzziness, there is a systematic inversional relationship here. Dividing a string at its midpoint would create a point of balance: the pitches for both sides would meet an octave above the open string. Away from this midpoint, though, whenever one side of the string is shortened, the other is lengthened.

Frith exploits these affordances through finger tapping, a technique that would become a standard part of the solo rock guitar vocabulary, particularly associated with the virtuoso Eddie Van Halen.[14] With tapping, both hands articulate notes through hammer-ons and pull-offs.[15] In other words, the guitarist strikes a string

13. This method of charting free improvisation parallels a mode of "phenomenological analysis" by Borgo (2005, 77–78).

14. For a discussion of Van Halen's use of the technique, see Waksman (2001).

15. "Hammer-ons" and "pull-offs" are guitar techniques whereby notes are attacked by the fretting hand alone. With a hammer-on a finger is percussively placed on the fret; with a pull-off it is percussively removed.

instead of fingering-and-plucking it. Tapping thus introduces a disjunction within the kinesthetic domain: besides freeing up associations between hand and ear, it undoes the guitarist's usual coordination between hands. Like Lachenmann's "Dal niente" for clarinet, it breaks playing technique into schematic components.

"Hello Music" thematizes several patterns of body-instrument interaction. The A motive, which opens and pervades the piece, engages the guitar's cross-string dimension. It features a loud chord repeated twice, followed by quieter, quicker plinks. The chord, obviously, stops multiple strings at once, and Frith maintains its placement as he repeats the motive. He does not move it up or down the neck. The motive's plinking tail descends across the strings in clean, disjunct leaps. (Near the beginning of the track, these downward skips involve successive perfect fourths, a characteristic interval from standard guitar tuning.) The self-doubling created by the guitar's preparation further clarifies this movement: with the plinking, the two "parts" have the same contour. (As just noted, moving along one string would create contrary motion between parts.)

Frith's A motive, then, juxtaposes two common ways to articulate a guitar chord, activating the strings simultaneously and activating them in succession. Despite the unusual timbre, the motive's basic gestural or textural profile can be found in much music for non-prepared guitar.

After establishing the string-crossing motive, Frith gradually introduces motion along the guitar's neck. While this strategy briefly appears in his "answer" to A2 (0:14), it becomes prominent in the middle sections of "Hello Music." In the section I have labeled B1 (0:31), Frith moves a chord up and down the neck, an action that brings out the inversional relationship between doubled pitches. This is especially clear at 0:38, when the two parts move fret by fret in contrary motion. Sections C and D also highlight movement along the neck. The bimanual tapping of C creates rapid triplets on a single string, involving the open string and then two higher notes (one played with the left hand, the other with the right). In C1, the two tapped notes move up and down in parallel; later (C2), they diverge in a "wedge" shape. The independence of hands is also particularly audible in the D section that intervenes between C1 and C2: here Frith develops a kind of counterpoint between a sustaining part that slowly slides up a string and another that taps in place. These prolonged glissandi, near the piece's midpoint, are the most expansive along-string gestures in the piece.

From this perspective, the central "themes" of "Hello Music" are distinctive modes of exploring the prepared guitar's fretboard. Its "form" emerges from the contrast between these strategies. In Table 4.1, I separate these large-scale sections with horizontal lines. From A1 to A3 Frith focuses on the chords and string crossing of the opening motive. The middle section (from B1 to C2) is more varied, exploring several ways of moving along the strings. The final section (from A4 to F), perhaps surprisingly, resembles a conventional recapitulation, juxtaposing his earlier themes. Frith returns to the opening motive, then a gesture from the middle section (B2), and closes with a kind of codetta (the quickly ascending scale of F). As mentioned earlier, the pitches throughout "Hello Music" are fuzzy. But Frith's gestural strategies are clearly differentiated and audibly related to the guitar's space. That is why this prepared guitar—a thumping, plinking guitar—still sounds *like a guitar*. On this level, "Hello Music" is experimental and, at the same time, highly idiomatic.

Note that "Hello Music" explores one particular setup, just as other tracks on *Guitar Solos* take shape around other preparations—playing with objects, placing a capo in the middle of the fretboard, and so on. Each preparation offers distinctive materials for a player to explore. Similarly, the same preparation on individual instruments may produce different results.[16]

In the words of Frith's collaborator, the guitarist Derek Bailey, "The instrument is not a tool but an ally. It is not only a means to an end, it is a source of material, and technique for the improviser is often an exploitation of the natural resources of the instrument" (1992, 99). From this perspective, the instrument can be understood as a creative partner. The linear motion developed in the middle sections of "Hello Music," then, responds to the inversional relations created by the nut pickup. Imagining body-instrument interaction as collaboration recalls Frith's writing about improvisation with human partners: "Improvising is … a place where we can meet on equal terms and discover things we never knew, or hear what we thought we knew in a new light. It's a conversation, an exchange. There are no rules, other than to listen well and act accordingly" (Frith 2005). Improvising with other musicians—or instruments—demands listening, respectfully attending to their difference from me. In this sense, instrumental alteration reveals instrumental alterity.

Redesigned Instruments: Pat Metheny, "Into the Dream"

As instrumental preparation modifies the body of the instrument, it overlaps with instrumental redesign. Whether or not Frith's extra pickup creates a "new" instrument, his later work moved in that direction. From the 1980s, much of his solo improvisation involved homemade instruments: pieces of wood with strings, a pickup, and a bridge. Imposing too crisp a distinction between preparation and redesign would be unhelpful, but let me propose a working definition. Retuning and preparation change an instrument's sonic affordances but not its basic interface. Redesign, by contrast, alters an instrument's basic shape or space and, correspondingly, possibilities for interacting with it.

The Grammy Award–winning jazz guitarist Pat Metheny has long been involved in processes of instrument design, and his work here illustrates a range of possibilities. His collaborations with the Ibanez guitar company, for example, produced the PM-100 and PM-120 models, promoted as "the first radically new body shape in a major commercially released jazz guitar since the late seventies" (Metheny 2000, 11). These archtop guitars feature a double cutaway that is more commonly associated with rock guitars like the Gibson SG. This cutaway is not

16. Cage, for example, said that his experiences with prepared piano "showed [him] how different two pianos are from one another [even though] music (so-called) makes us think two pianos are the same" (1961, 182).

merely cosmetic: it lets Metheny curl his thumb over the top of the neck at higher fret positions. Still, this represents a relatively subtle change.

With Metheny's "Orchestrion" project, he uses a guitar, equipped with MIDI technology, to control an array of mechanical acoustic instruments, including pianos, basses, tuned and untuned percussion, and "guitarbots."[17] These may play preprogrammed parts or improvised loops. This redesign affects action-sound coupling, much like the self-activating instruments discussed in Chapter 2. When the Orchestrion functions as "something that runs," the guitar acts as an input device, the means by which Metheny intervenes in a technologically sustained process. This innovation changes the overall instrumental system but has minimal effects on the interface. The Orchestrion's varied robotic parts are all played through a standard fretboard.

For present purposes, I am most interested in the kind of redesign that alters the instrument's interface. This is realized in one of Metheny's collaborations with the Canadian luthier Linda Manzer. Manzer has created many instruments for Metheny, including a baritone guitar, an acoustic soprano guitar, an acoustic sitar-guitar, and a fretless classical guitar. Arguably their most unusual creation, however, is the forty-two-string Pikasso II guitar (see Figure 4.16).[18] "In 1984," remembers Manzer, "Pat Metheny asked me to design and build a guitar with 'as many strings as possible.' "[19] To achieve this goal, however, they did not expand the fretboard: the Pikasso's main neck, like a standard guitar's, has only six strings. Instead they added three new sets of twelve strings, which are always open. This means that the Pikasso participates in a tradition of "harp guitars," dating from the nineteenth century, that include additional, unstopped strings.[20]

To describe the Pikasso, Metheny has offered an instrumental analogy. "It's really the closest thing I've come to something like a piano that's also a guitar," he says. "You can really have a lot of notes ringing and sustaining over other notes without using any kind of electronics."[21] With its capacity for sustained notes and its extended range, the Pikasso may certainly recall the piano. Beyond any sonic similarities, though, the Pikasso may resemble the piano in terms of interface and playing technique. Though the baritone neck replicates a standard tiered-array

17. Metheny names this system after various historical "orchestra machines," which are discussed by Dolan (2013, 187). The main distinction between the Orchestrion and MIDI guitar controllers—which Metheny has used since the 1980s—is that its sounds are not synthesized or sampled but produced live.
18. The first Pikasso guitar is an electric version, played, for example, on Metheny's collaboration with Ornette Coleman, *Song X* (1986). Here I will simply refer to the acoustic Pikasso II as the "Pikasso," since it has featured more prominently in Metheny's work. I have discussed the Pikasso and "Into the Dream" in a chapter on the Pat Metheny Group's 2001 concert video *Imaginary Day Live* (De Souza 2016a). Though certain analytical details overlap, the focus there is on visual aspects of performance rather than instrumental alteration.
19. See http://www.manzer.com/guitars/index.php?option=com_content&view=article&id=25&Itemid=24. Manzer would later increase this maximum by ten for the fifty-two-string Medusa guitar made for Henrik Andersen.
20. On the history and organology of harp guitars, see Miner (2015).
21. For Metheny's comments on the Pikasso, see "About the instrumentation," http://www.patmetheny.com/features/imaginary/inst.htm.

Figure 4.16 Pat Metheny playing the Pikasso II guitar (Rodby 2008).

fretboard, the other set of strings offer spaces that are linear, like a keyboard. Moreover, when Metheny plays the instrument, his hands are independent, and they combine activation and control. The right hand typically realizes the principal melody, while accompanied by the left. He keeps his left hand on the baritone-guitar neck, using hammer-ons and pull-offs exclusively. Meanwhile, the right hand explores the other areas, plucking or strumming the strings with fingers or a pick. This separation of hands, like Frith's bimanual tapping, pulls apart guitaristic action schemas that are usually coordinated. That said, pianistic or tapping hands are independent but develop effectively the same technique. With the Pikasso guitar, by contrast, the hands serve different functional purposes. This instrumental redesign, then, heightens the distinction between fretting and picking hands. The disalignment of existing motor schemas, responding to the instrument's affordances, is the basis of what is claimed to be a "totally new guitar technique" (Metheny 2000, 10).

Metheny's preferred tuning for the Pikasso both differentiates and unites the different sets of strings. The six strings on the fretboard are tuned as a baritone guitar. That is, they transpose standard E tuning down a major third, producing the notes C2, F2, B♭2, E♭3, G3, C4. The strings that are connected to the headstock above the neck, which nearly parallel the fretboard, are tuned to a G-minor pentatonic collection (G, B♭, C, D, F); the zitherlike strings that cross the instrument's body, to an incomplete C natural-minor or C Dorian scale (C, D, E♭, F, G, B♭). The almost vertical strings connected to the top headstock are tuned to a G-minor triad (G, B♭, D). Since these pass beneath two other sets of strings, they function mainly as sympathetic strings. Though each set of strings maps to a distinct set of pitch classes, their collections overlap substantially. In fact, the forty-two open strings instantiate only six pitch classes, which form a segment from the cycle of fifths.[22] This tuning strategy minimizes dissonances among the Pikasso's open strings. Metheny refers to the result as a "big C-minor kind of sound" (Adelson 2002). With the Pikasso, as with the harmonica, there is a gap between scale and macroharmony, and irregularity fosters the sense of a home key. Each set of open strings offers a fixed tuning that can variously be understood as a chord or a scale.[23] Each involves its own subset of a C-minor scale that is never presented in full.

Metheny most often plays the Pikasso on tracks titled "Into the Dream," and I have consulted fifteen performances of the piece, ranging from 1997 to 2010.[24] Melodic and rhythmic details vary widely across these versions. Nonetheless, "Into the Dream" has a clear four-part form:

> Section A: During a slow introduction, Metheny develops a rhythmically free fingerstyle dialogue between the two right-hand areas. This starts with the zither-like strings and is accompanied by hammer-on trills in the left hand. This section typically lasts around a minute and a half, although … it may vary from 44 seconds (New York, 1998) to over two minutes (2006). The original 1997 version from the CD involves this section only and does not follow the form established by Metheny's later live performances.
>
> Section B1: Next, while maintaining active right-hand plucking, Metheny establishes the meter with sustained bass notes. Though the baritone-guitar neck can play all twelve pitch classes, the bass part only uses a C natural-minor mode; Metheny plays most of these notes with his left index finger, tending to move stepwise. (On occasion, Metheny also taps on the body as part of this section.)
>
> Section C: For a climactic third section, Metheny switches to a pick, alternately strumming the two right-hand sets of strings over a more active bass line. While this section usually runs longer than a minute, Metheny keeps it to 30 seconds in a 2000 live recording and omits it in a 2009 performance.
>
> Section B2: Finally, he returns to the calmer fingerpicking texture of the second section, using the bass to set up a final cadence. (This cadence is where he most often strums the G-minor sympathetic strings.) In the performances I have examined, this recapitulation is never the longest section and its variation is least pronounced, ranging from 44 seconds (New York, 1998) to 1 minute 23 seconds (2010). (De Souza 2016a, 164–65)

Overall, "Into the Dream" explores two oppositions: one between the C-minor and G-pentatonic collections and another between fingerpicking and strumming

22. In set-theoretic terms, this hexachord is a member of set class 6-32 [024579]. Uniquely among hexachord classes, it includes no instances of interval class 6 and only one instance of interval class 1.
23. This conceptual crossover, like my discussion of instrumental "scales" in Chapter 3, resonates with Tymoczko's idea that "a scale is a large chord, and a chord is just a small scale" (2011, 153).
24. For many years, the exceptions here were duets: "The Sound of Water" with the pianist Brad Mehldau (on their 1996 album, *Quartet*) and "*Cichy Zapada Zmrok* (Here Comes the Silent Dusk)" with the Polish singer Anna Maria Jopek (on their 2002 album, *Upojenie*). More recently, though, Metheny used the Pikasso on *What's It All About* (2011) to cover Paul Simon's "The Sound of Silence."

with a pick. The first has to do with the Pikasso as musical technology; the second, with Metheny's playing technique. From this perspective, "Into the Dream" is not a precomposed sequence of notes and harmonies. It is a series of idiomatic performance strategies, a kind of improvisational template to be realized anew in each performance.

Of course, while the Pikasso offers new sounds, it also constrains Metheny's improvisation. The fixed pitch collections cannot be changed in performance, the pitches in the supplementary collections cannot be bent, and so on. Most of Metheny's compositions are not easily played on the Pikasso, since they involve chromatic shifts that exceed its tonal affordances. (While they could be played on the baritone-guitar neck, the sympathetic resonance from the overlapping strings and the bulk of the instrument make this less than feasible.) This particular instrumental redesign, then, becomes so specialized that in the end it feels less flexible than a regular guitar. For all its complexity, it almost seems that Metheny's Pikasso II, like a purpose-built music box, can play just one piece.

This kind of constraint, however, points to the Pikasso's influence on its players' perception. Where Rosenwinkel's retuned guitar skewed expected associations between action and sound and where Frith's prepared guitar reduced auditory expectations by rendering pitches doubled and indistinct, Metheny's redesigned guitar refocuses his musical imagination by splitting apart performance techniques and fixing—or radically reducing—tonal possibilities. This instrument does not afford the performative or conceptual habits associated with the performance of jazz compositions with wide-ranging chromaticism. As Metheny puts it, "You have to learn to think like the instrument you're playing" (Webb 1985). Since most of the Pikasso's strings are fixed and its macroharmony (overall pitch collection) is consonant, it is possible to stop thinking about particular notes and focus on gesture, density, and so on. As the instrument neutralizes harmonic movement—or achieves a kind of tonal stasis—it redirects attention to the instrument's timbre and the player's physical actions; it engenders particular modes of performance and perception. In terms of sound, technique, and visual spectacle, the Pikasso II guitar creates a piece that stands apart from Metheny's other playing, a kind of musical breakdown.

Conclusions

This chapter's analyses show three ways that alteration can change an instrument's affordances. Retuned instruments produce unexpected pitches; prepared instruments produce unexpected sounds; redesigned instruments reconfigure a familiar interface. Instrument, technique, and sound coevolve, as elements of each are preserved or adjusted. There are, of course, countless other idiosyncratic extensions of instrumental resources—from J. S. Bach's five-string violoncello piccolo to Tod Machover's "hypercello" (Ledbetter 2009, 43–45; Rothstein 1991). Still, the music of Rosenwinkel, Frith, and Metheny has highlighted some broad connections between altered instruments, performance, and perception. Whether retuned, prepared, or redesigned, altered instruments offer new possibilities in terms of harmony, timbre, texture, and so on. But at the same time, they play with habitual connections between action and sound, between performers' auditory and motor perception. They create new opportunities to relearn my instrument, moments when I become conscious of my bodily engagement with it, when I begin to listen to and think about and feel the sound differently. Changing the instrument, then, changes the player. Alteration illuminates everyday experiences of instruments, even as it disrupts them.

By way of conclusion, I wish to briefly relate these musical examples to some problems in phenomenological theory, problems around the opposition of *Zuhandenheit* and *Vorhandenheit*. "When we discover its unusability," says Heidegger (2010, 72), "the thing becomes conspicuous." But this conspicuous presence, he suggests, is temporary: "Mere objective presence makes itself known in the useful thing only to withdraw again into … handiness." On one level, this fits with my dynamic account of perception and action (for example, I get used to my guitar's alternate tuning). Yet this dismissal of "mere" presence has been critiqued even by Heidegger's supporters (e.g., Stiegler 1998, 245; Harman 2002, 3–4). And the philosopher himself abandoned the dialectic of *Zuhandenheit* and *Vorhandenheit* after *Being and Time*. The post-Heideggerian phenomenology of Emmanuel Levinas shows that handiness and presence are not simply opposed—rather, they coexist (see Harman 2009). This refines the philosophical framework underpinning the book's earlier chapters and interacts suggestively with the cases of instrumental alteration discussed here.

Recall how Rosenwinkel plays a chord on his radically retuned guitar but claims not to know what it is. In the moment, he cannot name it or place it in a theoretical system. He cannot reduce its sensual qualities—its felt shape, its sonic color, even its specific pitches—to an internal idea. Levinas associates this sort of "deconceptualization" with music (1989, 133). But more generally, this irreducibility is also crucial to his phenomenology of enjoyment, a mode of intentionality that supplements handiness. Levinas argues that tools' materiality produces a kind of sensory contact that goes beyond their usefulness (1969, 133).[25] From this perspective, my relationship to the guitar is not simply "instrumental" (that is, directed toward some purpose); it is also aesthetic. The instrument never fully disappears in its practical functioning: it is also savored like wine, caressed like a lover. Here the grooves of "Zhivago" or Metheny's interaction with the Pikasso can be understood in terms of the pleasures of repetition or the sensual interplay of the erotic.

Where earlier chapters explored instrumental extension, then, this one highlights instrumental exteriority. For Levinas, touch always encounters something exterior, something outside of myself: "In contact itself the touching and the

25. Likewise, where Merleau-Ponty focuses on bodies' competence, Levinas highlights bodies' sensible or sensual exposure to things.

touched separate, as though the touched moved off, was always already other, did not have anything in common with me" (1981, 86). Touch, both literal and figurative, depends on separation, otherness.[26] This alterity is central to Levinas's ethics—and also his aesthetics. I never totally know another person, just as I never totally know a favorite piece.[27] Earlier I broached this topic through Frith's discussion of improvisation as conversation, a responsible practice of listening and responding to another musician. In this regard Simon Critchley's summary of Levinasian ethics seems to echo Frith: "In speaking or calling or listening to the other, I am not reflecting upon the other, but I am actively and existentially engaged in a non-subsumptive relation, where I focus on the particular individual in front of me. I am not contemplating; I am conversing" (2002, 12). Frith's conversational attitude, extended to instruments, again goes beyond the transparency of *Zuhandenheit*. Playing an altered instrument, like being with the Other, is a practice of co-presence where two touch without fusing, without losing their mutual strangeness.

"Hello Music" and "Into the Dream" show how such practices unfold in time. I have suggested that they might be understood as gestures or strategies for interaction, as object-centered processes rather than musical work-objects themselves. A template for improvisation, Levinas might say, is a *how*, not a *what*. In fact, when the philosopher wishes to emphasize temporal aspects of presence, he turns to musical instruments:

> Music, for example in Xenakis' "Nomos Alpha for Unaccompanied Cello," bends the quality of the notes emitted into adverbs. Every quiddity becomes a modality, the strings and wood turn into sonority.... The cello *is* a cello in the sonority that vibrates in its strings and its wood, even if it is already reverting into notes, into identities that settle into their natural places in gamuts from the acute to the grave, according to the different pitches. Thus the essence of the cello, a modality of *essence*, is temporalized in the work. (1981, 41, emphasis in original)

The sound of the instrument may "revert" to notes. It may return to the *zuhanden*, withdrawing into melody or harmony. But this never exhausts its sonority, its sensible presence. Here Levinas's work points toward a phenomenology of listening, to experiences of music's materialization, a line of thought that will be developed more fully in Chapter 6.

Though this chapter highlights the flexibility of technology and technique, it nonetheless focuses on individual, isolated instruments. In truth, however, instrumental alteration takes place within social networks that include players, instrument builders, listeners, and so on, as well as with other instruments, other

26. This underlies the paradoxes of self-touch explored by Merleau-Ponty (1968, 133). When I touch my left hand with my right, I find myself both inside and outside of my body, both touching and touched.

27. Against claims that art expresses something "more real than reality," Levinas asks, "Does not the function of art lie in *not* understanding? … Will we then say that the artist knows and expresses the very obscurity of the real?" (1989, 131, emphasis added). On the relation between ethics and aesthetics in Levinas, see Harman (2007).

machines, other technologies. Note, for example, how Metheny describes the Pikasso II in terms of the piano, how Frith's idea of prepared guitar responds to Cage's prepared piano, or how Cage and Lachenmann describe their new approaches to the piano in terms of percussion instruments. The following chapter explores relations among instruments in the music of Johann Sebastian Bach. Yet in theorizing such connections, it cannot avoid practices of musical writing—which is to say, it must consider the relation between instruments and composition.

CHAPTER Five

Compositional Instruments

When Johann Sebastian Bach died, he owned *eight* harpsichords. And this was only part of a larger collection. The composer also had two violins plus a piccolo violin, three violas, two cellos, a lute, a viola da gamba, and a five-string viola pomposa (*NBR*, 251–52).[1] Bach rented and sold instruments. He was an expert in organ building and, of course, a renowned keyboard virtuoso. The man, by any standard, was deeply involved with instrumental technology.

Nonetheless, Bach's counterpoint is sometimes envisioned as a kind of composition without instrumentation. *The Art of Fugue*, for example, is transcribed for countless instrumental combinations but belongs exclusively to none. Related to this is the notion that *The Art of Fugue* was intended purely for contemplation, that it need not be played or heard. Though such idealist views are rare among musicologists today, they linger in popular discourse. This interpretive tradition—to quote Bach's first biographer, Johann Nikolaus Forkel—imagines the composer as "a true disembodied spirit, who soars above everything mortal" (*NBR*, 438). It understands his counterpoint as abstract rather than concrete, music of the mind and soul, not the body.

This is, again, a metaphysics of presence related to the nineteenth-century aesthetics of absolute music. Yet it would be a mistake to dismiss it too quickly, for it uncovers interesting tensions between performance and composition, between instrumental technics and a technics of musical writing.[2] A composition is realized only through some musical medium, where seemingly self-sufficient tonal patterns may be supplemented by layers of corporeal or instrumental organization. But at the same time, the composition cannot be reduced to the means of its realization. How, then, might composers respond to instruments? And how do instruments relate to each other? This chapter pursues such questions by analyzing varied instrumental resources in Bach's music, from clavier to violin to lute.

1. Throughout this chapter, I use the abbreviation *NBR* for *The New Bach Reader*, edited by David, Mendel, and Wolff (1998).
2. In a way, such tensions define the modern conception of composer and composition, which emerged in the late fifteenth century as part of a shift from improvised counterpoint toward written counterpoint (Wegman 1996). That said, impressive feats of oral counterpoint continued throughout the Renaissance (Canguilhem 2011).

Figure 5.1 Johann Sebastian Bach, excerpts from the Canon at the Twelfth from *The Art of Fugue*, BWV 1080: (a) mm. 1–11 (note the fleeting imitation in m. 9); (b) mm. 34–45 (note return to the opening in the left hand, m. 42).

(a)

(b)

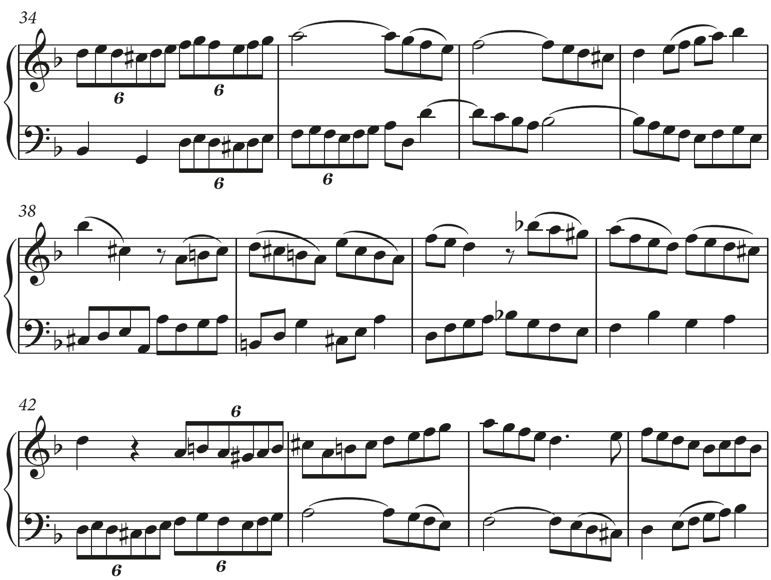
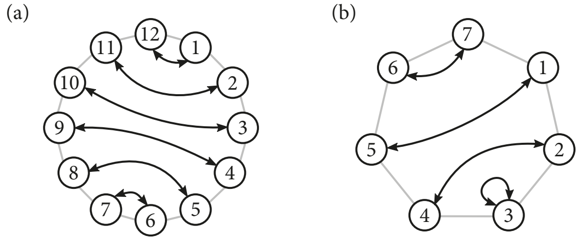


Figure 5.2 Two networks for invertible counterpoint at the twelfth, which use numbers to represent generic intervals: (a) a mod-12 mapping indicates that unisons become twelfths (and vice versa), thirds become tenths (and vice versa), and so forth; (b) a mod-7 mapping gives the same practical results but asserts octave equivalence (e.g., octaves are reduced to unisons, ninths to seconds, tenths to thirds, and so on).



Contrapuntal Hands

A canon is a kind of self-referential music. For the *comes* (or follower) is not an independent line, but a reflection, an echo of the *dux* (leader). With the canons from *The Art of Fugue*, such reflections proliferate as in a hall of mirrors. In the Canon at the Twelfth, for example, the *comes* enters after eight measures (see Figure 5.1a). But Bach introduces additional, fleeting resemblances at a half-measure distance (m. 9, mm. 34–35, mm. 66–71). In this contrapuntal funhouse, it is sometimes hard to tell the copy from the original. When the opening subject returns in m. 42, it is no longer the leader in a canon at the twelfth but the follower in a canon at the octave (see Figure 5.1b). Bach, it turns out, has written two canons in one. Just as *comes* follows *dux*, the second canon derives systematically from the first: the lower line moves to the top, with the intervals between parts transformed according to the well-known formula for invertible counterpoint at the twelfth, a form of "double counterpoint."[3] Though the composer and his contemporaries represented these intervallic exchanges in numerical tables, they can equally be understood via modular arithmetic, as a self-mapping of the cyclic groups $\mathbb{Z}_{12}$ or $\mathbb{Z}_7$ (see Figure 5.2).

Other exchanges are possible with triple invertible counterpoint. Bach's Sinfonia in D major (BWV 789), for example, has a main subject (A) and two countersubjects—one with slower syncopations (B) and one with running sixteenth notes (C). Each of these lines can serve as top, middle, or bass part (see Figure 5.3). Following Daniel Harrison (1988), I use ordered letters to represent arrangements of these melodies. The arrangement ABC would have theme A in the highest part, B in the middle, and C in the bass. Harrison's group-theoretic analysis shows how the D-major Sinfonia explores these arrangements (31–37).[4]

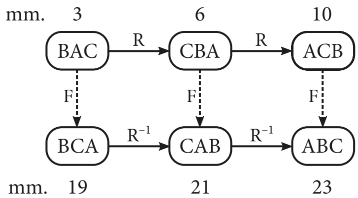
3. Invertible counterpoint is a technique whereby parts in a polyphonic texture exchange registral positions (for example, the bass becomes the melody, while the melody becomes the bass). For a more detailed analysis of the *Art of Fugue*'s Canon at the Twelfth, see Yearsley (2002, 190–201).

4. The simplified analysis presented here departs from Harrison's in two ways. First, it uses Edward Gollin's revised labeling of parts, which names the opening subject A (2000, 328–34). Second,

Figure 5.3 Johann Sebastian Bach, Sinfonia in D major, BWV 789.

Figure 5.3 Continued

Figure 5.4 Transformation network for registral arrangements in Bach's D-major Sinfonia. The operation R and its inverse R^{-1} rotate the parts, whereas F flips the position of the middle and bass parts.



In the piece's exposition, Bach repeatedly rotates the melodies through the three registral positions: BAC becomes CBA, then ACB (see Figure 5.4 and Video 5.1). The slower countersubject, which first appears in the highest part, ultimately ends up in the bass. In the recapitulation, the rotations reverse: the bass's material goes to the middle voice, the middle part's to the top, and the top's to the bass. This second set of rotations is flipped relative to the first set—that is, the first element stays in place while the others swap positions. With its final rotation, the piece exhausts all the possible arrangements of these three melodic elements in a process that combines musical and mathematical constraints.

And physical constraints too. These pieces are both performable (meaning that they fit a keyboardist's hands) and also performative (meaning that they are showy, full of rhetorical flourishes).[5] As David Yearsley argues, "Canonic artifice and virtuosic display [in *The Art of Fugue*] are equally audible, and indeed are inseparable" (2002, 189). The contrapuntal exchanges in the Canon at the Twelfth, then, are also manual exchanges, a kind of choreography. If the hands, in this metaphor, form a dancing couple, then the left hand plays Ginger to the right hand's Fred.[6] It does all the same things, only backward. Much keyboard music—even the layout of the keyboard itself, with the higher notes on the right—is designed for a right-handed player. But Bach's keyboard canons balance the parts, challenging the player to overcome the nondominant hand's resistance. They demand not just dexterity but ambidexterity.[7]

whereas Harrison and Gollin approach triple counterpoint via the symmetric group S_3 (the group of permutations on a set with three elements), I approach it through the dihedral group D_6 (the group of symmetries of an equilateral triangle). The groups S_3 and D_6 are isomorphic. Note, however, that Harrison's permutation transformations act on thematic elements—for example, the permutation (ABC) takes A to B, B to C, and C to A, regardless of the starting arrangement—whereas my approach, based on the rotations and flips of an equilateral triangle, highlights registral positions—for example, R always takes the first position to the second, the second to the third, and the third to the first. For further discussion, see Harrison (1988, 48n12).

5. Here I am thinking of Richard Schechner's definition of performance as "showing doing" (2013, 28).
6. According to an often quoted line by the cartoonist Bob Thaves, "Ginger Rogers did everything [Fred Astaire] did … backwards and in high heels."
7. With claviers with multiple manuals, the hands may even play on separate keyboards. Certain moments in Bach's Goldberg Variations, for example, are composed for two manuals. Their difficulty

Matthew Hall notes this correspondence between double counterpoint and ambidexterity. But he further argues that the effects of two-handedness are clearer in triple counterpoint, where one hand must realize two lines at the same time (2015, 96). For Hall, then, the arrangement ABC is either [AB]C, with two higher parts in the right hand and a lower one in the left, or A[BC], with one in the right and two in the left. Drawing on historical thoroughbass pedagogy (and, certainly, his own expertise as a keyboardist), Hall links triple counterpoint with three keyboard techniques (103):

(1) With a "contrapuntal inversion," the hands exchange material ([AB]C becomes C[AB]).
(2) With a "thoroughbass inversion," the two parts in the same hand trade places, and the other hand is unaffected ([AB]C becomes [BA]C).
(3) With a "voice transfer," the middle part switches hands ([AB]C becomes A[BC]).

Hall is dissatisfied with descriptions of triple counterpoint that emphasize "abstract permutational structure" and "disembodied, purely conceptual operations" (88), and he critiques Harrison's essay at length (92–95). Yet Hall's keyboard gestures are easily formalized and integrated into a transformational model of triple invertible counterpoint.

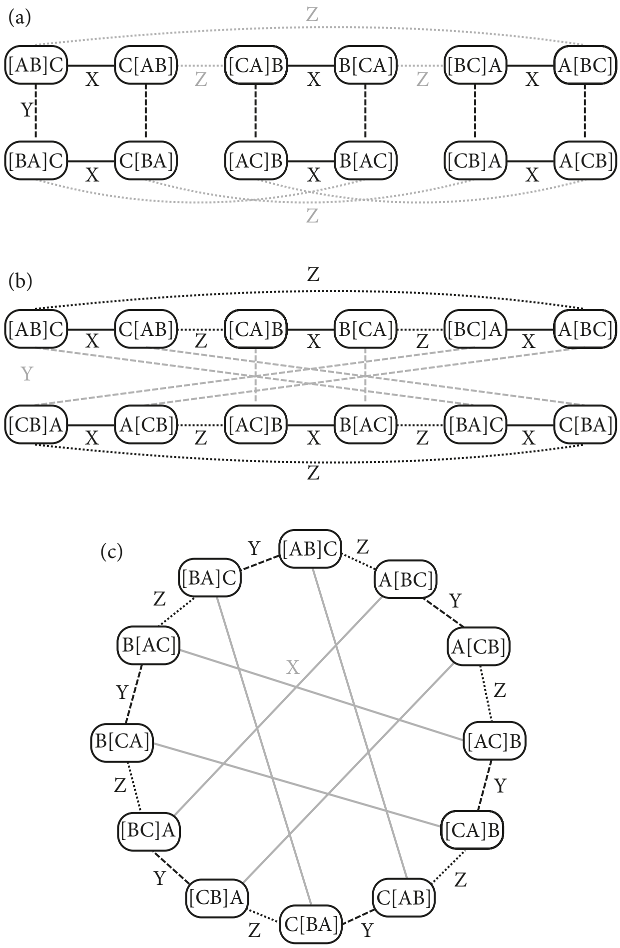
To do so, I use ordered pairs that combine letter arrangements discussed earlier with the +/– system used for harmonica breathing in Chapter 3.[8] Pairs with a + sign have two parts in the right hand, and pairs with a – sign have two in the left. That is, (ABC, +) is the same as [AB]C, and (ABC, –) the same as A[BC]. As such, I will continue to use this more compact notation. Note that this doubles the number of arrangements, giving twelve possibilities instead of six. Ordered pairs can also serve as transformations. The operation (R, +), for example, would rotate the parts while maintaining their distribution between the hands. This, in fact, models the first move in the D-major Sinfonia, taking [BA]C to [CB]A.

Hall's keyboard operations can fit into the model too. For convenience, I label each one with a letter: X for contrapuntal inversion between hands, Y for the thoroughbass inversion within one hand, and Z for the voice transfer involving the middle part. The operations X and Z change the sign, while Y preserves it. In the ordered-pair notation, Z is equivalent to (e, –), where e is the identity element. Technically speaking, each of these actions is an involution—an operation that is its own inversion. Like flicking a light switch, repeating an involution undoes it. Figure 5.5 maps these routes between the twelve elements in the system, giving three isographic visualizations of the same structure. Alternating between any two of the three operations produces a cycle. For present purposes,

is compounded when both hands share the same keyboard. For a reflection on the challenges of ambidexterity in Bach, see Kramer (1995, 232–42).

8. In other words, this has the structure of a direct product group, $D_6 \times \mathbb{Z}_2$.

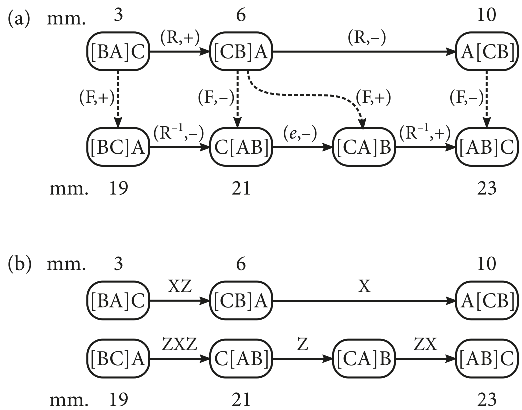
Figure 5.5 Three isographic maps of the space created by Hall's keyboard operations, emphasizing (a) XY cycles, (b) XZ cycles, and (c) the YZ cycle. Note that there are three XY cycles (with four elements each), two XZ cycles (with six elements each), and a single twelve-element YZ cycle.



I am most interested in XZ cycles, produced by the combination of contrapuntal inversions and voice transfers. There are two such cycles. Each has six elements, and they are analogous to the hexatonic cycles used to study triadic transformations.[9]

9. Each of these XZ cycles corresponds to one of Harrison's "conjugations" (1988, 31). For an introduction to hexatonic cycles, see Cohn (2012, ch. 2). A simple exercise can give a sense of these cycles. Play any triad at the keyboard, with a single note in one hand and two in the other. Performing one of Hall's keyboard operations will give a new voicing of the chord, and repeatedly alternating between any two of them will eventually bring you back to your starting arrangement.

Figure 5.6 Transformation networks for contrapuntal-manual arrangements in Bach's D-major Sinfonia: (a) an interpretation using ordered-pair transformations; (b) an interpretation using Hall's keyboard operations. (The versions in mm. 19 and 21 can be linked by either XZX or ZXZ.)



These operations and cycles offer new perspectives on the D-major Sinfonia. The two transformation networks in Figure 5.6 analyze the piece using ordered-pair operations and Hall's keyboard operations. (The contents of the networks' nodes are identical. Video 5.2 animates the analysis based on XZ cycles.) Its first arrangement, [BA]C, has two parts in the right hand. The "rotation" into the second arrangement [CB]A can be understood as (R, +), or the compound transformation XZ.[10] In the third arrangement, A[CB], the left hand takes two parts. It might be approached as a rotation with change of sign (R, –) or as a single contrapuntal inversion X. Either way, this keeps the subject A in a hand by itself and maintains the relative position of the countermelodies. Note that, from Hall's perspective, the second and third arrangements are "closer" to each other than the first and second are.[11]

The recapitulation begins with [BC]A, again keeping A on its own.[12] Thus far, each presentation of the themes has corresponded to a single element within the system. But the version in mm. 21–23 splits in two: the subject's head and tail are separated by a voice transfer, which takes C[AB] to [CA]B. And these brief parallel thirds are the only time in the piece that A and C—the more active lines—are grouped in the same hand. The concluding arrangement, [AB]C, can be understood as the thoroughbass inversion (Y) of the first.

10. Note that these operations do not commute: XZ does not give the same result as ZX (in fact, XZ is the inverse of ZX).

11. The first and third arrangements, [BA]C and A[CB], are as far away from each other as two elements in the cycle can be. In other words, they resemble hexatonic poles. Though Hall does not examine these cycles, he notes this distance between two configurations in the A♭-major Fugue from *The Well-Tempered Clavier*, Book I (2015, 104).

12. In m. 19, Bach adjusts the parts to avoid a voice crossing in the right hand (Hall 2015, 104–5). Hall suggests that the arrangement here derives from m. 6, via thoroughbass inversion (Y).

But it is also interesting to note that the ordered-pair transformations combine both R and R^{-1} with + and – exactly once. Both contrapuntal and manual operations repeat, but their repetitions do not align, increasing transformational variety.

This interpretation addresses aspects of the sinfonia's physical organization that may be felt by performers but not necessarily heard by listeners.[13] Yet this in no way invalidates the earlier, sonic analysis. The two analyses simply address different *levels*, and the relation between these levels can begin to explain how instrumentation participates in composition. To illustrate the concept of levels, Merleau-Ponty uses a linguistic analogy (1963, 91–92). A word has a motoric level, a sonic level, and a semiotic level. It can be approached as bodily action, sound, or meaning. Concentrating on a certain level may cause the others to withdraw temporarily. (If I say a word again and again and again, it seems to lose its meaning, turning weirdly into a sound my mouth makes.) Yet these levels are not opposed. Instead, they fit together. They harmonize.

It is likely that the semiotic level itself includes a similar kind of harmonization. Bidirectional influences between the motor system and language comprehension have been demonstrated in both behavioral and neuroscientific experiments, even with abstract language (Aravena et al. 2010; Guan et al., 2013). Arthur Glenberg, a psychologist who has made important contributions in this area, describes this interplay in terms of "mesh." In human cognition, he proposes, affordances in the environment are meshed with invisible properties, known through prior experience. Through this process, "the path becomes the path *home* and the cup becomes *my* cup" (Glenberg 1997, 4).[14] The perceived object is meshed with concepts, memories, or goals.

A similar integration is involved in composition, for music, too, has motoric, sonic, and semiotic features. In this view, composition is not just about putting together notes. It is also about putting together these different levels. In the D-major Sinfonia, Bach negotiates contrapuntal, corporeal, and instrumental constraints. He avoids combinations that would be tonally but not physically viable (for example, keeping A and C in separate hands). The relation between these levels is not fixed or deterministic. Composers often use notation to work through ideas, and there are always possibilities for alternate fingerings and so forth. Still, a piece can be performed only if it has been adequately "instrumented." From this perspective, instrumentation is not a mere adjunct to composition. Instrumentation is, instead, a fundamental part of composition, for just as counterpoint coordinates melody and harmony, instrumentation coordinates tonal and performative patterns.

13. Where my interpretation focuses on the disposition of *hands*, Bungert (2015) focuses on *fingering* in the Corrente from Bach's Keyboard Partita in E minor.

14. Here Glenberg emphasizes different modes of experience: I may attend to patterns in the environment, or I may also consciously suppress them (1997, 3).

Transcription and Instrumental Ensembles

But what about transcription? Here the composer and the arranger are often different people. In such cases, it seems that composition precedes instrumentation, that the instrumental level changes without affecting a piece's identity. This kind of faithful transcription, however, requires particular technical conditions. It is possible because instruments are not isolated, but joined in a larger technological ecosystem.

For Heidegger, such coordination characterizes "useful things" in general. "Strictly speaking," he writes, "there 'is' no such thing as *a* useful thing" (2010, 68). A utensil is encountered not on its own, but in some context. This is a context of use—since by definition I take up a useful thing *in order to* do something with it—and it is also a context of other utensils. "Useful things," the philosopher continues, "always are *in terms of* their belonging to other useful things: writing utensils, pen, ink, paper, desk blotter, table, lamp, furniture, windows, doors, room" (68). Heidegger figures this "in order to" and this "in terms of" as a kind of reference. Pen and paper "refer" to each other, to their own materials, and to the activity of writing. All of this is readily translated into musical terms. My violin, bow, shoulder rest, rosin, mute, case—they belong or refer to each other, as do various parts of the violin itself (tuning pegs, strings, nut, bridge, tailpiece, fine tuners). I use the violin in order to play fiddle tunes while my daughters dance, to sight-read a string quartet with friends, to perform in an orchestra or a band.

Among other things, then, the violin alludes to other violins, to violas and cellos. It refers to other instruments that it plays with, to a greater ensemble. At the beginning of an orchestra concert, it is possible to hear varied instruments being calibrated to the same standard. Players adjust their instruments to the oboe's A440, while also checking characteristic notes or patterns (such as open strings). Here it is worth noting that mutual tuning of instruments precedes the standardization of pitch and that tuning to a unison is just one way of "sounding together." For example, consider the ocarina duets played by the Venda people of southern Africa, analyzed by John Blacking (1959). The *tshipotoliyo* ocarina, made from fruit shells, is used to produce four tones, but the exact notes are unpredictable. A single ocarina's pitches change over time and are easily adjusted by the embouchure, and multiple ocarinas generally produce different notes. In fact, for players of these duets, ocarinas with the same pitches do not "sound well together" (17). They find this musically uninteresting (19). Keeping that in mind, standard tuning should not be naturalized. This kind of tuning is, rather, a musical technology that affords unison playing and the transfer of pitch patterns from one instrument to another.

Notation plays a role here too. Many keyboard instruments even have built-in music stands, which refer clearly to scores. For Bach and his contemporaries, the keyboard correlated with various kinds of notation, both German keyboard tablature and "Italian tablature" (that is, staff notation). German tablature involves a one-to-one relation between symbols and keys on the instrument, since it differentiates among octaves but not enharmonically equivalent pitches. C♯4 and D♭4, for example, are represented by the same sign, since both are played on the black key between C4 and D4. While staff notation distinguishes between C♯s and D♭s, it involves an opposition of natural and accidental notes that generally maps onto the instrumental opposition of white and black keys. With few exceptions, notes bearing flats and sharps fall on black keys, and the resulting key signatures frame different tonal keys as inflected deviations from a white-note mode. Bach often used German tablature for compositional sketches, including parts for non-keyboard instruments (Marshall 1972, 141). And staff notation, of course, was used for diverse vocal and instrumental parts. Both forms of notation, then, were situated in a broader technical context, referring to notes and to instruments. In this view, notation achieves a quasi-abstract representation of tones not by eliminating instrumental references but by multiplying them. A shared notational system, like a shared tuning, makes it easier for multi-instrumentalists like Bach to realize violin or vocal parts on the keyboard, to translate among performance media.

Yet such translations are rarely exact. They require shared pitch affordances, involving scale, range, and texture. It would be difficult to transcribe Bach's D-major Sinfonia for a solo violin, though it works well for a string trio. (Zoltán Kodály boldly transcribed Bach's BWV 903 Chromatic Fantasy for a solo viola, but that piece does not combine independent contrapuntal lines.) Even closely related instruments, though, may diverge in significant ways.

Compare the organ, harpsichord, and clavichord.[15] Their keyboards support very similar actions in performance. Still, their ranges vary, from the smallest spinet to the largest pipe organ. And this involves not only the length of the keyboard but also the number of keyboards. Organs and pedal harpsichords include keyboards for the feet, and pieces like the Goldberg Variations exploit multiple manuals (without them, the hands run over each other).[16] Variations in timbre and loudness relate to the instruments' social affordances or musical environments: the organ's sonic power makes it arguably the most public of keyboards (except perhaps the carillon); the harpsichord's cutting tone suits its continuo role in large ensembles; and the clavichord's softness fits more intimate settings. Further differences involve action-to-sound conversion. With organ or harpsichord, the force of the player's fingers is not reflected in the dynamics. On these instruments, in contrast to clavichord, the player does not require an even or expressive touch. Thus C. P. E. Bach states, "A good clavichordist makes an accomplished harpsichordist, but not the reverse" (1949, 37–38). The clavichord also affords modification of the tone during play: the player can raise the pitch to create a kind of vibrato, or

15. Though I consider the clavichord here, there were no references during Bach's lifetime to his playing clavichord. As David Ledbetter explains, the first such reference was made by Johann Friedrich Agricola in 1775 (2002, 18–19). In 1802, Bach's biographer J. N. Forkel claimed that the clavichord was the composer's favorite clavier—but this statement is tied up with anti-French nationalism, since he considered the clavichord more expressive and, therefore, more "German."

16. Of course, temperament was also not standardized in Bach's day, meaning that not all instruments were suited to the keys the composer explored in his *Well-Tempered Clavier*.

Figure 5.7 Comparison of Bach's transcriptions of Concerto in C by Johann Ernst, Prince of Saxe-Weimar, for clavier (BWV 984) and for organ (BWV 595), mm. 1–6.

Bebung.[17] Finally, the organ's unlimited sustaining capacities contrast with the others' rapidly decaying percussive sound.

Such differences are evident in J. S. Bach's two transcriptions of a concerto by Johann Ernst, Prince of Saxe-Weimar—one for organ (BWV 595) and one for clavier (BWV 984). The piece begins with a two-measure subject that moves from tonic to dominant, which alternates with episodic sequences. To be sure, the differences between the two versions go beyond instrumentation. The organ version, for example, is longer, having more iterations of the subject. Yet the instruments' distinct affordances are also immediately apparent. From the start, the organ pedals add a bass part that constitutes its own rhythmic-metric layer in a tiered polyphonic texture (see Figure 5.7).[18] In the first sequential episode, the hands move

17. For a discussion of this idiomatic clavichord technique, see Brauchli (1998, 267–74).
18. Auerbach (2008) theorizes different kinds of tiered polyphony, with analytical applications to Brahms's piano music.

Figure 5.8 Sequential episode from BWV 984, mm. 14–17, and BWV 595, mm. 20–23. Note the organ's alternation between *Oberwerk* and *Rückpositiv*.

in parallel, alternating at the half-measure between more widely and more closely spaced consonances (mm. 3–6). On the clavier, this division is based on the opposition of tenths and sixths. On the organ, however, Bach also switches between manuals, setting the *Oberwerk* (the main manual or "great organ") against the secondary *Rückpositiv* (the department at the player's back, typically used for soloistic or coloristic effects). The organ thus offers a timbral, spatial, and kinesthetic juxtaposition that the composer exploits throughout BWV 595.

In the second sequential episode, Bach interpolates solo moments on the *Rückpositiv* (see Figure 5.8). As his beaming shows, this instrumental shift suggests an antiphonal texture that is not necessarily apparent in the clavier version.[19] A later variant of this sequence introduces a canon at the fifth below over a new bass line (see Figure 5.9). On the clavier, the left hand takes the bass while the right

19. For a discussion of instrumentation and perceived textural organization, see De Souza (2015). Bach's repetition of the bass figure here also clarifies the similarity between this descending fifths sequence and the first.

Figure 5.9 Variation on the previous figure's sequence from BWV 984, mm. 43–46, and BWV 595, mm. 58–61, with a canon in the organ manuals.

Figure 5.10 Organ trio texture in BWV 595, mm. 52–57.

has both parts of the canon; on the organ, the feet cover the bass, and each upper part is given to a single hand in a busier *Rückpositiv* passage. While both versions offer a three-part texture here, the performative realization is distinct.

The independence of the organist's hands and feet is perhaps even clearer in the preceding section (mm. 52–57), which has no counterpart in the clavier version (see Figure 5.10). Such passages recall a Germanic "organ trio" tradition, in which three lines are mapped onto three keyboards, realized by the organist's two hands and feet. "It is as if each part of the body must have a mind of its own," says Yearsley (2012, 50). "Anyone who has played a trio at the organ … knows what thinking this way feels like in the body."

This is not to say that Bach's clavier version is a lesser imitation of the organ work. The clavier's unique passages often highlight the linear dimension of the keyboard instead of the contrast between multiple manuals. The sweeping contrary motion of mm. 26–29 indexes both the spatiality of the instrument and the symmetry of the player's body (see Figure 5.11). While the melodic material of the organ version partially overlaps with this passage, its texture is wholly different (continuing the interplay of *Oberwerk* and *Rückpositiv*).

Obviously these pieces are closely related, just as the instruments are closely related. Yet subtle differences between the versions also show the *limits* of translation, which are often more immediate for performers. Parallel passages in Figure 5.9 may sound similar but feel different. This kinesthetic element of the music, which is ultimately grounded in particular instrumental spaces, is often "lost in translation."

Bach's transcriptions, then, show him attending to instrumental affordances. Thanks to connections among instruments, he is able to reproduce the piece in another medium. Yet adjustments at the instrumental level affect tonal organization too. In this sense, the instruments might be understood as tools for investigating a piece. As Christoph Wolff puts it, "organ and clavier [served] as indispensable pieces of equipment in Bach's experimental musical laboratory" (2000, 8). The analogy is worth pursuing, since scientific instruments, like musical ones, are found in ensembles. For a laboratory's results to be directly comparable, its scientific instruments must be calibrated to each other; for its experiments to be repeated consistently in other labs, the instruments must also be standardized. Likewise ensembles of musical instruments are tuned to each other and standardized, so that they can consistently reproduce particular compositions. For the historian of science Peter Galison (2005), material culture thus supports theoretical culture; instrumental conditions facilitate generalization. Yet he argues that generalization does not simply involve "translation" of preexisting meanings. Generalization, for Galison, is fundamentally a form of delocalization. It involves negotiations, changing contexts, communication through pidgins (that is, "exchange languages" that are both hybrid and simplified). In brief, transcription both preserves and transforms. And this suggests, again, that composition and instrumentation are not opposed but entwined.

Figure 5.11 Comparison of BWV 984, mm. 25–30, and BWV 595, mm. 38–43. Note contrary motion in the clavier.

The Violin as Compositional Instrument

Two passages from Carl Philipp Emanuel Bach reveal his father's engagement with possibilities on both contrapuntal and instrumental levels:

> When he listened to a rich and many-voiced fugue, he could soon say, after the first entries of the subjects, what contrapuntal devices it would be possible to apply, and which of them the composer by rights ought to apply, and on such occasions, when I was standing next to him, and he had voiced his surmises to me, he would joyfully nudge me when his expectations were fulfilled. (*NBR*, 397)

In a fugal exposition, the elder Bach heard possibilities, or almost obligations. He sensed immediately whether a subject could (or should) be combined with itself in stretto, whether a subject-countersubject pair could (or should) be inverted at the octave or twelfth. Bach, in other words, was attuned to *contrapuntal affordances*. Here, again, expertise "appears in the way the world shows up" (Dreyfus 2002, 373). To write the rest of the fugue, then, the contrapuntist pursues tendencies that seem latent in the material. The subject constrains a composer, just as the instrument constrains an improviser—shaping but never determining the music.

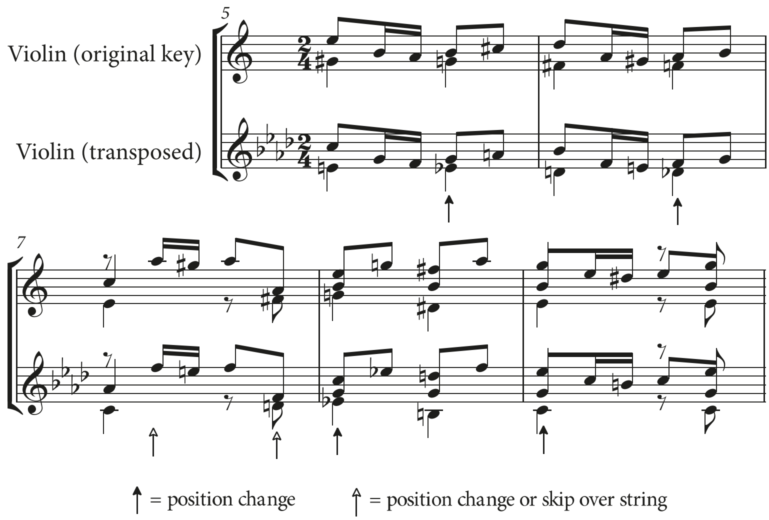
Yet C. P. E. Bach also suggests that his father's ability to play various instruments informed his compositional practice:

> In his youth, and until the approach of old age, he played the violin cleanly and penetratingly, and thus kept the orchestra in better order than he could have done with the harpsichord. He understood to perfection the possibilities of all stringed instruments. This is evidenced by his solos for the violin and for the violoncello without bass. (*NBR*, 397)

These solos are difficult but highly idiomatic. Through open strings, multiple stops, and string crossing, Bach creates rich polyphonic textures with a single violin. This is particularly notable in fugues and in movements where a continuous bass line supports an upper melody (such as the Andante from the Second Sonata or the Adagio from the Third Sonata). If the pieces are transposed into other keys, many of these instrumental features are obscured, and certain passages become impracticable. Figure 5.12, for example, presents two versions of an excerpt from the Second Sonata's Fugue. In the original key of A minor, my left hand stays in first position throughout. The three contrapuntal voices map onto the three strings in play (the only exception is the brief G-sharp neighbor note in m. 6).[20] Transposing the passage down to F minor introduces uncomfortable leaps: since it is impossible to simultaneously play E♭4 and G4 on the D string, I must jump to third position for the second half of m. 5, then back again; to

20. Throughout this fugue, the descending chromatic figure introduced in mm. 5–7 never crosses strings. Its semitones always move along the string. This is also true of the figure's inversion, which first appears at m. 239. In terms of the transformational model of fretboard space developed earlier in the book, this figure's falling semitones are always of the form (0, −1), not (−1, +6).

Figure 5.12 Johann Sebastian Bach, Fugue from Sonata no. 2 in A minor for Unaccompanied Violin, BWV 1003, mm. 5–9. The original key stays in first position, with each contrapuntal voice effectively staying on a single string. Transposed to F minor, however, the passage demands frequent position changes and difficult triple stops. (The use of arrows to indicate position changes follows Argent [2000, 19].)



catch the high entry of the subject in m. 7, I must either shift positions again or skip the bow over the A string. Using open strings does not make the passage easier. While not impossible, the F-minor version is significantly less idiomatic, less satisfying in my hands.

Bach's solo string music, then, goes beyond competent instrumentation. In these compositions, Bach responds to instrumental affordances as much as contrapuntal ones. He investigates musical possibilities that are specific to the interactions between four strings, four fingers, and a bow. The instrument, then, seems not to express preexisting ideas but to reveal new ones. It shapes both the invention of musical material and its disposition throughout a piece.[21]

Consider the Prelude from the Third Partita in E major for Unaccompanied Violin (BWV 1006). After a two-measure introductory gesture, the piece launches into the running sixteenth notes that will continue until the dominant of the final cadence (mm. 134–35; see Video 5.3). Bach then juxtaposes two figures that form the *inventio* of the movement: a figure with a repeated pedal note in mm. 3 and 5 and a scalar figure in mm. 4 and 6 (see Figure 5.13). In the pedaling figure, by contrast, the left hand is anchored: my index finger stops two strings at the same location, forming a perfect-fifth frame. This creates the repeated B4 on the A string,

21. I borrow this distinction between invention and disposition from Laurence Dreyfus's *Bach and the Patterns of Invention* (1996).

Figure 5.13 Johann Sebastian Bach, Prelude from Partita no. 3 in E major for Unaccompanied Violin, BWV 1006, mm. 1–6. The opposition of string crossing and scalar motion in mm. 3–6 forms the basic material for the movement.

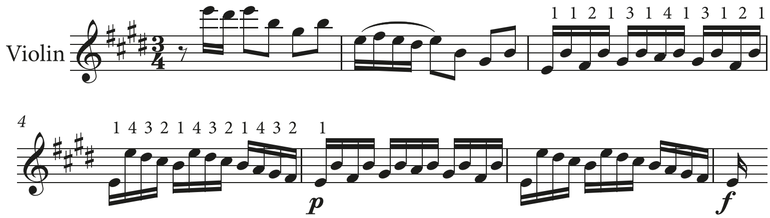
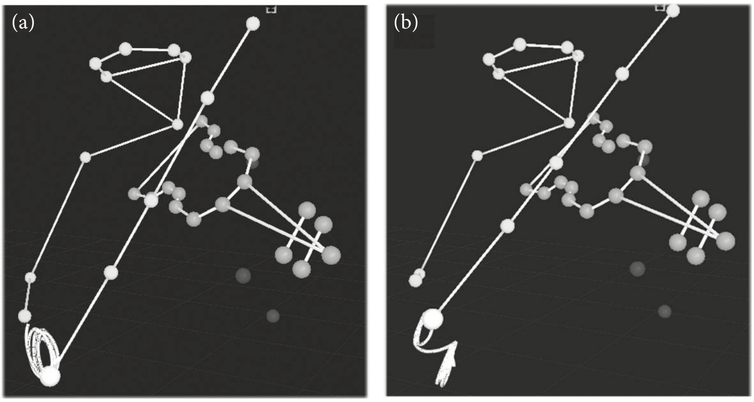


Figure 5.14 Motion-capture images tracing bow-hand movement in the Prelude from BWV 1006: (a) string crossing in m. 3; (b) scalar figure in m. 4.



as the second through fourth fingers walk up and down the D string.[22] Meanwhile my bow moves in a simple string-crossing routine, pulling down on the D string and pushing up on the A string. As the motion capture in Video 5.4 shows, my bow hand moves in a circle (traced in white; see Figure 5.14a). In the scales, mobile fingers form a single melody, descending along the string with linear fingering (4–3–2–1).[23] Here the bowing, traced in red on the video, involves more of a back-and-forth motion, shifting down with the change of string (Figure 5.14b).

Bach focuses on string crossing in mm. 13–28 (see Figure 5.15).[24] The technical term for such bowing patterns, which combine open and stopped strings,

22. This movement resembles the contextual operation K in the analysis of Rosenwinkel's "Zhivago" in Chapter 4, in which notes in a higher position were held constant while other fingers moved along a lower string.
23. Here I use violinists' numbering of fingers (which, of course, differs from pianists'): the index finger is 1; the middle finger, 2; the ring finger, 3; the little finger, 4.
24. Uniquely, the higher variation on this figure in mm. 9–12 does not necessarily involve string crossing: if it is played exclusively on the E string, though, it introduces an open-string pedal that will be important in the following section.

Figure 5.15 Johann Sebastian Bach, Prelude from Partita no. 3 in E major for Unaccompanied Violin, BWV 1006, mm. 13–28.

is “bariolage” (from the French, meaning “odd mixture of colors”). First, in mm. 13–16, he explores the instrumental gesture established in m. 3: crossing back and forth between two strings with movement along the lower string (see Videos 5.5–5.6). Bach is careful to indicate the string crossing, notating two melodic strands with opposed beaming. Note, however, that most of the pitches on the lower A string sound *higher* than the open E-string pedal! Basic bowing and fingerboard schemas repeat; the pitch relationship between melodic strands does not. Throughout this passage, I play the “same” E5 in two different places, a clear instance of the violin’s many-to-one place-to-pitch mapping.

In m. 17, Bach adds a third string to the pattern (see Video 5.7). Down bows stay on the A string, but up bows alternate between the E and D strings. In accordance with the method of numbering strings introduced in Chapter 3 (which labels the highest string as 1), this pattern of strings is represented as 2–1–2–3.[25] The transformational graphs in Figure 5.16 isolate moves in cross-string space: they show how Bach expands the bariolage by taking the original two-string pattern (–1, +1) and adding on its inversion (+1, –1). The central

25. To be clear, the E string = 1, the A string = 2, the D string = 3, and the G string = 4. These numbers are conventionally used by violinists, though they typically write string numbers in Roman numerals.

Figure 5.16 Transformational graphs for cross-string moves in the Prelude from BWV 1006. The first graph (a) represents the crossing introduced in m. 3 on the D and A strings (and repeated in mm. 13–16 on the A and E strings): it moves up one string (–1), then back down (+1). A second graph (b) expands this to the three-string bariolage from mm. 17–28. The bowing pattern starts in the middle node of the graph (on the A string): the first loop (–1, +1), on the right, doubles the smaller graph (moving up to the E string and back), while the second (+1, –1), on the left, inverts it (moving down to the D string and back).

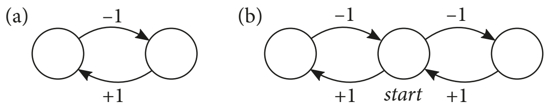
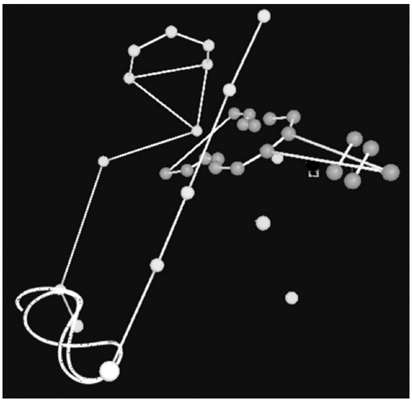


Figure 5.17 Motion-capture image tracing bow-hand movement in the three-string bariolage pattern from the BWV 1006 Prelude, mm. 17–28.



string in the pattern—here the A string—forms a balance point, from which I reach up and down. This means that that the bow hand moves in a figure eight (see Video 5.8 and Figure 5.17), doubling the loops shown Videos 5.4 and 5.6.

At first the three-string bariolage sounds a repeated third—the pitch E5 is alternately presented on the open E string and high on the D string. Then, continuing the established instrumental strategy, the position on the lowest string moves while those on the upper strings remain constant (mm. 17–19). This downward motion spreads to the A string in the following chain of 7–6 suspensions (mm. 20–28). Two-measure-long "links" in this chain repeat fingerboard movement exactly—the A-string note moves down, then the D-string note—but because the open-string pedal never moves, they are not pitch transpositions of each other

Figure 5.18 Transformational network for the Prelude from BWV 1006, mm. 21–28, showing movement in fingerboard space. Lines without arrowheads correspond to the identity element (0, 0). The lower two strings alternately descend one step while the top string remains open.

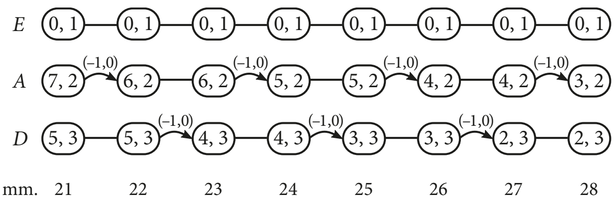


Figure 5.19 Johann Sebastian Bach, Prelude from Partita no. 3 in E major for Unaccompanied Violin, BWV 1006, mm. 43–50.

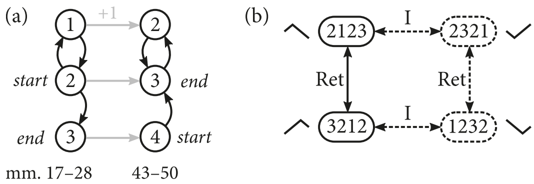
(see Figure 5.18).[26] Here the piece comes closest to chordal figuration preludes like the Prelude in C major from the first book of *The Well-Tempered Clavier*. The passage from mm. 13–28 will reappear, transposed down a fifth—that is, down one string (0, +1)—in mm. 63–78. Here the pedal note is an open A string.[27]

Before that, though, Bach turns the bariolage patterns inside out (mm. 43–50; see Figure 5.19). Mobile and fixed strings are flipped: the lowest string, not the highest, holds the pedal note; the note on the D string generally moves each bar;

26. The transformational model of fingerboard space underlying this network is isomorphic to the fretboard-space model discussed in Chapters 3 and 4. However, unlike the fully chromatic steps of guitar frets, here I represent steps on the violin's fingerboard in terms of diatonic "positions." For example, "second position" (2, *x*) is found two letter names above the open string, regardless of accidentals. (Second position on the A string, then, would involve either C♮ or C♯.) While this approach involves some ambiguity (which could be problematic in highly chromatic situations), it has the benefit of following an important way that violinists conceptualize space on their instrument. Bow direction could easily be added to this model, through the +/– system used for harmonica breathing.

27. As Joel Lester discusses, this cross-string transposition strategy appears elsewhere in Bach's oeuvre for solo violin, as in opening movements from the G-minor and A-minor Sonatas (1999, 52).

Figure 5.20 Transformational networks for three-string bariolage patterns in the Prelude from BWV 1006. Numbers in the nodes refer to strings (1 = E string, 2 = A string, 3 = D string, 4 = G string), and labels on arrows represent cross-string transformations. In (a), the formation on the right (for mm. 43–50) reverses the ordering from the left (for mm. 17–28). The spatial network in (b) shows "prime forms" of three-string bariolage patterns with four elements and adjacent string motion. Bach uses the patterns on the left side of the network, which have similar contours in string space. Both move to higher strings, then lower ones. (Ret stands for retrograde, and I for inversion.)



the A string, each beat. Each measure's initial four-note group reverses the three-string bowing pattern, while the remaining groups reverse the two-string pattern.

The transformation networks in Figure 5.20 help clarify this reversal in cross-string space. The string sequence 4–3–2–3 is a backward, one-string-down version of 2–1–2–3 (see Figure 5.20a). Again the pattern orbits a central string. But with down bows on the outer strings, it feels as though I am *reaching in* to the repeated string, instead of *reaching out* from it.[28] Now I move across three strings at the beginning of the pattern rather than the end. Yet as the spatial network of Figure 5.20b shows, this reversed string sequence (unlike its unused inversions) preserves the string-space contour of the original: both cross to higher strings, then come back down. Video 5.9▶ shows how my bow hand again moves through a figure eight—but with the direction reversed, relative to the pattern in Video 5.8—then cycles between the two higher strings (see Figure 5.21).

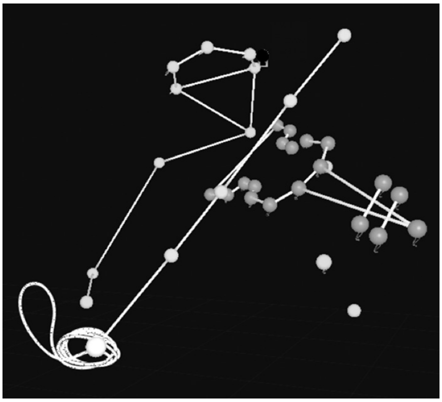
Throughout, these extended string-crossing passages are interposed with more linear sections based on the scalar figure that first appeared in m. 4. Without going into more detail, I will note that bariolage recurs near the end of the piece—for example, between mm. 109–12 and leading up to the chords of the final cadence (mm. 130–33). Here again the notes on the A string ascend above the open E5.

In this prelude, Bach treats string-crossing patterns the way that he often treats melodic or contrapuntal themes: repeating, extending, inverting them. This persistent development of an instrumental gesture, though, involves constantly varied pitch material. As abstract sequences of notes, these passages seem to have little in common; as I play them on the violin, they feel wonderfully connected.

Of course, it is impossible to know how Bach used the instrument in composing this piece. He might have generated ideas by improvising, then worked them out on paper. He might have composed on paper but tested out finished passages

28. While some editions add slurs to this pattern, these are not present in the autograph manuscript (unlike, say, the slurs in the string crossing that leads to the final cadence).

Figure 5.21 Motion-capture image tracing bow-hand movement in the three-string bariolage pattern from the BWV 1006 Prelude, mm. 43–50.



on the instrument. C. P. E. Bach remembered his father using both strategies (*NBR*, 399). On another level, though, such details are unimportant: either way, Bach certainly drew on his embodied know-how as a violinist. Just as instrumental practice may drive improvisation, such know-how becomes a resource for composition.[29] The composer's instrument-specific habits and auditory-motor connections reveal certain possibilities, shaping the way that musical affordances show up. This goes beyond *instrumental composition*—that is, writing music that is playable or idiomatic. The violin here functions as a conceptual tool and a source of material; it becomes a *compositional instrument*.

Idiomatic Translations

Bach's student Johann Friedrich Agricola reported that the composer often played his solo violin pieces on the keyboard, filling out the harmony as needed (David and Mendel 1945, 447). An autograph manuscript from the 1730s presents a suggestive record of this practice: here Bach recasts the E-major Partita, transposing it down an octave and adding a bass line. The range and texture of this arrangement—which is cataloged as BWV 1006a—suggest the lute, and it is often played on this instrument. The composer also arranged the Partita's Prelude for organ and orchestra as part of his civic cantata *Wir danken dir, Gott, wir danken dir* (BWV 29). With the two versions of the C-major Concerto, Bach translates between instruments with similar interfaces, much as one might translate a text from French to Spanish, drawing frequently on cognates. With his arrangements of the violin piece, though, the instruments involved are less similar. The bariolage

29. This aligns with the computational model created by Huron and Berec (2009), which suggested that composers who can play the trumpet write more idiomatically for the instrument.

passages from the original, in particular, serve to illustrate sonic and physical translations.

Playing the prelude on the lute brings out similarities to the violin. With both, a tiered array allows for the juxtaposition of strings, the elaboration of held, shifting chordal shapes. The left-hand fingers stop the strings, while the right hand activates the sound. Yet there is an important difference in this action-to-sound conversion: the difference between the violinist's bow and the lutenist's fingertips. The bow is a tense line of horsehair drawn down or pushed up, sustaining sound as it rubs against the string. As a single surface, this allows for the activation of multiple strings—but they must be adjacent. This unity of the bow contributes to a concept of string crossing that seems less important with the lute, where each right-hand finger can independently activate a string. These plucking fingers, unlike the scraping bow, make momentary, percussive contact with the string. They can also move up or down—as in strumming—but lutenists' fingers (like classical guitarists'), typically pluck upward. The difference between the violinist's bow hand and the lutenist's plucking hand can be summed up by a distinction, articulated by the philosopher Raymond Tallis (2003), between the brachiochiral hand—the hand at the end of the arm, which reaches and gestures—and the chirodigital hand—the hand with fingers that can tie knots, that can count, that can play the flute.

This flexibility in plucking correlates with two other differences. The first is the addition of bass notes, played with the thumb. These may add to the original melody (see Figure 5.22a) or be pulled out from the original in an idiomatic fingerpicking routine (mm. 43–50, see Figure 5.22b).

A second, subtler difference involves the instruments' contrasting sizes. Given the lute's longer neck (and string length), the span of my hand covers fewer semitones. On the violin, I can easily reach an octave from my index finger to my little finger on the string above. On the lute, this is not possible: for example, I cannot set up the chain of 7–6 suspensions in mm. 20–28 on adjacent strings. Clearly this also relates to differences in tuning. Because the violin is tuned in fifths, the repeat in mm. 63–78 involves physical transposition—down one string (–1, 0)—as well as pitch transposition (down a perfect fifth). On the lute, this repeated passage involves new fingering, since the instrument was typically tuned to a D-minor chord—to (A2, D3, F3, A3, D4, F4)—above unfingered diapason courses. BWV 1006a is typically played in F major to take advantage of the open-string $\hat{1}$ and $\hat{3}$. Even so, it is less idiomatic under the lutenist's hands—like most of Bach's lute works, it needs creative adjustments to work. (Though Bach owned a lute, he was not a skilled lutenist.)

Obviously these two versions have much in common—bariolage patterns change to fingerpicking patterns. At the same time, the lower register and bass make it sound typical of the lute. Toccata-like chord patterns over ringing pedal notes, for example, are particularly characteristic of this instrument. And David Ledbetter notes the prelude's resemblance to an undated caprice, possibly by Bach's lutenist friend Silvius Leopold Weiss (2009, 53–54) (see Figure 5.23).

In his BWV 29 cantata, Bach transcribes the piece for an ensemble. The featured organ part, however, is an idiomatic keyboard version of the piece. Here Bach changes the key—down a step to D major—to accommodate his three natural trumpets. And he emphasizes the original opposition between scalar and

Figure 5.22 Johann Sebastian Bach, excerpts from BWV 1006a Prelude for Lute: (a) mm. 125–30, with thumbed bass notes *added* to the violin's original melody; (b) mm. 43–50, with bass notes *extracted* from the violin's original melody.

string-crossing material by setting the former as tuttis and the latter as solos (see Figure 5.24).

The "string-crossing" pattern, however, works differently in the linear space of the keyboard: it becomes a back-and-forth turning of the hand that is anchored by a boundary digit, either thumb or little finger. In mm. 13–16, the same directed-stem notation Bach used to indicate string crossing, in this context, denotes the disposition of the keyboardist's hands (see Figure 5.25).[30] Instead of a single hand

30. Peter Williams (1994) discusses notation and hand distribution in the music of Bach and his contemporaries.

Figure 5.23 Silvius Leopold Weiss (?), Caprice for Lute (from Ledbetter 2009, 54).

moving along the strings (connected to a neighboring string by the movement of bow or plucking), the organist's hands intertwine in a kind of bimanual hocketing. With this passage, the keyboard—with its one-to-one place-to-pitch mapping—offers greater congruence between instrumental and sonic spaces. The repeated D5s occur in only one location.

From mm. 17–28, Bach makes more free translation to the organ idiom. Without the complication of the three-string bariolage pattern, m. 17 would simply present alternating thirds. Instead the composer refigures this passage. The chromatic passing tone (from the violin's D string) is lost as Bach introduces a more expansive dipping gesture, which resembles the original's triple-string-crossing movement more than its sound (see Figure 5.25). The following chain of suspensions (mm. 20–28) turns into Alberti-bass-like broken chords over a pulsing bass pedal.

While this section is translated more freely, the sinfonia as a whole bears traces of its violinistic origins. I find the solo organ part thrilling—with its constant linear motion, skipping across the keyboard—but it is hardly a typical texture for the instrument. It almost treats the organ as a monophonic instrument.[31] The performer's right hand plays no simultaneities, not even at the final cadence, where the violin

31. This resembles the BWV 964 keyboard arrangement of the Allegro from Bach's Second Sonata for Unaccompanied Violin in A minor (BWV 1003). Here the distribution of the melody between the hands would seem to affect performers' sense of grouping (if not listeners').

Figure 5.24 Johann Sebastian Bach, Sinfonia from *Wir danken dir, Gott, wir danken dir* (BWV 29), mm. 1–7. String-crossing passages from BWV 1006 become organ solos, while scalar passages become tutti passages.

Figure 5.25 Comparison of Prelude from BWV 1006 and organ part from Sinfonia BWV 29, mm. 13–29. In mm. 13–16, string crossing maps onto bimanual interlocking. After that, Bach writes an idiomatic keyboard figure for the organ.

breaks into multiple stops (mm. 134–35). A texture that is idiomatic to one instrument seems unusual on another.[32] Transcribed into another context of instrumental affordances and physical habits, the "same" notes may take on different resonances.

Certainly it makes sense to hear Bach's arrangements of the BWV 1006 prelude as three versions of the "same piece."[33] Yet this analysis also highlights moments of delocalization, negotiation, and changing contexts—much like the processes of scientific generalization discussed by Galison. Sometimes Bach preserves aspects

32. Williams, for example, suggests that the famous Toccata in D minor (BWV 565) may reflect traces of another interface: "All the oddities one might hear in the piece disappear as soon as it is seen that the D minor Toccata may be a transcription of something else. The opening octaves, for instance, could well be a transcriber's way of making more rhetorical and effective on the organ a series of opening gestures that would have been solo on a melodic instrument (say viola da gamba, flute, or violin)" (1981, 335). Other authors suggest different sources, such as five-string cello (Argent 2000) or lute (Altschuler 2005).
33. Another notable version is created by Robert Schumann's piano accompaniment. Lester compares this arrangement to Bach's orchestra and organ version, emphasizing their different rhythmic profiles (1999, 117–22).

of body-instrument interaction, whether heard or felt. Listening to these arrangements together, for example, brings out similarities between affordances of the violin and lute and differences from the organ.[34] Other times Bach overwrites the original, engaging the unique affordances of the new medium—adding bass notes, changing figuration, and so on. With the lute version, the adjustments continue with performers, since Bach's version is not entirely idiomatic to the instrument. The largest change here is the shift in key from E major to F major. In fact, because E major clashes with the most common D-minor lute tuning, some believe that BWV 1006a is not a lute arrangement but a lute-inspired keyboard arrangement. Continuing along these lines, it has been suggested that this is Bach's only surviving work for the lute clavier, or *Lautenwerk* (Burguéte 1977, 52).

Playing Lute at the Keyboard

The *Lautenwerk* shows that Bach did not simply use existing instruments; he also helped develop new ones. According to Agricola, Bach designed a "lute harpsichord" (*Lautenclavicymbel*), which was built by the organ builder Zacharias Hildebrandt. This may have been one of the two lute claviers that Bach owned at the time of his death. The composer had been an early adopter of this experimental keyboard instrument. He facilitated the purchase of a *Lautenwerk* made by his elder cousin Johann Nicolaus Bach as early as 1715, only a few years after the first documented reference to the instrument.[35]

J. N. Bach's student Jacob Adlung claimed that "after the organ, the lute harpsichord is the most beautiful of the keyboard instruments" ([1768] 2011, 133). Yet *Lautenwerke* were never widely built or played, and no specimens survive. Organological details, however, are available from contemporaneous sources, including Adlung's *Musica mechanica organoedi* (*Musical Mechanics for the Organist*). The *Lautenwerk* was an undamped instrument, a clavier with ringing strings. To control this resonance it was equipped with a buff stop, which might be understood as the functional opposite of a piano's sustain pedal. Like lutes, *Lautenwerke* were strung with gut strings, with courses doubled at the octave in the lower range, doubled at the unison above that, and single courses in the highest register. (J. S. Bach's model, additionally, had single-strung theorbo-style bass strings made of brass.) J. N. Bach's *Lautenwerk* also offered dynamic and timbral variation through three manuals, each of which plucked strings at a different

34. Huron and Berec also note unexpected similarities between the violin's and the organ's affordances: "Bach's organ transcriptions of Vivaldi violin concertos reflect certain affinities between the organ and violin that are not immediately apparent— especially when compared to (say) hypothetical transcriptions of these same concertos for flute. Vivaldi's long melodic lines would leave a flautist struggling for air. Moreover, Vivaldi's frequent alternating figures (including unisons) between two violin strings are readily replicated using two organ manuals" (2009, 104).

35. Incidentally, this instrument was bought by Duke Ernst August of Saxe-Weimar, whose younger brother Johann Ernst composed the concerto discussed earlier in this chapter (Ledbetter 2002, 28; Williams 2004, 151).

distance from the nut. It is unclear how many manuals J. S. Bach's had, though it evidently included several stops (Ledbetter 2002, 29).

Peter Williams wonders about this instrument: "What the advantage of the *Lautenwerk* was other than a pretty sound is unclear: easier to tune or voice or restring, less sensitive to climate, less loud, good for accompanying?" (2004, 151). In my view, this "advantage" seems clear: the sound of the *Lautenwerk refers* to another instrument.[36] After all, it seems difficult to conceive of this instrument in isolation, to describe it—even to name it—without noting its organological hybridity. As the *Lautenwerk* combines the harpsichord's interface and basic mechanism with the lute's strings, it links playing techniques of the former and sonic textures of the latter. As Adlung puts it, the *Lautenwerk* makes it "possible to play the lute from a keyboard" (2011, 135).

Agricola reports that J. S. Bach's *Lautenwerk* sounded very much like a real lute:

> It is true that in its regular setting (that is, when only one stop was drawn) it sounded more like the theorbo than like the lute. But when the stop that on harpsichords is called the Lute stop … was drawn with the Cornet stop, it was almost possible to deceive even professional lute players. (*NBR*, 366)

Adlung's comments go further, recounting how Bach's cousin employed the instrument:

> Mr. J. N. Bach, in playing this instrument out of sight, [was able to] deceive the finest lutenist; one would have sworn that it was a regular lute. But it is necessary to keep playing rapidly and in arpeggios, as skilled lutenists are accustomed to play. It is also necessary to stay in the same key; any modulation will immediately be noticeable, since one cannot depart from the key on a lute without retuning it. (Adlung 2011, 137)

This effect, then, did not rely simply on the instrument's timbre but on idiomatic musical figures. It depends on evoking the lute's tonal affordances and manner of performance. While the *Lautenwerk*'s resonance would surely enhance this reference, its timbre can be separated from these other idiomatic features.

In fact, there was a long tradition of "playing lute at the keyboard." Harpsichord transcriptions from seventeenth-century France highlight the lute's characteristic features: low tessitura, broken or strummed chords, bass pedals, thin texture, irregular figuration, loose imitation, held notes (*tenues*), campanella (repeating note) figures.[37] Marin Mersenne recommended that keyboardists play such transcriptions "in order to transfer the beauties and riches of the lute to other instruments" (quoted in Ledbetter 1987, 30). Mersenne specifically links this to instrumental differences in action-sound coupling: the lute's dynamics reflect a

36. Of course, the organ contains such instrumental references too, with stops named for trumpet, oboe, viola da gamba, vox humana, and so on (see Yearsley 2012, 69–70).

37. This style is often referred to as the "style brisé" (broken style). Yet Buch (1985) shows that this term emerged in the twentieth century.

player's force of touch, where the harpsichord is insensitive to this aspect of performance. Keyboardists adopted such textural devices as a means to approach the lute's *expressivity* on the harpsichord (Ledbetter 1987, 26). This is to say that the lute clavier, before its invention as a material object, existed as a conceptual blend.

It is hardly surprising, then, that such keyboard arrangements of lute music led to new, original keyboard pieces in lute style. This hybrid style uses the means of the keyboard to imitate the sonority of the lute. Here the lute functions as a compositional instrument. It is not used to perform such works (say, lute-style pieces by François Couperin). Instead, the lute becomes a source of ideas. Its affordances inform composition for other instrumental means.[38]

In cognitive terms, this involves meshing or cross-domain mapping. Cross-domain mapping is a kind of conceptual metaphor, like the linking of pitch and vertical position discussed in Chapter 1. As Lawrence Zbikowski explains, "Cross-domain mapping is a process through which we structure our understanding of one domain (which is typically unfamiliar or abstract) in terms of another (which is most often familiar and concrete)" (2002, 13). Whereas Zbikowski illuminates mappings between musical and nonmusical domains—for example, between musical and bodily movement or between musical and poetic imagery—the lute style represents an "intra-musical" mapping, from one instrument to another. Like all metaphor, cross-domain mappings depend on some enabling similarity between source and target domains. This also shows how mappings are selective, partial. Lute and clavier share the standardized pitch materials of Western tonal culture; both afford polyphonic textures with bass, chords, and melody, played solo or in the continuo. Yet the mapping breaks down in terms of timbre and action-to-sound relationships: the lute has resonance and dynamic range, while the harpsichord has more piercing tone, allows for fuller chord voicings, and so on.

If auditory-motor integration grounds modes of perception, my hearing of Bach's E-major prelude is colored by my experience as a violinist. I listen with my hands. The experiment by Drost, Rieger, and Prinz (2007), discussed at the beginning of Chapter 3, suggests that this is interface-specific, automatically activated through bottom-up processes. But the lute style further suggests that this may be driven from the top down: in other words, *musicians may creatively apply this hands-on style of listening to instruments that they themselves do not play*. Indeed, these complementary possibilities are central to Glenberg's theory of mesh: embodied conceptualization can respond to the environment, subconsciously integrating memories with perceived affordances; yet such conceptualization might also be consciously directed (1997, 10–11). I can distance myself from my current situation, contemplating objects or actions that are not present. When Bach listened to his friend Weiss improvise on the lute, for example, he could have imagined playing along on the keyboard.

38. Ledbetter notes an interesting conflict between these elements in Bach's Suite in E minor (BWV 996): "Paradoxically, it is the 'lute-like' low tessitura that makes for too much business on the diapason courses and is one of the main problems for playing this suite on the lute" (2009, 246). In a sense, the suite is more lutelike than actual lute music. It is perhaps unsurprising, then, that Johann Tobias Krebs marked this manuscript *aufs Lauten Werk*.

Figure 5.26 Johann Sebastian Bach, Prelude in E♭ major, *The Well-Tempered Clavier*, Book II, mm. 1–8.

Weiss's influence might be heard in Bach's Prelude, Fugue, and Allegro in E♭ (BWV 998)—whose autograph score is marked "for lute or keyboard"—but also in the Prelude in E♭-major from *The Well-Tempered Clavier*, Book II (see Figure 5.26). The two pieces' similarities go beyond their shared key and compound meter: the keyboard prelude's *arpeggiando* style (with sustained, broken chords, mm. 25–28), pedaling bass (mm. 5–8, 13–16), and open-voiced chords all recall the lute piece.

Such instrumental strategies can be found throughout Bach's work.[39] For example, the Prelude in E♭ major from the *first* book of *The Well-Tempered Clavier* recalls an organ style—with long sustained pedal, extensive ties, and so on—though it was unlikely to have been played on organ. (The C-major prelude from the second book shares such features.) More generally, this may help explain the stylistic blending and contrast that marks *The Well-Tempered Clavier*, with its alternation between preludes and fugues. The fugues exploit the keyboard's polyphonic affordances, often obscuring patterns of the hand by distributing independent voices among the fingers. The preludes, by contrast, may reference various genres, through dance forms or instrumental effects: these include the famous broken-chord preludes whose heritage can be traced back to the toccatas of seventeenth-century lutenist Johann Hieronymus Kapsberger. From this perspective, the interplay of Bach's preludes and fugues represents a negotiation of instrumental and contrapuntal elements, which are never fully separate but never identical.

Conclusions

Bach's compositional achievements, in sum, cannot be divorced from his activities as a keyboardist, transcriber, violinist, instrument designer, and so forth.

39. Ledbetter (2002) argues that this strategy of evoking one medium in terms of another is particularly prevalent in the second book of *The Well-Tempered Clavier*.

His music is grounded in embodied know-how, though not determined by it. Bach draws flexibly on instrumental idioms—with an original instrument, transcribed to another, or explored metaphorically in a process of cross-domain mapping. Examining these compositional strategies can help differentiate instruments' affordances, while also highlighting connections or references among instruments (and other musical technologies). Throughout Bach's music, instrumental and tonal levels mingle like the parts in *The Art of Fugue*'s Canon at the Twelfth, alternately leading or following, coupled or free, woven together in a larger whole.

Though this chapter has focused on Bach, "compositional instruments" appear in other milieus as well. For example, Jonathan Goldman has documented the influence of free-reed instruments—specifically, accordion and bandoneon (a large concertina associated with Argentinean tango)—on several twentieth-century composers. The Argentinean German composer Mauricio Kagel, who played bandoneon, exploited physical patterns on the instrument in his *Pandorasbox* (1960). The piece includes disjunct atonal lines, which move through adjacent buttons in the bandoneon's irregular interface (Goldman 2012, 34–35). The American pianist David Tudor, to whom *Pandorasbox* is dedicated, also used the bandoneon as he transitioned from performing to composing. His first public composition was the 1966 multimedia piece *Bandoneon! (a combine*), which extended the instrument electronically. For Tudor, this collapsed the distinction between composition and instrumentation. "*Bandoneon! (a combine)* uses no composing means," he wrote, "since when activated it composes itself out of its own composite instrumental nature" (quoted in Goldman 2012, 54). Goldman (forthcoming) also shows how the music of the spectralist composer Gérard Grisey employs gestures associated with his first instrument, the accordion, as when multiple instrumental parts share an exact dynamic contour. (As mentioned in Chapter 2, simultaneously played notes on the accordion have the same dynamic because they are activated by the same bellows.) This would involve a kind of metaphorical transcription, almost treating the ensemble as a virtual accordion. Despite considerable historical distance from Bach, then, these composers respond to instruments in similar ways, taking them as sources of material, as compositional tools.

It is a small step, of course, from compositional instruments to theoretical ones. Though instruments like the monochord are used primarily for theoretical investigation rather than performance, I would suggest that any instrument may inform theoretical understanding. Historical examples here are numerous. When the medieval keyboard with its one-to-one place-to-pitch mapping gained prominence around 1500, Western theories of pitch shifted from a contextual model, based in the hexachord system, to an absolute model, where a note's name represented a measurable pitch (Bent 1984). Likewise, the popularity of strummed guitar music in seventeenth-century Europe contributed to emergent tonal thinking, since these guitarists (like many of their counterparts today) treated chords as objects, with little concern for issues of inversion and counterpoint so important for keyboardists (Christensen 1992). In fact, one of the most important concepts of tonal theory, the circle of fifths that is used to explain relations among keys and chords, first appeared in a 1596 guitar manual. It uses a kind of tablature that linked fretboard positions, finger placement, and sounding chords. Any musical instrument, then, can function as a theoretical instrument, an "epistemic tool."[40]

Even as I highlight instruments, I do not wish to overlook the significance of notation here. Just as writing lets language appear in the absence of a living speaker, notation productively distances music from its performance.[41] This suggests that any score is open to many possible realizations, that transcribability is built into notation from the start. Notation, then, is not simply a written copy of performance. After all, it is possible to write things that have never been performed and even things that are unplayable.[42] At the same time, insofar as consistent instruments facilitate musical repetition (as prostheses or artifacts of external memory), they represent a kind of proto-notation or proto-recording. And this repeatability, rather than notation itself, seems essential for the sense of musical objects in theory or composition.

Composers, like performers, are involved in poiesis. They make music. But what about listeners who neither perform nor write music? How might they relate to Bach's violinistic string crossing or his lutelike keyboard pieces? How, more generally, might instrumental technologies condition their musical perception and understanding? Such questions demand an account of musical listening that differentiates listeners from performers and composers—but also differentiates among lay listeners themselves. Such questions, in other words, require a musical aesthetics that is sensitive to musical technics.

40. While Magnusson (2009) discusses digital instruments as "epistemic tools," I take a broader view. Similarly, Lewin suggests that musical instruments with stable pitch affordances might make it possible to link pitch intervals "with *res extensae*, that is, with visible and tangible spatial distances outside the body-mind complex of the singer—distances between holes in a pipe, between points along a bow-string, between shorter and longer pipe lengths, etc." (1977, 234).

41. This compressed treatment of musical notation is inspired by Derrida's classic investigation of speech and writing. As Derrida puts it, "Writing is at the same time more exterior to speech, not being its 'image' or its 'symbol,' and more interior to speech, which is already in itself a writing" (1976, 46).

42. Of course, there is also music that can be played but not notated, that does not fit the symbolic representations of notation. As Friedrich Kittler argues, Western notation puts sound through an alphabetic filter, whereas phonography inscribes traces of sonic events that include noise (1999, 3–4, 23).

CHAPTER Six

Horns To Be Heard

The finale of Joseph Haydn's Symphony no. 73 starts with a jaunty tune played by the whole orchestra. Fast, loud, and rhythmically active, the music rushes, races ahead, and arrives at the dominant (mm. 26–29; see Figure 6.1). Then, a break. A pause. The silence defuses the rhythmic energy of the opening, and like the famous *subito forte* from Haydn's "Surprise" Symphony, it demands my attention. How should I describe what happens next? In mm. 30–37, I hear two melodic lines moving together; dyads that reassert the home key; a blend of sound colors, one brash, the other bright. Yes, I can hear these textural, tonal, and timbral features. But I might also say that I hear a pair of horns, doubled by oboes.

These alternative descriptions reflect different *modes of listening*—that is, different ways of experiencing or relating to sound. Where the first highlights sonic features, the second identifies sources of sound in the world. For some authors, there is a categorical difference between these modes (e.g., Jonas 1966; Gaver 1993, 1–2; Scruton 1997, 221). The former would represent "musical listening," and the latter ecological or everyday listening. One would be aestheticized, the other mundane. The philosopher Hans Jonas, for example, claims that musical hearing "refers not to an object other than the sensory contents but to their own order and interconnection" (1966, 138). This opposition, then, tends toward a metaphysics of listening in which musical experience would supposedly be cleansed of instrumental traces.

Yet instruments are not so easily hidden. They constantly reappear in experience, supplementing pure sound and revealing an interplay of musical and ecological listening strategies. The French composer Pierre Schaeffer refers to this interplay in terms of an "instrumental paradox" (1966, 43). "The musical phenomenon … has two correlative aspects," he writes, "a tendency to abstraction, insofar as play releases structures; and the adherence to the concrete, insofar as it remains attached to instrumental possibilities" (46).[1] For instrumentalists, the concrete aspect is bound up with their own bodily actions. But how does this paradox affect listening? How, in other words, do listeners relate to instruments they cannot play, instruments they never touch?

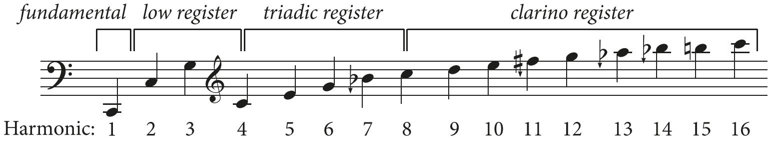
With these questions, the book turns from music-makers to audiences, from poiesis to aesthesis. Haydn's horn music forms a useful case study here, and not

1. "Le phénomène musical a donc deux aspects corrélatifs: une tendance à l'abstraction, dans la mesure où le jeu dégage des structures; l'adhérence au concret, dans la mesure où il reste attaché aux possibilités instrumentales." Translations from Schaeffer are my own.

Figure 6.1 Joseph Haydn, Symphony no. 73 in D major, "La chasse," mvt. iv, mm. 26–37.


31

Figure 6.2 Open notes of the natural horn. (Note the microtonal inflections at harmonics 7, 11, 13, and 14.)



only because of the composer's contributions to modern orchestration. The horns in Haydn's ensemble, like other instruments discussed in this book, have a distinctive idiom. By deploying this idiom in varied contexts, Haydn's music suggests several ways that contemporaneous audiences responded to horns. Ultimately, it shows how instrumental invariance shapes perception and understanding for listeners, much as it does for players. At certain points, this investigation will return to theories of grounded cognition and phenomenology, discussed in Chapter 1. But first it will be helpful to review the horn's affordances and its role in eighteenth-century European culture.

Haydn's Horns

In the aforementioned passage from Haydn's Symphony no. 73, the horn functions as a compositional instrument. That is, Haydn's melodic and harmonic choices are tied to his decision to feature the horns. Such connections are common in Haydn's music. As Emily Dolan has shown, his orchestration contributed to emerging discourses of instrumental character, by which each member of the orchestra was typecast in particular musical and expressive roles (2013, 148–68). Still, instrumentation and tonal design are especially entwined with the horns because of their distinctive pitch affordances.

Brass instruments—that is, wind instruments played with vibrating lips—afford a harmonic series above a fundamental pitch (see Figure 6.2).[2] Players move through the series by varying lip tension. Note that this overtone space is "irregular," as defined in Chapter 3. Its pitch collection may be reckoned in terms of a diatonic or chromatic scale, yet either way, there are both missing notes and added notes (such as the "out-of-tune" seventh partial). A "step" in this instrumental space corresponds to various pitch intervals, which become smaller as the player ascends through the series. The valves on a modern French horn expand the instrument's pitch affordances: pressing a valve (or a combination of valves) modifies the functional length of the instrument and thereby changes the fundamental.

2. Specific pitches vary from instrument to instrument and do not exactly match the mathematical harmonic series. The fundamental itself is generally weak. Of course, "brass" instruments need not be made out of metal. Indeed, the word "horn" indicates that such instruments have long been made from animal horns.

Haydn himself was indirectly involved in such technical developments: in 1796, he wrote a concerto for an experimental "keyed" trumpet. But the horns in his ensemble, valveless or "natural" horns, were more closely tied to the pattern of overtones.

That is not to say that hornists of the time could not play other notes. On the contrary, they developed techniques to bend pitches with the embouchure ("lipping") or putting a hand into the horn's bell ("stopping"). They also used these methods to adjust the "out-of-tune" harmonics. Still, stopping could be difficult, and it altered the instrument's timbre. While horn soloists were expected to master such techniques, orchestral horn parts typically stayed within the harmonic series.[3] The seventh harmonic's too-flat B♭ was usually avoided; the bright F-quarter-sharp, often accepted as is.

In many ways, the problems facing early horn players resemble those of harmonica players examined in Chapter 3: their instruments offer diatonic pitch collections with gaps, gaps that can be filled by the development of new techniques or alteration of the instrument. Where harmonica players carry an instrument in each key, horn players would have interchangeable crooks, each of which would set the instrument for a particular key. Just as the jazz harmonica player Howard Levy always thinks in C major, natural horn music was always notated in this key. Some of the technical solutions to these problems are strikingly similar. Much like the chromatic harmonica, the chromatic horn invented by John Clagget in 1788 effectively couples two instruments tuned a semitone apart, which are played through a single mouthpiece (Tuckwell 2002, 35). Another approach, closer to cross-harp harmonica playing, was the early-nineteenth-century *cor mixte* approach: here a hornist carried crooks only for F, E, E♭, and D, using them for closely related keys and faking or cutting the outside notes (Humphries 2000, 19–20). Neither of these approaches to the horn was very satisfactory, though, and neither caught on. Many preferred the sound of the natural horn long after its valved counterpart was widespread, particularly in France.[4]

The valveless horn's affordances gave rise to certain idiomatic figures, such as melodies that outline a major triad. Three examples of this phenomenon, taken from Haydn's symphonies, appear in Figures 6.3–6.5. In the first movement of his Symphony no. 6, the composer starts the cheery main theme with an unaccompanied horn, moments before the flute and strings initiate the recapitulation proper (see Figure 6.3).[5] Horns help create a different mood at the beginning of Haydn's Symphony no. 22, nicknamed "The Philosopher." As shown in Figure 6.4, this somber adagio begins with horns in octaves, moving in half notes against the muted strings' steady eighth notes (mm. 1–2). Symphony no. 31 also begins with

3. Composers typically used horns in pairs, where one player was a specialist in high-register playing (*cor alto*) and the other was a specialist in the lower register (*cor basse*).

4. The highly developed French tradition of valveless horn playing led to the instrument's common English name, the "French" horn (Tuckwell 2002, 17).

5. This moment, then, is a precedent for the famous "early" horn entry in Beethoven's "Eroica" Symphony.

Figure 6.3 Joseph Haydn, Symphony no. 6 in D major, “Le matin,” mvt. i, mm. 85–90.

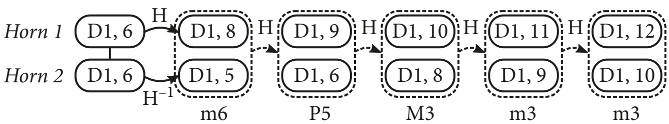
Figure 6.4 Joseph Haydn, Symphony no. 22 in E♭ major, “The Philosopher,” mvt. i, mm. 1–4.

horns and strings—but its quicker tempo and rearticulated notes create a thrilling sense of momentum (see Figure 6.5). Although these excerpts are stylistically and affectively distinct, each of them prominently uses horns to outline the tonic triad.

In the latter two examples, the horns double each other at the unison or octave. The duet from Symphony no. 73 involves another kind of doubling. The

Figure 6.5 Joseph Haydn, Symphony no. 31 in D major, "Hornsignal," mvt. i, mm. 1–5.

Figure 6.6 Transformation network for the horn duet from Haydn's "La chasse" symphony, mvt. iv, mm. 30–31. The two horns make similar moves, above the same fundamental.



horns start on different harmonics, then make similar moves through the instrumental "scale" presented in Figure 6.2.[6] This motion can be represented via Kris Shaffer's transformational model of natural horn music. Shaffer (n.d.) represents the instrument's "overtone space" in terms of ordered pairs of the form (*f, p*), where *f* is the fundamental pitch and *p* is a numbered partial. For example, the first note of the horn duet would be (D1, 6), sounding as A3. Given the habitual avoidance of the seventh partial, it might make sense to define an operation H that skips this out-of-tune note. This can be achieved (somewhat artificially) by mapping 6 to 8, 7 to itself, and any other number x to $x + 1$. From this perspective, the horn duet would involve parallel motion in the instrumental space—even though the pitch intervals between the parts vary (see Figure 6.6).

In terms of pitches, the most distinctive part of this pattern is the similar-motion approach to the perfect fifth. This move, forbidden by contrapuntal tradition,

6. Again, Haydn avoids the seventh partial. This note, in fact, appears in only four of his symphonies (Bryan 1975, 214).

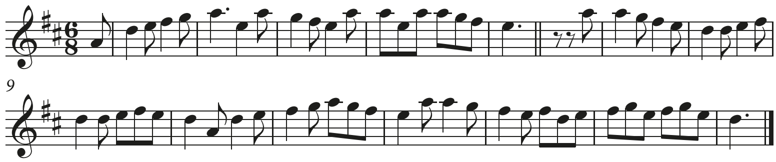
Figure 6.7 Joseph Haydn, Symphony no. 103 in E♭ major, "Drumroll," mvt. iv, mm. 1–4. (No other instruments play at this moment.)

Figure 6.8 Joseph Haydn, Symphony no. 31 in D major, "Hornsignal," mvt. iii, mm. 41–44.

represents a clash between instrumental and tonal idioms. Haydn's corrections on students' exercises and annotations in his copy of *Gradus ad Parnassum* show that the composer's attitude toward "hidden" or "direct" fifths was even stricter than that of the textbook's author, Johann Joseph Fux (Mann 1970, 719). Yet these fifths are ubiquitous in Haydn's horn parts. As shown in Figure 6.7, unaccompanied horn fifths start the final movement of Symphony no. 103. They may also be woven into a thicker orchestral texture: for example, they accompany melodies in the oboes and strings throughout the trio from Symphony no. 31 (Figure 6.8).

These two-part figures have roots in an earlier tradition: hunters often played *cors de chasse* in pairs. Such duets appear in the first published collection of hunting calls, Jean de Serré de Rieux's *Les dons des enfans de Latone: La musique et la chasse du cerf* of 1734 (Monelle 2006, 51). Paired horns, then, recall the instrument's use outside of the concert hall. They reference the horn as *communication technology*. The instrument, in fact, was required equipment for hunters. A 1719 hunting manual notes that "by law every mounted member of a Parforce-hunt must wear his Parforce-horn round his neck, otherwise he will not be admitted to the field" (quoted in Fitzpatrick 1970, 18n2). Such practices were very much part of Haydn's world. His patron Prince Nikolaus Esterházy was an avid huntsman: he built the Esterháza summer palace at the remote site of his old hunting lodge and

Figure 6.9 "La sourcillade," as recorded by Serré de Rieux (1734).



founded a forestry school at Eisenstadt where all students learned how to play the horn (Fitzpatrick 1970, 18n2).

This tradition gives Symphony no. 73 its nickname, "La chasse." Though Haydn often writes in a generalized hunt style, the reference here is more precise. In mm. 30–37, the horns play an actual hunting call: the "sourcillade" or "vue," sounded when the quarry is first sighted (Ringer 1953, 150–51; Monelle 2006, 89–90). While Haydn likely knew the call from the hunting of his aristocratic patrons, his version is close to Serré de Rieux's, published nearly half a century earlier (see Figure 6.9).[7] This consistency across temporal and geographic distance speaks to the hunting tradition's strength—which relies on the horn itself, as an object of external memory.

This cultural significance made horns attractive for opera composers—who were the first to use the instruments orchestrally. In 1639, Francesco Cavalli added them for hunting scenes in his *Le Nozze di Teti e di Peleo* (Tuckwell 2002, 13). Horns here represented a kind of diegetic music—even diegetic sound or noise. The finale from Symphony no. 73 also derives from this theatrical tradition: it originated as the overture to Haydn's 1780 opera, *La fedeltà premiata*, which opens with a mythical hunt dedicated to the goddess Diana. At the same time, the hunt itself was highly aestheticized, and Raymond Monelle argues that the horn may have been borrowed from the theater: "The baroque hunting horn was poised between musical expression and practical utility. Less effective than the oxhorn as a signaling tool, it was more evocative of the splendor and exhilaration of the hunt. Thus, the signifier of the hunt topic was already halfway to being its own signified.… It may well have originated as a theatrical instrument. Such was baroque culture; the world was a stage" (2006, 41).

Haydn expected his audience to recognize common hunting calls—and to understand their meaning.[8] As Daniel Heartz puts it, hunting calls "came as close to universality as any musical language of the time" (1976, 529). The composer dramatizes this in no. 26 from his oratorio *The Seasons*. Here horn signals

7. Both versions are in D, which was associated with French hunting horns. German hunting horns were typically in E♭ (Monelle 2006, 42). Note that all of the horn solos cited in this section (plus the horn concertos attributed to Haydn) are written in one of those keys—and the hunting scene in *The Seasons* shifts from one to the other.

8. This recognition was not limited to human listeners: a German hunting manual published in 1783 (one year after the premiere of Symphony no. 73) notes that "the dogs must understand the calls as well as the huntsmen, and indeed they do understand them perfectly with some experience" (quoted in Heartz 1976, 526).

act out each stage of a hunt—from the "queste," which gathers the hunting party, to the "halili," which celebrates their victory. As the hunters and countryfolk comment on the action, they repeatedly direct attention to the instrument itself:

Hört! hört das laute Getön,	Hark! Hear the loud noise
Das dort im Walde klinget!	that rings there in the woods!
Welch' ein lautes Getön	What a loud noise
Durchklingt den ganzen Wald!	rings through all the wood!
Es ist der gellenden Hörner Schall …	It is the shrill sound of the horn …

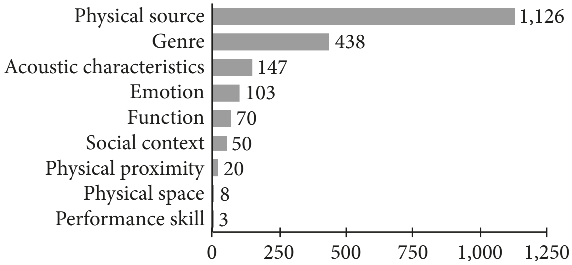
Hearing Things, Hearing Tones

When Haydn's hunters and countryfolk hear the horns, they recognize them instantly. And their first word—the imperative "Hark!"—is an invitation to join in that hearing. The scene, then, stages a particular mode of listening. Heidegger calls this mode "hearkening." In it, I attend not to sounds themselves but to meaningful *things*, which the sounds reveal. " 'Initially' we never hear noises and complexes of sound," the philosopher writes, "but the creaking wagon, the motorcycle. We hear the column on the march, the north wind, the woodpecker tapping, the crackling fire" (2010, 158). Hearkening to things in the world, Heidegger argues, is more primordial than "hearing" bits of sonic sense data. This argument situates aural perception in an environment from the start. As such, it resonates with work in ecological acoustics (discussed in Chapter 2), which examines sonic information about objects and events. It also fits with the results of an open-ended empirical study by Nicola Dibben (2001). In it, participants were asked to describe various audio clips, some musical and some nonmusical. Overall, the responses were diverse, mentioning the sounds' acoustic qualities and their associations with musical genres, emotions, or social contexts. Many descriptions, moreover, reflected an individual respondent's cultural and educational background. But by far the most common type of description—by participants with and without musical training—referred to physical sources of sound. As Figure 6.10 shows, more than 1,000 responses named a physical source, whereas fewer than 150 mentioned sonic characteristics.[9]

Of course, this does not mean that it is impossible to experience sound *as* sound, just that such an approach involves particular learned techniques. As Heidegger

9. Some ethnomusicologists have come to related conclusions through fieldwork. For example, Greg Downey explores such issues in an essay on *capoeira*, the Brazilian martial art–dance form: "When practitioners describe the berimbau's sound, they … do not say that they hear a changed pitch, for example, but that they hear the coin pressing on the string" (2002, 496). The berimbau is a kind of musical bow that accompanies *capoeira*. (See also Baily 1996, 172.)

Figure 6.10 Frequencies of sound-description categories from Dibben (2001, 179).



writes, "It requires a very artificial and complicated attitude in order to 'hear' a 'pure noise'" (2010, 153). This type of attitude might be found in the science of acoustics, where the horn's sound can be described in terms of resonance peaks and input impedance in a pressure-response curve (see Benade 1973). In light of Heidegger's ideas about technics (1977), it becomes clear that this acoustic description is made possible by scientific instruments, by a kind of technological enframing. For Pierre Schaeffer, radios and record players may perform a similar function.[10] Concealing sonic sources, he claims, can help reveal the sounds themselves.

In his *Traité des objets musicaux* (1966, 104), Schaeffer goes beyond the opposition of hearkening and hearing to propose four modes of listening:

(1) *Écouter* (listening), corresponding to hearkening, attends to a sound's source. For example, in the horn call, I hear an index of the instrument or the player's action.
(2) *Ouïr* (passive aural sensation) receives the sound unconsciously or indirectly. While I am in the car, driving and chatting with my wife, a horn might play quietly on the radio. Strictly speaking, I hear the sound (and this background music might even affect my mood), but I am not consciously aware of it.
(3) *Entendre* (hearing) focuses exclusively on sonic morphology. Here I would experience the horn call as a sound object out of context, as a particular timbre, rhythm, or pitch structure.
(4) *Comprendre* (understanding) interprets a sound's meaning. The horn call, at this level, is a symbol that might say, "The quarry has been sighted."

Each of Schaeffer's modes requires some kind of withdrawal. With *écouter* or *comprendre*, I do not listen *to* the sound. Instead, I listen *through* it to a physical source or a message. Like a written word, the horn call feels "transparent"; like a hammer, it is handy (*zuhanden*). With *entendre*, by contrast, I contemplate

10. Carlos Palombini (1998) draws parallels between Heidegger's and Schaeffer's approaches to technology, with particular attention to enframing (*Ge-stell*).

sounding patterns, while source and meaning withdraw. I seem to be concerned not with the instrument but with "the music itself."[11]

Though Schaeffer explores various tensions and relations among the four modes, he ultimately valorizes *entendre*. "*All music*," he proclaims, "*is made to be heard*" (1966, 133).[12] This resolves the instrumental paradox in favor of musical abstraction. For while *écouter* reveals things that can be seen or touched, *entendre* supposedly deals with sound alone. Here, Brian Kane (2014) has demonstrated, the composer faithfully employs Husserlian reduction techniques. *Entendre*, then, is often referred to as a "reduced listening." Setting aside the differences between sounds heard and sounds imagined, Schaeffer envisions an experience of pure hearing, of pure sound objects freed from their worldly origins. This accords with Husserl's own thoughts on music. "However much [Beethoven's 'Kreutzer' Sonata] itself consists of sounds, it is an ideal unity," Husserl writes, "and its constituent sounds are no less ideal. They are obviously not the sounds dealt with in physics; nor are they the sounds pertaining to sensuous acoustic perception, the sounds that come from things pertaining to the senses" (1969, 21; quoted in Schaeffer 1966, 132).[13] This is a radical view of musical autonomy, detaching music not only from its social function but even from its real existence as vibration. Moreover, if the sound object is to be constituted as an unchanging, self-grounded essence, then any trace of mediation or exteriority—any trace of technics—must be excluded.[14] Separating *écouter* from *entendre*, then, would theoretically sever the instrument from its sound.

Yet Heidegger's tool analysis teaches that withdrawal cannot always be sustained. When the horns' limited pitch affordances differentiate them from their orchestral companions, when they play direct fifths or a slightly sharp $\hat{4}$, when a performer of this notoriously difficult instrument botches a note—then horns become "present-to-hand" (*vorhanden*). Such disruptions draw attention to the instrument, shifting from *entendre* to *écouter*. (That pause in Haydn's Symphony no. 73 creates a similar effect. In it, Haydn orchestrates a moment of breakdown, directing attention to the horn call that follows.) Moreover, as discussed in Chapter 4, Levinas would emphasize that withdrawal is never complete, that handiness does not preclude enjoyment. From this perspective, Schaeffer's modes of listening are unstable at best. Each one may be dispelled by unfulfilled expectations; each one depends on a certain kind of habit or habituation. This connects listening, like the development of performance expertise, to instrumental invariance.

Listen again to the horn call. The melody emerges from pitch and rhythmic variance (which correlate, too, with a player's actions). The timbre, meanwhile, is

11. With *ouïr*, the sound would withdraw from consciousness more or less completely.
12. "*Toute musique est faite pour être entendre*" (emphasis in original). Similar arguments appear in other Husserlian treatments of sound and music, such as those of Jonas (1966) and Scruton (1997).
13. On the role of hearing—and, particularly, "hearing-oneself-speak"—in Husserl's metaphysics, see Derrida (2011).
14. For further discussion, see Gallope (2011, 59) and Kane (2014, ch. 4).

relatively stable, implying that these varied notes are produced by the same source. Because of this consistency, I may become habituated to the sound of the instrument, which facilitates its withdrawal. But instrumental timbre also affects the way that instrumental parts are grouped or divided (Bregman 1990, ch. 5; De Souza 2015). In other words, changing the instrumentation can change the music's perceived organization. Curiously, it seems that both timbral variance and timbral invariance may highlight the tension between structure and source. With Haydn's re-orchestration of repeated themes, the melody is more stable than its instrumental presentation. According to Dolan (2013, 134), this contributed to the idea of an abstract theme that transcends any single manifestation. Meanwhile, Thomas Christensen argues that four-hand piano transcriptions of orchestral music, by erasing differences in instrumental color, played into the nineteenth-century aesthetics of absolute music (1999, 290). The piano reduction, like a phenomenological reduction, was thought to reveal pure tone structures or spiritual essences.

As transcriptions changed performance medium and context—transforming an orchestral work, played in public, into a pianistic one, played at home—they blurred distinctions between genres. And this, too, could affect the perception of tonal structure. Research in music cognition indicates that tonal expectations are situated, contextual. Listeners develop different schemas—that is, different sets of expectations—for particular musical genres.[15] Even without formal musical training, they tune in to a genre's statistical regularities. So just as instrumental consistency grounds hand-ear connections for players, tonal consistency grounds style-specific expectations for listeners. Yet genre identification is so rapid that it must rely on timbre rather than harmonic information (Perrott and Gjerdingen 2008). In this case, instruments, whether heard or seen, may provide contextual cues, priming particular expectations or helping listeners learn new schemas (Huron 2006, 204–5). That is to say, Haydn's eighteenth-century audiences—and, to some extent, classical-music fans today—would be attuned to the relation between the horn's timbre and its idiomatic figures. Horn parts are far more predictable than, say, violin parts. As soon as I hear the horns' sixth at the opening of the "Drumroll" Symphony, I am primed for the possibility of direct motion to a perfect fifth. Here source identification informs tonal expectation. *Écouter* guides *entendre*.

For an experienced listener, the horn call might be heard to "sound good," imbued with a positive affect that rewards successful prediction.[16] But the instrumental-tonal expectations at play may be even clearer when they are denied. Carl Maria von Weber's 1821 opera, *Der Freischütz*, provides a striking example. The opera centers on hunting culture. Its protagonist, Max, is a gamekeeper, and the horn, as a tool of his trade, is an essential part of the opera's sound world. Desperate to win a shooting contest, Max decides to cast seven magic bullets in the Wolf's Glen at midnight—and unwittingly becomes involved in a demonic pact. Each bullet's production is accompanied by some

15. For example, a series of experiments by Bryn Hughes (2011) examines Western listeners' different harmonic expectations for classical music and the blues.

16. On musical expectation and emotion, see Huron (2006, 7–15).

disturbing supernatural event: nightbirds gather, a hurricane bends the trees, and wheels of fire cross the stage. After the fifth bullet has been cast, horns herald the imminent arrival of the devil Samiel (see Figure 6.11). But these horns outline a dissonant diminished-seventh chord rather than a consonant major

Figure 6.11 Carl Maria von Weber, *Der Freischütz*, no. 10 (Act II Finale), mm. 336–46.

triad.[17] They sound an augmented fourth in place of a perfect fourth, and minor thirds in place of major thirds. Moreover, the timbre makes it clear that none of the notes are stopped. That is, these horns appear to violate the laws of physics that ground the instrument's overtone space. They are not natural horns, then; they seem to be *unnatural* horns. Weber creates this illusion by combining horns in multiple keys: two in E, one in F, and one in B♭. In itself, this is not a new technique. It is particularly common in minor-mode works, such as Mozart's Symphony no. 40 in G minor, K. 550. Yet in the Wolf's Glen scene, the consistent timbre and aligned temporal attacks make it sound as though notes from multiple instruments come from a single, fictional source. The moment engages several modes of listening at once: the sound's source, its dissonant sonority, and its dramatic significance are all interrelated.

This example from Weber also suggests how instrumental sources may contribute to musical meaning. As I listen to the beginning of Haydn's Symphony no. 22 (see Figure 6.4), the horns might withdraw. I might be more aware of the piece's solemn, somewhat archaic character, its nickname "The Philosopher," or traditional interpretations that hear it as a dialogue between God and a sinner (Landon 1976, 566). But imagine how such experiences would change if the horns were replaced by electric guitars or kazoos.[18] Here, again, *écouter, entendre*, and *comprendre* are profoundly interconnected.

Phantom Horns

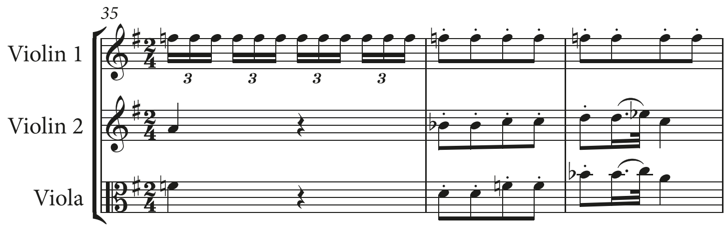
Let me return to Symphony no. 73, to an earlier section that has nothing to do with the hunt. In the second movement, Haydn's song "Gegenliebe" (Hob. XXVI:16) forms the refrain in a rondo-variation form.[19] Recognizing the song—or even its songlike character—represents another instance of handiness (*Zuhandenheit*). That is, the strings might be heard as relatively "neutral" instruments realizing the voice and piano parts from the original lied (see Figure 6.12a).

The rondo's first episode begins in m. 25. It presents the main theme in the parallel minor, G minor, then modulates to B♭ major. When the theme appears in this new key, though, I experience a moment of presence-to-hand (mm. 36–37; see Figure 6.12b). Something sticks out. As it happens, the upper strings have momentarily broken with their usual style of voice leading to accompany the tune with a horn-fifths figure. The actual horns in the ensemble are silent throughout this

17. The dramatic effect engages the diminished-seventh chord's inherent dissonance, as well as associations between the tritone and devils in Western art music generally and throughout this opera in particular. But, in my view, the distortion of the expected horn idiom is crucial here. The dissonance is more unpredictable, because of its instrumental context.
18. For an empirical study of instrumental affordances and emotion, see Schutz et al. (2008).
19. In *Haydn and the Classical Variation*, Elaine Sisman distinguishes between "rondo-variation" (variation form with contrasting periods) and "variation-rondo" (rondo form with incidental changes to the refrain) (1993, 72). She lists this movement as an instance of the former (268).

Figure 6.12 Joseph Haydn, excerpts from Symphony no. 73 in D major, "La chasse," mvt. ii.

(a) Main theme, derived from Haydn's song "Gegenliebe," mm. 1–4.



(b) Strings introduce horn fifths into the theme, mm. 35–37.

(c) Horns accompany the theme with direct fifths, mm. 55–56.

Figure 6.12 Continued

(d) The main theme, transformed into a horn figure, mm. 96–97.

episode, since its distance from the movement's home key makes it poorly suited to their tonal affordances. After the music returns to G major, though, the horns join the main theme for the first time, playing the direct fifth that the strings had introduced (mm. 55–56; see Figure 6.12c). And after another episode, at the main theme's final occurrence, the horns triumphantly take the complete tune (mm. 96–97; see Figure 6.12d). Now their distinctive fifths, doubled by the second violins, have become fully integrated into the theme. This movement, then, enacts a technique that is common in Haydn's slow movements—what Dolan calls "developing orchestration" (2013, 115). It seems that the strings in m. 36 were foreshadowing the horns' final arrival and the instrumental transformation of Haydn's song.

This horn-specific process of developing orchestration is found with other composers too. Monelle collects a few examples of this "hidden-reference" strategy, in which an idiomatic horn figure is presented initially by other instruments (2006, 100). Indeed, I briefly showed one earlier: the excerpt from Haydn's "Le matin" Symphony, where a solo horn anticipated the recapitulation (see Figure 6.3). In that movement, the triadic theme first appeared as a flute solo. Such pieces seem to emphasize other instruments' imitations of horns.

Yet horn idioms often appear without such confirmation. The most obvious examples reference the hunt, combining horn motion with lilting equestrian rhythms in six-eight time. For example, Haydn's first string quartet begins with a unison horn call, leading to its nickname, "La chasse" (see Figure 6.13). But imagined horns appear in other stylistic contexts too. In the "Emperor Hymn" from his String Quartet no. 62, Haydn harmonizes the first three notes of the melody with a triad in the second violin to create horn motion in the upper parts (see Figure 6.14). Whether the composer had horns or trumpets in mind, the direct fifth certainly echoes ceremonial brass and contributes to the music's stately character. Here, as in Bach's imitations of the lute style, Haydn puts an instrumental idiom in a new performative context.

In the nineteenth century, as valved brass instruments became more common, references to the natural horn took on new connotations, epitomized by the nostalgic horn fifths in Beethoven's Piano Sonata no. 26 in E♭ major, "Les adieux," and the slow movement from Johannes Brahms's 1865 Horn Trio, op. 40 (mvt. iii, mm. 59–65). Instruments like horns and bells—that is, instruments that can be heard far away—were particularly important for a Romantic aesthetics obsessed with distance, absence, and interiority (Hoeckner 1997, 61; Beller-McKenna 2005). All of this speaks to the historical significance of the horn topic, to the representation of an instrument that is not just distant, but actually *absent*. Such representations diverged from actual horn writing. The natural horn part for Brahms's trio goes beyond the instrument's open notes, requiring extensive stopping.[20] Passages *evoking* the horn, however, are more stereotypical, more schematic (for example, see the opening of Brahms's String Quartet in B♭-major in Figure 6.15).

This trend continues in the twentieth century with György Ligeti. His Hamburg Concerto (1998–2002) features four natural horns, using the "out-of-tune" upper harmonics that earlier composers avoided. These parts keep much from earlier horn idioms, even as they trade a triadic-diatonic profile for a spectral one. In the second movement, for example, Ligeti replicates the instrumental logic behind horn fifths: as two horns make parallel moves through the overtone series, the sounding intervals vary constantly (Shaffer, n.d.; see Figure 6.16). Yet in his piano étude "Fanfares," the composer uses a standard horn-fifths motif.[21] The imagined horns pop out of the texture, even in this nontonal context.

From Haydn to Ligeti, I have barely skimmed this tradition of instrumental reference. In these examples, horns seem to be simultaneously present and absent, real and ideal. They might thus be understood as virtual instruments, as phantoms haunting the music or its listeners.[22] Further examples could be provided ad nauseam, including examples that do not engage a conventionalized musical

20. Examining Brahms's manuscript, Peter Jost (2001) concludes that the part was originally written for valved horn, then modified.

21. This prelude is closely related to the manic second movement of Ligeti's Horn Trio (1982). Note, also, that the trio's final movement alludes to the horn fifths from Beethoven's "Les adieux" Sonata. (For an analysis, see Cuciurean 2000, 155–61.)

22. Here I would note that "phantom" and "phenomenon" both derive from the Greek verb *phanein* (to show).

Figure 6.13 Joseph Haydn, String Quartet no. 1 in B♭ major, "La chasse," mvt. i, mm. 1–4.

Figure 6.14 Joseph Haydn, String Quartet no. 62 in C major, "Emperor," mvt. ii, mm. 1–2.

Figure 6.15 Johannes Brahms, String Quartet no. 3 in B♭ major, op. 67, mvt. i, mm. 1–4.

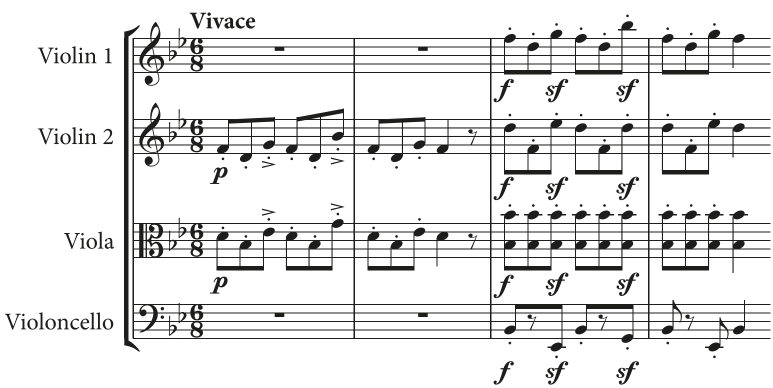


Figure 6.16 Transformation network for György Ligeti, *Hamburg Concerto*, mvt. ii, m. 9 (adapted from Shaffer, n.d., figs. 4–6). Parallel moves in overtone space give rise to varied sonorities. (100c is equivalent to one equal-tempered semitone.)

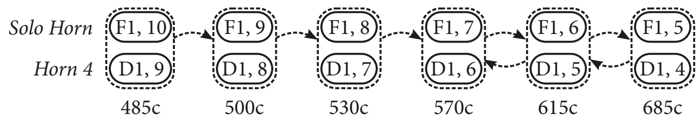


Figure 6.17 Pyotr Il'yich Tchaikovsky, *Album for the Young*, op. 39, no. 13.

topic. Briefly consider a short piano piece from Pyotr Il'yich Tchaikovsky's 1878 *Album for the Young* (see Figure 6.17). The piece is texturally and tonally constrained: right and left hands always move in the same rhythm, often doubling each other at the octave, and the harmonies simply alternate between close-position tonic and dominant chords. Here, again, the music is governed by a phantom source. Tchaikovsky is treating the piano as a virtual harmonica.[23]

Even without such examples, though, this section's survey provides enough context to launch a new set of questions. What do these phantom instruments presuppose, psychologically speaking? Which listeners can perceive them? And what might they show about the ways that audiences relate to instruments?

Instrumental Schemas

Since ecological listening responds to the physics of sound production, it is, to some degree, cross-cultural. For example, American listeners—including children—with no prior experience of Chinese music can hear how Chinese orchestral instruments are played and successfully group them into families (Palmer et al. 1989). And identifying sound sources often relies on visual cues.[24] Yet in these respects, a piano's "horn call" differs from a real horn call. Recognition of the absent instrument cannot rely on its timbre or its visual appearance. Instead, it depends on links between culturally situated sensorimotor experience and musical imagination.

Here I return to Lawrence Barsalou's theory of perceptual symbol systems. Recall how players' brains develop patterns of auditory-motor coactivation. Though listeners without instrumental training will not acquire these specific patterns, their engagement with music also combines multiple neural systems. Auditory perception coincides with vision, bodily states, emotions, and so on. And even a single note has various qualities—such as pitch, timbre, and loudness—that can stimulate distinct areas in the brain. Listening to music, then, cultivates sensory representations that are separate on the neural level but also dynamically interrelated. Once developed, such connections can be reactivated through bottom-up or top-down cognitive processes. Because these connections are bidirectional, horns can cue certain tonal schemas, and these same tonal schemas can evoke horns. To paraphrase Lawrence Zbikowski, references to the horn reactivate some of the same neural structures associated with actually listening to horn music, giving rise to an imperfect but still vivid simulation of that experience (2010, 48).[25]

23. Without the octave doubling, Tchaikovsky's piece is fairly easy to play on a harmonica, since it sticks to the tonal affordances presented in Figure 3.8. The final section of the piece does not require movement along the comb, only rhythmic breathing in and out (mm. 13–22). (In this respect, it resembles Bob Dylan's huffing and puffing, discussed in Chapter 3.) The last four bars of Tchaikovsky's piece might be the most taxing for a harmonica player, though, because they demand constant inhalation. That would explain the gradual diminuendo—the harmonica player is tiring, filling up with air. Although this breathing problem is foreign to the manual interface of the piano, it might be evoked in a pianist's interpretation.
24. Visual cues may shape listening in various ways. Jane Davidson (1993) has shown how performers' bodily movements visually communicate expressive features. Michael Schutz further shows how such gestures can affect perceived note duration (see Schutz and Manning 2012).
25. Zbikowski draws on perceptual symbol systems theory in an analysis of musical analogy in Louis Moreau Gottschalk's 1853 piano piece, "The Banjo," op. 15 (2010, 44–48).

Barsalou is careful to distinguish between conscious experience and its neural underpinnings (1999, 581–84). In experience, I encounter meaningful things situated in an environment.[26] But perceptual components, though integrated in conscious imagery, are processed and stored separately. Perceptual symbols are not holistic but componential and schematic. And this allows for the production of novel images and concepts:

> Productivity in perceptual symbol systems is approximately the symbol formation process run in reverse. During symbol formation, large amounts of information are filtered out of perceptual representations to form a schematic representation of a selected aspect. During productivity, small amounts of the information filtered out are added back. Thus, schematicity makes productivity possible. (Barsalou 1999, 593)

The horn call's tonal features can thus be separated from other sonic aspects, filled in with a different timbre. This allows me to recognize horn calls played by other instruments and also to imagine things that I have never heard (like the opening horn parts of Haydn's "Philosopher" Symphony played on kazoos). Because components are separate at the neural level, different musical elements—tone and timbre, source and meaning—are mutually irreducible; because they connect within and across modalities, they are also never fully autonomous.

Previous listening experience makes it possible for me to hear phantom horns, just as Beethoven's performing experience helped him hear phantasmal tones. The ability to notice horn calls thus depends on personal history, on an individual's immersion in a consistent cultural environment. This view, along with Barsalou's framework more generally, resonates with perspectives on historical modes of listening from musical schema theory (cf. Gjerdingen 2007a; Byros 2012). Indeed, idiomatic horn figures are readily interpreted as schemas. They are musical "constructions," pairing form and function, that appear at the musical surface (Gjerdingen and Bourne 2015). One of schema theory's main premises, derived from Leonard Meyer (1956, 60–62), is that the schemas that orient listening are acquired through social experience. As Meyer's bicycling analogy shows, this treats musical listening as a kind of know-how, habit, or skill. I cannot train my ears to notice horn fifths simply by reading a book about the cultural history of hunting in Europe. Instead, I learn to hear them though repeated listening. This perspective supplements a semiotic approach that would treat the string quartet's horn calls as signs representing some object. Instead it emphasizes how listeners attune to instrumental invariance, how instrumental idioms shape perceptual capacities. This is to say that listening, in its own way, is technical. Like performing, it is embodied, ecological, and historically specific.

26. Some of Barsalou's experimental research shows that categories and objects are situated against a background (see Yeh and Barsalou 2006; Wu and Barsalou 2009).

Conclusions

As I listen to Haydn's Symphony no. 73, I rely on previous experiences—hearing, studying, teaching, and playing classical music. What I have learned appears in the way the symphony shows up. The horns' entrance in the finale cues certain tonal expectations; in the second movement, direct fifths cue instrumental ones. In both cases, orchestration and tonal design are mutually implicated.

In the end, musical experience cannot be contained by any single mode of listening. Merleau-Ponty's assessment of Husserl thus applies to Schaeffer as well: "The most important lesson of the reduction is the impossibility of a complete reduction" (Merleau-Ponty 2012, lxxvii). Instead of being associated with one privileged mode, then, musical listening might be marked by the intertwining of *écouter, entendre*, and *comprendre*. Music, as Merleau-Ponty claims, would point to "an ideality that is not alien to the flesh, that gives it its axes, its depth, its dimensions" (1968, 152). That is, music would reveal ideas that cannot be disentangled from their sensible appearances, that can be accessed only through the lived body. From this perspective, Schaeffer's instrumental paradox cannot be resolved. A sound is never absolutely free of its source, yet never totally bound to it, because audition is never absolutely free of other corporeal powers, yet never reducible to them.

Even as an expert, I cannot recover the experiences of Haydn's contemporaries. My knowledge of the "sourcillade" is more declarative than procedural. I can only imagine its significance to an eighteenth-century hunter, for whom Haydn's quotation might summon memories of mornings in the woods, of animal sights and smells, of adrenaline. For such a listener, the horn call would be a call to action ("The quarry has been sighted," roughly meaning "Let's go!"). At best, I recognize this meaning at a distance. Here I enjoy Haydn's music without forgetting that it is a music of the past.

As Kane observes, Schaeffer's taxonomy includes no mode that can evaluate the recorded character of recorded sounds (Kane 2014, 126). Similar modes would be needed to register the symphony's historical character and other forms of mediation. If Haydn puts orchestral development "on display" (Dolan 2013, 135), this presumes a kind of listening that may reflect on that process. When the string quartet "samples" a horn call, playing it back in a different medium, I hear that the style is borrowed. Continuing along these lines, modes of listening would proliferate endlessly as a function of musical technics.

Indeed, that might be the central thesis of this book: Technics opens up possibilities for musical action and cognition. As I use instruments to make music, they also make me a musician. I come to sense hands at the keyboard in Beethoven's sonata, Chopin's prelude, or Lachenmann's study; fingers on strings in Rosenwinkel's waltz or Bach's partita; breath and reeds in Dylan's or Williamson's solos. The instruments call not only to my ear but also to my body. They alternately support and resist me, as partners or adversaries, implements or obstacles. Through technology and technique, then, this fleeting art is made tangible; through instruments, I come to encounter music at hand.

REFERENCES

Abbate, Carolyn. 1999. "Outside Ravel's Tomb." *Journal of the American Musicological Society* 52: 465–530.

Adelson, Steve. 2002. "Interview with Pat Metheny." *Twentieth-Century Guitar Magazine*, May. http://hepcat1950.com/pmiv02sa.html.

Adlington, Robert. 2003. "Moving Beyond Motion: Metaphors for Changing Sound." *Journal of the Royal Musical Association* 28: 297–318.

Adlung, Jacob. 2011. *Musica Mechanica Organoedi*. Translated by Quentin Faulkner. Lincoln, NE: Zea E-Books.

Adorno, Theodor W. 2002. *Aesthetic Theory*. Edited by Gretel Adorno and Rolf Tiedemann. Newly edited and translated by Robert Hullot-Kentor. London: Continuum.

Alibali, Martha W., Robert C. Spencer, Lucy Knox, and Sotaro Kita. 2011. "Spontaneous Gestures Influence Strategy Choices in Problem Solving." *Psychological Science* 22: 1138–44.

Altenmüller, Eckart, and Wilfried Gruhn. 2002. "Brain Mechanisms." In *The Science and Psychology of Music Performance*, edited by Richard Parncutt and Gary E. McPherson, 63–82. Oxford: Oxford University Press.

Altschuler, Eric Lewin. 2005. "Were Bach's Toccata and Fugue BWV565 and the Ciacconia from BWV1004 Lute Pieces?" *Musical Times* 146 (1893): 77–86.

Appleby, Amy. 1992. *The Harp Styles of Bob Dylan*. New York: Amsco Publications.

Aravena, Pia, Esteban Hurtado, Rodrigo Riveros, Juan Felipe Cardona, Facundo Manes, and Agustin Ibáñez. 2010. "Applauding with Closed Hands: Neural Signature of Action-Sentence Compatibility Effects." *PLoS ONE* 5: e11751.

Argent, Mark. 2000. "Decoding Bach 3. Stringing Along." *Musical Times* 141 (1872): 16–23.

Aschersleben, Gisa, Jörg Gehrke, and Wolfgang Prinz. 2001. "Tapping with Peripheral Nerve Block: A Role for Tactile Feedback in the Timing of Movements." *Experimental Brain Research* 136: 331–39.

Ashby, W. Ross. 1956. *An Introduction to Cybernetics*. London: Chapman & Hall.

Auerbach, Brent. 2008. "Tiered Polyphony and Its Determinative Role in the Piano Music of Johannes Brahms." *Journal of Music Theory* 52: 273–320.

Baber, Christopher. 2003. *Cognition and Tool Use: Forms of Engagement in Human and Animal Use of Tools*. London: Taylor & Francis.

Bach, Carl Philipp Emanuel. 1949. *Essay on the True Art of Playing Keyboard Instruments*. Translated by William J. Mitchell. New York: W. W. Norton.

Bailey, Derek. 1992. *Improvisation: Its Nature and Practice in Music*. Cambridge, MA: Da Capo.

Baily, John. 1977. "Movement Patterns in Playing the Herati Dutar." In *The Anthropology of the Body*, edited by John Blacking, 275–330. London: Academic Press.

———. 1996. "Using Tests of Sound Perception in Fieldwork." *Yearbook for Traditional Music* 28: 147–73.

———. 2006. "John Blacking and the 'Human/Musical Instrument Interface': Two Plucked Lutes from Afghanistan." In *The Musical Human: Rethinking John Blacking's Ethnomusicology in the Twenty-First Century*, edited by Suzel Ana Reily, 107–23. Aldershot: Ashgate.

Baily, John, and Peter Driver. 1992. "Spatio-Motor Thinking in Playing Folk Blues Guitar." *World of Music* 34: 57–71.

Bangert, Marc, and Eckart O. Altenmüller. 2003. "Mapping Perception to Action in Piano Practice: A Longitudinal DC-EEG Study." *BMC Neuroscience* 4: 26.

Bangert, Marc, Thomas Betzwieser, Gottfried Schlaug, Michael Rotte, Dieter Drescher, Hermann Hinrichs, Hans-Jochen Heinze, and Eckart Altenmüller. 2006. "Shared Networks for Auditory and Motor Processing in Professional Pianists: Evidence from fMRI Conjunction." *Neuroimage* 30: 917–26.

Bangert, Marc, Udo Haeusler, and Eckart Altenmüller. 2001. "On Practice: How the Brain Connects Piano Keys and Piano Sounds." *Annals of the New York Academy of Sciences* 930: 425–28.

Barolsky, Daniel, and Edward Klorman. 2016. "Performance and Analysis Today: New Horizons." *Music Theory Online* 22. http://mtosmt.org/issues/mto.16.22.2/mto.16.22.2.barolsky_klorman.html.

Barrett, David. 1995. *Mel Bay's Complete Classic Chicago Blues Harp*. Pacific, MO: Mel Bay.

Barsalou, Lawrence W. 1999. "Perceptual Symbol Systems." *Behavioral and Brain Sciences* 22: 577–660.

———. 2003. "Situated Simulation in the Human Conceptual System." *Language and Cognitive Processes* 18: 513–62.

———. 2008. "Grounded Cognition." *Annual Review of Psychology* 59: 617–45.

———. 2010. "Grounded Cognition: Past, Present, and Future." *Topics in Cognitive Science* 2: 716–24.

Barthes, Roland. 1977. *Image, Music, Text*. Translated by Stephen Heath. New York: Hill & Wang.

Bates, Eliot. 2012. "The Social Life of Musical Instruments." *Ethnomusicology* 56: 363–95.

Bateson, Gregory. 1972. *Steps to an Ecology of Mind*. New York: Ballantine Books.

Baudrillard, Jean. 1996. *The System of Objects*. Translated by James Benedict. London: Verso.

Behmer, Lawrence Paul, and Kelly J. Jantzen. 2011. "Reading Sheet Music Facilitates Sensorimotor Mu-Desynchronization in Musicians." *Clinical Neurophysiology* 122: 1342–47.

Beller-McKenna, Daniel. 2005. "Distance and Disembodiment: Harps, Horns, and the Requiem Idea in Schumann and Brahms." *Journal of Musicology* 22: 47–89.

Benade, Arthur H. 1973. "The Physics of Brasses." *Scientific American* 229 (1): 24–35.

Bent, Margaret. 1984. "Diatonic 'Ficta.'" *Early Music History* 4: 1–48.

Berliner, Paul F. 1993. *The Soul of Mbira: Music and Traditions of the Shona People of Zimbabwe*. Chicago: University of Chicago Press.

Bijsterveld, Karin, and Marten Schulp. 2004. "Breaking into a World of Perfection: Innovation in Today's Classical Musical Instruments." *Social Studies of Science* 34: 649–74.

Blacking, John. 1959. "Problems of Pitch, Pattern and Harmony in the Ocarina Music of the Venda." *African Music* 2: 15–23.

———. 1973. *How Musical Is Man?* Seattle: University of Washington Press.

Blasius, Leslie David. 1996. "The Mechanics of Sensation and the Construction of the Romantic Musical Experience." In *Music Theory in the Age of Romanticism*, edited by Ian Bent, 3–24. Cambridge: Cambridge University Press.

Borgo, David. 2005. *Sync or Swarm: Improvising Music in a Complex Age*. New York: Continuum.

Botvinick, Matthew, and Jonathan Cohen. 1998. "Rubber Hands 'Feel' Touch That Eyes See." *Nature* 391: 756.

Brauchli, Bernard. 1998. *The Clavichord*. Cambridge: Cambridge University Press.

Bregman, Albert S. 1990. *Auditory Scene Analysis: The Perceptual Organization of Sound*. Cambridge, MA: MIT Press.

Brower, Candace. 1997. "Pathway, Blockage, and Containment in Density 21.5." *Theory and Practice* 22/23: 35–54.

Brown, Roberta W. 1934. "A Preliminary Study of the Touch Method of Learning Piano Music." *Journal of Applied Psychology* 18: 516–27.

Bryan, Paul R. 1975. "The Horn in the Works of Mozart and Haydn: Some Observations and Comparisons." *Haydn Yearbook* 9: 189–255.

Buch, David J. 1985. "*Style brisé, Style luthé*, and the *Choses luthées*." *Musical Quarterly* 71: 52–67.

Bungert, James. 2015. "Bach and the Patterns of Transformation." *Music Theory Spectrum* 37: 98–119.

Burguéte, André. 1977. "Die Lautenkompositionen Johann Sebastian Bachs. Ein Beitrag zur Kritischen Wertung aus Spielpraktischer Sicht." *Bach-Jahrbuch* 63: 26–52.

Butler, Mark. 2014. *Playing with Something That Runs: Technology, Improvisation, and Composition in DJ and Laptop Performance*. New York: Oxford University Press.

Byros, Vasili. 2012. "Meyer's 'Anvil': Revisiting the Schema Concept." *Music Analysis* 31: 273–346.

Cage, John. 1961. *Silence*. Middletown, CT: Wesleyan University Press.

———. 1979. *Empty Words: Writings '73–'78*. Middletown, CT: Wesleyan University Press.

Calvo-Merino, Beatriz, Daniel E. Glaser, Julie Grèzes, Richard E. Passingham, and Patrick Haggard. 2005. "Action Observation and Acquired Motor Skills: An FMRI Study with Expert Dancers." *Cerebral Cortex* 15: 1243–49.

Canguilhem, Philippe. 2011. "Singing Upon the Book According to Vicente Lusitano." Translated by Alexander Stalarow. *Early Music History* 30: 55–103.

Cardinali, Lucilla, Francesca Frassinetti, Claudio Brozzoli, Christian Urquizar, Alice C. Roy, and Alessandro Farnè. 2009. "Tool-Use Induces Morphological Updating of the Body Schema." *Current Biology* 19: R478–79.

Chen, Jessie, Marjorie Woollacott, Steve Pologe, and George P. Moore. 2013. "Stochastic Aspects of Motor Behavior and Their Dependence on Auditory Feedback in Experienced Cellists." *Frontiers in Human Neuroscience* 7: 419.

Chen, Joyce L., Charlotte Rae, and Kate E. Watkins. 2011. "Learning to Play a Melody: An fMRI Study Examining the Formation of Auditory-Motor Associations." *Neuroimage* 59: 1200–1208.

Chopin, Frédéric. 1993. *Esquisses pour une méthode de piano*. Edited by Jean-Jacques Eigeldinger. Harmoniques. Paris: Flammarion.

Christensen, Thomas. 1992. "The Spanish Baroque Guitar and Seventeenth-Century Triadic Theory." *Journal of Music Theory* 36: 1–42.

———. 1999. "Four-Hand Piano Transcription and Geographies of Nineteenth-Century Musical Reception." *Journal of the American Musicological Society* 52: 255–98.

Chua, Daniel. 1999. *Absolute Music and the Construction of Meaning*. Cambridge: Cambridge University Press.

Cimini, Amy. 2012. “Vibrating Colors and Silent Bodies: Music, Sound, and Silence in Maurice Merleau-Ponty’s Critique of Dualism.” *Contemporary Music Review* 31: 353–70.

Clarke, Eric F. 2005. *Ways of Listening: An Ecological Approach to the Perception of Musical Meaning*. New York: Oxford University Press.

Clifton, Thomas. 1983. *Music as Heard: A Study in Applied Phenomenology*. New Haven, CT: Yale University Press.

Clough, John, and Jack Douthett. 1991. “Maximally Even Sets.” *Journal of Music Theory* 35: 93–173.

Cohn, Richard. 2012. *Audacious Euphony: Chromatic Harmony and the Triad’s Second Nature*. Oxford Studies in Music Theory. New York: Oxford University Press.

Cole, Jonathan, and Jacques Paillard. 1995. “Living without Touch and Peripheral Information about Body Position and Movement: Studies with Deafferented Subjects.” In *The Body and the Self*, edited by Jose Luis Bermudez, Anthony J. Marcel, and Naomi M. Eilan, 245–66. Cambridge, MA: MIT Press.

Cook, Nicholas. 2014. *Beyond the Score: Music as Performance*. New York: Oxford University Press.

Couchman, Justin J., Robertson Beasley, and Peter Q. Pfordresher. 2012. “The Experience of Agency in Sequence Production with Altered Auditory Feedback.” *Consciousness and Cognition* 21: 186–203.

Cox, Arnie. 1999. “The Metaphoric Logic of Musical Motion and Space.” PhD dissertation, University of Oregon.

———. 2006. “Hearing, Feeling, Grasping Gestures.” In *Music and Gesture*, edited by Anthony Gritten and Elaine King, 45–60. Aldershot: Ashgate.

———. 2011. “Embodying Music: Principles of the Mimetic Hypothesis.” *Music Theory Online* 17. http://www.mtosmt.org/issues/mto.11.17.2/mto.11.17.2.cox.html.

Critchley, Simon. 2002. “Introduction.” In *The Cambridge Companion to Levinas*, edited by Simon Critchley and Robert Bernasconi, 1–32. Cambridge: Cambridge University Press.

Cross, Ian. 2007. “Music and Cognitive Evolution.” In *Oxford Handbook of Evolutionary Psychology*, edited by R. I. M. Dunbar and Louise Barrett, 649–68. Oxford: Oxford University Press.

Crump, Matthew J. C., Gordon D. Logan, and Jerry Kimbrough. 2012. “Keeping an Eye on Guitar Skill: Visual Representations of Guitar Chords.” *Music Perception* 30: 37–47.

Csikszentmihalyi, Mihaly. 1990. *Flow: The Psychology of Optimal Experience*. New York: Harper & Row.

Cuciurean, John. 2000. “A Theory of Pitch, Rhythm, and Intertextual Allusion for the Late Music of György Ligeti.” PhD dissertation, State University of New York at Buffalo.

Cusick, Suzanne G. 1994. “Feminist Theory, Music Theory, and the Mind/Body Problem.” *Perspectives of New Music* 32: 8–27.

Czerny, Carl. 1851. *Letters to a Young Lady on the Art of Playing the Pianoforte*. Translated by J. A. Hamilton. New York: Firth, Pond & Co.

Dahlhaus, Carl. 1989. *The Idea of Absolute Music*. Translated by Roger Lustig. Chicago: University of Chicago Press.

Damasio, Antonio R. 1989. “Time-Locked Multiregional Retroactivation: A Systems-Level Proposal for the Neural Substrates of Recall and Recognition.” *Cognition* 33: 25–62.

David, Hans T., and Arthur Mendel, eds. 1945. *The Bach Reader: A Life of Johann Sebastian Bach in Letters and Documents*. New York: W. W. Norton.

David, Hans T., Arthur Mendel, and Christoph Wolff, eds. 1998. *The New Bach Reader: A Life of Johann Sebastian Bach in Letters and Documents*. New York: W. W. Norton.

Davidson, Jane W. 1993. "Visual Perception of Performance Manner in the Movements of Solo Musicians." *Psychology of Music* 21: 103–13.

Dawe, Kevin. 2010. *The New Guitarscape in Critical Theory, Cultural Practice, and Musical Performance*. Farnham: Ashgate.

Demers, Joanna. 2010. *Listening through the Noise: The Aesthetics of Experimental Electronic Music*. New York: Oxford University Press.

Derrida, Jacques. 1976. *Of Grammatology*. Translated by Gayatri Chakravorty Spivak. Baltimore: Johns Hopkins University Press.

———. 1988. *Limited Inc*. Evanston, IL: Northwestern University Press.

———. 2011. *Voice and Phenomenon: Introduction to the Problem of the Sign in Husserl's Phenomenology*. Translated by Leonard Lawlor. Northwestern Studies in Phenomenology and Existential Philosophy. Evanston, IL: Northwestern University Press.

Descartes, René. 2001. *Discourse on Method, Optics, Geometry, and Meteorology*. Rev. ed. Translated by Paul J. Olscamp. Indianapolis: Hackett.

De Souza, Jonathan. 2013. "Musical Instruments, Bodies, and Cognition." PhD dissertation, University of Chicago.

———. 2014. "Voice and Instrument at the Origins of Music." *Current Musicology* 97: 21–36.

———. 2015. "Texture." In *The Oxford Handbook of Concepts in Music Theory*, edited by Alexander Rehding and Steven Rings [online]. New York: Oxford University Press.

———. 2016a. "'All Sights Were Perceived as Sounds': Pat Metheny and the Instrumental Image." In *Watching Jazz: Encounters with Jazz Performance on Screen*, edited by Björn Heile, Peter Elsdon, and Jenny Doctor, 147–68. Oxford: Oxford University Press.

———. 2016b. "Fretboard Transformations." Unpublished manuscript.

———. Forthcoming. "Timbral Thievery: Synthesizers and Sonic Materiality." In *The Oxford Handbook of Timbre*, edited by Alexander Rehding and Emily I. Dolan. New York: Oxford University Press.

Dibben, Nicola. 2001. "What Do We Hear, When We Hear Music? Music Perception and Musical Material." *Musicae Scientiae* 5: 161–94.

Dolan, Emily I. 2013. *The Orchestral Revolution: Haydn and the Technologies of Timbre*. Cambridge: Cambridge University Press.

Downey, Greg. 2002. "Listening to Capoeira: Phenomenology, Embodiment, and the Materiality of Music." *Ethnomusicology* 46: 487–509.

Dreyfus, Hubert L. 2002. "Intelligence without Representation—Merleau-Ponty's Critique of Mental Representation." *Phenomenology and the Cognitive Sciences* 1: 367–83.

Dreyfus, Laurence. 1996. *Bach and the Patterns of Invention*. Cambridge, MA: Harvard University Press.

Drost, Ulrich C., Martina Rieger, Marcel Brass, Thomas C. Gunter, and Wolfgang Prinz. 2005. "Action-Effect Coupling in Pianists." *Psychological Research* 69: 233–41.

Drost, Ulrich C., Martina Rieger, and Wolfgang Prinz. 2007. "Instrument Specificity in Experienced Musicians." *Quarterly Journal of Experimental Psychology* 60: 527–33.

Dyson, Frances. 2009. *Sounding New Media: Immersion and Embodiment in the Arts and Culture*. Berkeley: University of California Press.

Ealy, George Thomas. 1994. "Of Ear Trumpets and a Resonance Plate: Early Hearing Aids and Beethoven's Hearing Perception." *19th-Century Music* 17: 262–73.

Edelman, Shimon, and Elise M. Breen. 1999. "On the Virtues of Going All the Way: A Commentary on Barsalou." *Behavioral and Brain Sciences* 22: 614.

Ehrsson, H. Henrik, Charles Spence, and Richard E. Passingham. 2004. "That's My Hand! Activity in Premotor Cortex Reflects Feeling of Ownership of a Limb." *Science* 305: 875–77.

Eigeldinger, Jean-Jacques. 1986. *Chopin: Pianist and Teacher as Seen by His Pupils*. Edited by Roy Howat. Translated by Naomi Shohet with Krysia Osostowicz and Roy Howat. Cambridge: Cambridge University Press.

Eitan, Zohar, and Renee Timmers. 2010. "Beethoven's Last Piano Sonata and Those Who Follow Crocodiles: Cross-Domain Mappings of Auditory Pitch in a Musical Context." *Cognition* 114: 405–22.

Elbert, Thomas, Christo Pantev, Christian Wienbruch, Brigitte Rockstroh, and Edward Taub. 1995. "Increased Cortical Representation of the Fingers of the Left Hand in String Players." *Science* 270: 305–7.

Emsley, Jason. 2011. *The Laptop DJ Handbook: Setups and Techniques of the Modern Performer*. Boston: Course Technology.

Erman, Britt, and Beatrice Warren. 2000. "The Idiom Principle and the Open Choice Principle." *Text* 20: 29–62.

Fazeli Fard, Maggie. 2012. "Harmonica-Playing Elephant Is National Zoo's Newest Star." *Washington Post*, May 2. http://www.washingtonpost.com/blogs/the-buzz/post/harmonica-playing-elephant-is-national-zoos-newest-star-video/2012/05/02/gIQABRf-pwT_blog.html.

Feldman, Martha. 2015. "The Interstitial Voice: An Opening." *Journal of the American Musicological Society* 68: 653–59.

Field, Kim. 2000. *Harmonicas, Harps, and Heavy Breathers: The Evolution of the People's Instrument*. Rev. ed. New York: Cooper Square.

Finney, Steven A. 1997. "Auditory Feedback and Musical Keyboard Performance." *Music Perception* 15: 153–74.

Fisher, George, and Judith Lochhead. 2002. "Analyzing from the Body." *Theory and Practice* 27: 37–67.

Fitzpatrick, Horace. 1970. *The Horn and Horn-Playing and the Austro-Bohemian Tradition from 1680 to 1830*. London: Oxford University Press.

Foucault, Michel. 1995. *Discipline and Punish: The Birth of the Prison*. Translated by Alan Sheridan. New York: Vintage Books.

Freed, D. 1990. "Auditory Correlates of Perceived Mallet Hardness for a Set of Recorded Percussive Sound Events." *Journal of the Acoustical Society of America* 87: 311–22.

Friedson, Steven M. 1996. *Dancing Prophets: Musical Experience in Tumbuka Healing*. Chicago: University of Chicago Press.

Frith, Chris. 2005. "The Self in Action: Lessons from Delusions of Control." *Consciousness and Cognition* 14: 752–70.

Frith, Fred. 2005. Liner notes for *The Compass, Log and Lead*, Fred Frith, Stevie Wishart, and Carla Kihlstedt. Intakt CD 103/2006, compact disc.

Fulton, Will. 2015. "Stevie Wonder's Tactile Keyboard Mediation, Black Key Compositional Development, and the Quest for Creative Autonomy." In *The Oxford Handbook of Music and Disability Studies*, edited by Blake Howe, Stephanie Jensen-Moulton, Neil Lerner, and Joseph Straus, 272–92. New York: Oxford University Press.

Galison, Peter. 2005. "Material Culture, Theoretical Culture, and Delocalization." In *Collection–Laboratory–Theater: Scenes of Knowledge in the 17th Century*, edited by Helmar Schramm, Ludger Schwarte, and Jan Lazardzig, English ed., 490–506. Theatrum Scientarum 1. Berlin: Walter de Gruyter.

Gallager, Robert G. 2001. "Claude E. Shannon: A Retrospective on His Life, Work, and Impact." *IEEE Transactions on Information Theory* 47: 2681–95.

Gallagher, Shaun. 1986. "Body Image and Body Schema: A Conceptual Clarification." *Journal of Mind and Behavior* 7: 541–54.

———. 2012. "Multiple Aspects in the Sense of Agency." *New Ideas in Psychology* 30: 15–31.

Gallagher, Shaun, and Mette Vaever. 2004. "Body: Disorders of Embodiment." In *The Philosophy of Psychiatry: A Companion*, edited by Jennifer Radden, 118–32. Oxford: Oxford University Press.

Gallope, Michael. 2011. "Technicity, Consciousness, and Musical Objects." In *Music and Consciousness: Philosophical, Psychological, and Cultural Perspectives*, edited by David Clarke and Eric F. Clarke, 47–64. Oxford: Oxford University Press.

Gaver, William W. 1988. "Everyday Listening and Auditory Icons." PhD dissertation, University of California, San Diego.

———. 1993. "What in the World Do We Hear?: An Ecological Approach to Auditory Event Perception." *Ecological Psychology* 5: 1–29.

Gawboy, Anna. 2009. "The Wheatstone Concertina and Symmetrical Arrangements of Tonal Space." *Journal of Music Theory* 53: 163–90.

Gibson, James J. 1966. *The Senses Considered as Perceptual Systems*. Boston: Houghton Mifflin.

———. 1979. *The Ecological Approach to Visual Perception*. Boston: Houghton Mifflin.

———. 1982. *Reasons for Realism: Selected Essays of James J. Gibson*. Edited by Edward Reed and Rebecca Jones. Hillsdale, NJ: Lawrence Erlbaum.

Gjerdingen, Robert O. 2007a. *Music in the Galant Style*. New York: Oxford University Press.

———. 2007b. "*Partimento, que me veux-tu?*" *Journal of Music Theory* 51: 85–135.

———. 2009. "The Price of (Perceived) Affordance: Commentary for Huron and Berec." *Empirical Musicology Review* 4: 123–25.

Gjerdingen, Robert O., and Janet Bourne. 2015. "Schema Theory as a Construction Grammar." *Music Theory Online* 21. http://www.mtosmt.org/issues/mto.15.21.2/mto.15.21.2.gjerdingen_bourne.html.

Glenberg, Arthur M. 1997. "What Memory Is For." *Behavioral and Brain Sciences* 20: 1–55.

Goebl, Werner, and Caroline Palmer. 2008. "Tactile Feedback and Timing Accuracy in Piano Performance." *Experimental Brain Research* 186: 471–79.

———. 2009. "Synchronization of Timing and Motion Among Performing Musicians." *Music Perception* 26: 427–38.

Goehr, Lydia. 1998. *The Quest for Voice: On Music, Politics, and the Limits of Philosophy*. Oxford: Clarendon Press.

Goldin-Meadow, Susan, and Sian L. Beilock. 2010. "Action's Influence on Thought: The Case of Gesture." *Perspectives on Psychological Science* 5: 664–74.

Goldman, Jonathan. 2012. "The Buttons on Pandora's Box: David Tudor and the Bandoneon." *American Music* 30: 30–60.

———. Forthcoming. "Gérard Grisey and the Accordion." *Twentieth-Century Music*.

Goldstone, Robert L., and Lawrence W. Barsalou. 1998. "Reuniting Perception and Conception." *Cognition* 65: 231–62.

Gollin, Edward. 2000. "Representations of Space and Conceptions of Distance in Transformational Music Theories." PhD dissertation, Harvard University.

Graham, Keith. n.d. "Sonny Boy Williamson II, Help Me Solo." *HarpTab.com*. http://www.harptab.com/helpme/helpme3.shtml.

Graham, Kyran T., Mathew T. Martin-Iverson, Nicholas P. Holmes, Assen Jablensky, and Flavie Waters. 2014. "Deficits in Agency in Schizophrenia, and Additional Deficits in Body Image, Body Schema, and Internal Timing, in Passivity Symptoms." *Frontiers in Psychiatry* 5: 126.

Grahn, Jessica A. 2009. "The Role of the Basal Ganglia in Beat Perception: Neuroimaging and Neuropsychological Investigations." *Annals of the New York Academy of Sciences* 1169: 35–45.

Graziano, Michael S. A., and Matthew Botvinick. 2002. "How the Brain Represents the Body: Insights from Neurophysiology and Psychology." In *Common Mechanisms in Perception and Action: Attention and Performance XIX*, edited by Wolfgang Prinz and Bernhard Hommel, 136–57. Oxford: Oxford University Press.

Greimas, Algirdas J., and François Rastier. 1968. "The Interaction of Semiotic Constraints." *Yale French Studies* 41: 86–105.

Guan, Connie Qun, Wanjin Meng, Ru Yao, and Arthur M. Glenberg. 2013. "The Motor System Contributes to Comprehension of Abstract Language." *PLoS ONE* 8: e75183.

Guterstam, Arvid, Giovanni Gentile, and H. Henrik Ehrsson. 2013. "The Invisible Hand Illusion: Multisensory Integration Leads to the Embodiment of a Discrete Volume of Empty Space." *Journal of Cognitive Neuroscience* 25: 1078–99.

Hafke-Dys, Honorata, Anna Preis, and David Trojan. 2016. "Violinists' Perceptions of and Motor Reactions to Fundamental Frequency Shifts Introduced in Auditory Feedback." *Acta Acustica United with Acustica* 102: 155–58.

Hall, Matthew J. 2015. "Keyboard Technique as Contrapuntal Structure in J. S. Bach's Clavier Works." *Understanding Bach* 10: 85–107.

Halwani, Gus F., Psyche Loui, Theodor Rüber, and Gottfried Schlaug. 2010. "Effects of Practice and Experience on the Arcuate Fasciculus: Comparing Singers, Instrumentalists, and Non-Musicians." *Frontiers in Psychology* 2: 156.

Harman, Graham. 2002. *Tool-Being: Heidegger and the Metaphysics of Objects*. Chicago: Open Court.

———. 2007. "Aesthetics as First Philosophy: Levinas and the Non-Human." *Naked Punch* 9: 21–30.

Harrison, Daniel. 1988. "Some Group Properties of Triple Counterpoint and Their Influence on Compositions by J. S. Bach." *Journal of Music Theory* 32: 23–49.

Hasegawa, Takehiro, Ken-Ichi Matsuki, Takashi Ueno, Yasuhiro Maeda, Yoshihiko Matsue, Yukuo Konishi, and Norihiro Sadato. 2004. "Learned Audio-Visual Cross-Modal Associations in Observed Piano Playing Activate the Left Planum Temporale: An fMRI Study." *Cognitive Brain Research* 20: 510–18.

Hatten, Robert S. 2004. *Interpreting Musical Gestures, Topics, and Tropes: Mozart, Beethoven, Schubert*. Bloomington: Indiana University Press.

Haueisen, Jens, and Thomas R. Knösche. 2001. "Involuntary Motor Activity in Pianists Evoked by Music Perception." *Journal of Cognitive Neuroscience* 13: 786–92.

Hayles, N. Katherine. 1999. *How We Became Posthuman: Virtual Bodies in Cybernetics, Literature, and Informatics*. Chicago: University of Chicago Press.

Head, Henry. 1920. *Studies in Neurology*. Vol. 2. London: Oxford University Press.

Heartz, Daniel. 1976. "The Hunting Chorus in Haydn's *Jahreszeiten* and the 'Airs de Chasse' in the *Encyclopédie*." *Eighteenth-Century Studies* 9: 523–39.

Heidegger, Martin. 1968. *What Is Called Thinking?* Translated by Fred D. Wieck and J. Glenn Gray. New York: Harper & Row.

———. 1977. *"The Question Concerning Technology" and Other Essays*. Translated by William Lovitt. New York: Harper & Row.

———. 2008. *Basic Writings*. Edited by David Farrell Krell. New York: HarperCollins.

———. 2010. *Being and Time*. Translated by Joan Stambaugh. Revised. Albany, NY: SUNY Press.

Heyde, Herbert. 1975. *Grundlagen des natürlichen Systems der Musikinstrumente*. Beiträge zur musikwissenschaftlichen Forschung in der DDR 7. Leipzig: VEB Deutscher Verlag für Musik.

———. 2001. "Methods of Organology and Proportions in Brass Wind Instrument Making." *Historic Brass Society Journal* 13: 1–51.

Hicks, Jonathan. 2014. "Aesthetics over a Barrel." Paper presented at the Eighteenth Biennial International Conference on Nineteenth-Century Music, University of Toronto, June 19.
Hoeckner, Berthold. 1997. "Schumann and Romantic Distance." *Journal of the American Musicological Society* 50: 55–132.
Holman, Bobby Joe. 2000. *The Hal Leonard Complete Harmonica Method*. Milwaukee, WI: Hal Leonard.
Holmes, Allen. 2002. "Bent over Overbends." *Harmonica Sessions eZine*.
Hook, Julian. 2002. "Uniform Triadic Transformations." *Journal of Music Theory* 46: 57–126.
———. 2014. "Key-Color Invariance". Paper presented at the Mathematics of Music Interest Group Meeting, Society for Music Theory Annual Meeting, Milwaukee, WI, November 7.
Hornbostel, Erich M. von, and Curt Sachs. 1961. "Classification of Musical Instruments." Translated by Anthony Baines and Klaus P. Wachsmann. *Galpin Society Journal* 14: 3–29.
Howell, Peter, David J. Powell, and Ian Khan. 1983. "Amplitude Contour of the Delayed Signal and Interference in Delayed Auditory Feedback Tasks." *Journal of Experimental Psychology: Human Perception and Performance* 9: 772–84.
Hughes, Bryn. 2011. "Harmonic Expectation in Twelve-Bar Blues Progressions." PhD dissertation, Florida State University, Tallahassee.
Humbert, Nicolas, and Werner Penzel. 1990. *Step Across the Border*. Cine Nomades Filmproduction, Munich; Res Balzli & Cie Filmproduktion, Nidau.
Humphries, John. 2000. *The Early Horn: A Practical Guide*. Cambridge Handbooks to the Historical Performance of Music. Cambridge: Cambridge University Press.
Huron, David. 2006. *Sweet Anticipation: Music and the Psychology of Expectation*. Cambridge, MA: MIT Press.
Huron, David, and Jonathon Berec. 2009. "Characterizing Idiomatic Organization in Music: A Theory and Case Study of Musical Affordances." *Empirical Musicology Review* 4: 103–22.
Husserl, Edmund. 1960. *Cartesian Meditations: An Introduction to Phenomenology*. Translated by Dorion Cairns. The Hague: Martinus Nijhoff.
———. 1969. *Formal and Transcendental Logic*. Translated by Dorion Cairns. The Hague: Martinus Nijhoff.
———. 1973. *Zur Phänomenologie der Intersubjektivität: Texte aus dem Nachlass*. Edited by Iso Kern. Vol. 1. Husserliana 13. The Hague: Martinus Nijhoff.
———. 2012. *Ideas: General Introduction to Pure Phenomenology*. Translated by W. R. Boyce Gibson. London: Routledge.
Hutchins, Edwin. 1995. *Cognition in the Wild*. Cambridge, MA: MIT Press.
Hyer, Brian. 2011. "What Is a Function?" In *The Oxford Handbook of Neo-Riemannian Music Theories*, edited by Edward Gollin and Alexander Rehding, 92–139. Oxford: Oxford University Press.
Ihde, Don. 1986. *Experimental Phenomenology: An Introduction*. Albany, NY: SUNY Press.
———. 1990. *Technology and the Lifeworld: From Garden to Earth*. Bloomington: Indiana University Press.
———. 2007. *Listening and Voice: Phenomenologies of Sound*. 2nd ed. Albany, NY: SUNY Press.
———. 2009. *Postphenomenology and Technoscience: The Peking University Lectures*. Albany, NY: SUNY Press.
Ingold, Tim. 2000. *The Perception of the Environment: Essays on Livelihood, Dwelling and Skill*. London: Routledge.
Jeannerod, Marc. 1997. *The Cognitive Neuroscience of Action*. Fundamentals of Cognitive Neuroscience 1. Oxford: Blackwell.

———. 2006. *Motor Cognition: What Actions Tell the Self*. Oxford Psychology Series 42. Oxford: Oxford University Press.

Johnson, Mark. 1987. *The Body in the Mind: The Bodily Basis of Meaning, Imagination, and Reason*. Chicago: University of Chicago Press.

Johnson, Mark, and Steve Larson. 2003. "'Something in the Way She Moves'—Metaphors of Musical Motion." *Metaphor and Symbol* 18: 63–84.

Johnston, Robert B. 1987. "Pitch Control in Harmonica Playing." *Acoustics Australia* 15: 69–75.

Jonas, Hans. 1966. "The Nobility of Sight: A Study in the Phenomenology of the Senses." In *The Phenomenon of Life: Toward a Philosophical Biology*, 135–52. New York: Harper & Row.

Jost, Peter. 2001. "Klang, Harmonik, und Form in Brahms' Horntrio Op. 40." In *Internationaler Brahms-Kongress Gmunden 1997: Kongreßbericht*, edited by Ingrid Fuchs, 59–71. Tutzing: Hans Schneider.

Kane, Brian. 2011. "Excavating Lewin's 'Phenomenology.'" *Music Theory Spectrum* 33: 27–36.

———. 2014. *Sound Unseen: Acousmatic Sound in Theory and Practice*. New York: Oxford University Press.

Kartomi, Margaret J. 1990. *On Concepts and Classifications of Musical Instruments*. Chicago: University of Chicago Press.

Kirsh, David. 2013. "Embodied Cognition and the Magical Future of Interaction Design." *ACM Transactions on Computer-Human Interaction* 20 (1), Article 3.

Kittler, Friedrich A. 1999. *Gramophone, Film, Typewriter*. Translated by Geoffrey Winthrop-Young and Michael Wutz. Stanford, CA: Stanford University Press.

Knittel, K. M. 1998. "Wagner, Deafness, and the Reception of Beethoven's Late Style." *Journal of the American Musicological Society* 51: 49–82.

Koozin, Timothy. 2011. "Guitar Voicing in Pop-Rock Music: A Performance-Based Analytical Approach." *Music Theory Online* 17. http://www.mtosmt.org/issues/mto.11.17.3/mto.11.17.3.koozin.html.

Kozak, Mariusz. 2015. "Listeners' Bodies in Music Analysis: Gestures, Motor Intentionality, and Models." *Music Theory Online* 21. http://www.mtosmt.org/issues/mto.15.21.3/mto.15.21.3.kozak.php.

Kramer, Lawrence. 1995. *Classical Music and Postmodern Knowledge*. Berkeley: University of California Press.

Lachenmann, Helmut. 1980. "The 'Beautiful' in Music Today." *Tempo*, n.s., 135: 20–24.

———. 1995. "On Structuralism." *Contemporary Music Review* 12: 93–102.

———. 1996. *Musik als existentielle Erfahrung: Schriften, 1966–1995*. Wiesbaden: Breitkopf & Härtel.

Laeng, Bruno, and A. Park. 1999. "Handedness Effects on Playing a Reversed or Normal Keyboard." *Laterality* 4: 363–77.

Lahav, Amir, Elliot Saltzman, and Gottfried Schlaug. 2007. "Action Representation of Sound: Audiomotor Recognition Network While Listening to Newly Acquired Actions." *Journal of Neuroscience* 27: 308–14.

Lakoff, George, and Mark Johnson. 1980. *Metaphors We Live By*. Chicago: University of Chicago Press.

Landon, H. C. Robbins. 1976. *Haydn: Chronicle and Works*. Vol. 1. 5 vols. Bloomington: Indiana University Press.

Lange, Oskar. 1965. *Wholes and Parts: A General Theory of System Behaviour*. Translated by Eugeniusz Lepa. Oxford: Pergamon Press.

Langwill, Lyndesay G., and Arthur W. J. G. Ord-Hume. 2001. "Barrel Organ." *Grove Music Online*. http://www.oxfordmusiconline.com/subscriber/article/grove/music/02111.

Larson, Steve. 2012. *Musical Forces: Motion, Metaphor, and Meaning in Music*. Musical Meaning and Interpretation. Bloomington: Indiana University Press.

Latour, Bruno. 1991. "Technology Is Society Made Durable." In *A Sociology of Monsters: Essays on Power, Technology, and Domination*, edited by John Law, 103–31. Sociological Review Monograph 38. London: Routledge.

Ledbetter, David. 1987. *Harpsichord and Lute Music in 17th-Century France*. Bloomington: Indiana University Press.

———. 2002. *Bach's Well-Tempered Clavier: The 48 Preludes and Fugues*. New Haven, CT: Yale University Press.

———. 2009. *Unaccompanied Bach: Performing the Solo Works*. New Haven, CT: Yale University Press.

Le Guin, Elisabeth. 2006. *Boccherini's Body: An Essay in Carnal Musicology*. Berkeley: University of California Press.

Leppert, Richard. 1993. *The Sight of Sound: Music, Representation, and the History of the Body*. Berkeley: University of California Press.

Lerdahl, Fred. 2001. *Tonal Pitch Space*. New York: Oxford University Press.

Lerdahl, Fred, and Ray Jackendoff. 1983. *A Generative Theory of Tonal Music*. Cambridge, MA: MIT Press.

Lester, Joel. 1999. *Bach's Works for Solo Violin: Style, Structure, Performance*. New York: Oxford University Press.

Levinas, Emmanuel. 1969. *Totality and Infinity: An Essay on Exteriority*. Translated by Alphonso Lingis. Pittsburgh: Duquesne University Press.

———. 1981. *Otherwise than Being, or Beyond Essence*. Translated by Alphonso Lingis. The Hague: Martinus Nijhoff.

———. 1989. *The Levinas Reader*. Edited by Seán Hand. Oxford: Blackwell.

Levy, Howard. 1992. *New Directions for Harmonica: Expanding Your Technique*. Woodstock, NY: Homespun Tapes.

Lewin, David. 1977. "Forte's Interval Vector, My Interval Function, and Regener's Common-Note Function." *Journal of Music Theory* 21: 194–237.

———. 1986. "Music Theory, Phenomenology, and Modes of Perception." *Music Perception* 3: 327–92.

———. 1987. *Generalized Musical Intervals and Transformations*. New Haven, CT: Yale University Press.

———. 1993. *Musical Form and Transformation: 4 Analytic Essays*. New Haven, CT: Yale University Press.

———. 1998. "Some Ideas about Voice-Leading between PCSets." *Journal of Music Theory* 42: 15–72.

Lidji, Pascale, Régine Kolinsky, Aliette Lochy, and José Morais. 2007. "Spatial Associations for Musical Stimuli: A Piano in the Head?" *Journal of Experimental Psychology: Human Perception and Performance* 33: 1189–1207.

Lingis, Alphonso. 1998. *The Imperative*. Studies in Continental Thought. Bloomington: Indiana University Press.

Lotze, M., G. Scheler, H.-R.M. Tan, C. Braun, and N. Birbaumer. 2003. "The Musician's Brain: Functional Imaging of Amateurs and Professionals During Performance and Imagery." *NeuroImage* 20: 1817–29.

Magnusson, Thor. 2009. "Of Epistemic Tools: Musical Instruments as Cognitive Extensions." *Organised Sound* 14: 168–76.

Mann, Alfred. 1970. "Beethoven's Contrapuntal Studies with Haydn." *Musical Quarterly* 56: 711–26.

Marcel, Anthony. 2003. “The Sense of Agency: Awareness and Ownership of Action.” In *Agency and Self-Awareness: Issues in Philosophy and Psychology*, edited by Johannes Roessler and Naomi Eilan, 48–93. Oxford: Oxford University Press.

Margulis, Elizabeth Hellmuth, Lauren M. Mlsna, Ajith K. Uppunda, Todd B. Parrish, and Patrick C. M. Wong. 2009. “Selective Neurophysiologic Responses to Music in Instrumentalists with Different Listening Biographies.” *Human Brain Mapping* 30: 267–75.

Marshall, Robert. 1972. *The Compositional Process of J. S. Bach: A Study of the Autograph Scores of the Vocal Works*. Princeton, NJ: Princeton University Press.

Maturana, Humberto R., and Francisco J. Varela. 1980. *Autopoiesis and Cognition: The Realization of the Living*. Boston Studies in the Philosophy of Science 42. Dordrecht: Reidel.

McClary, Susan. 1998. “Unruly Passions and Courtly Dances: Technologies of the Body in Baroque Music.” In *From the Royal to the Republican Body: Incorporating the Political in Seventeenth- and Eighteenth-Century France*, edited by Sara E. Melzer and Kathryn Norberg, 85–112. Berkeley: University of California Press.

McClary, Susan, and Robert Walser. 1994. “Theorizing the Body in African-American Music.” *Black Music Research Journal* 14: 75–84.

McLuhan, Marshall. 1994. *Understanding Media: The Extensions of Man*. Cambridge, MA: MIT Press.

McNeill, David. 1992. *Hand and Mind: What Gestures Reveal about Thought*. Chicago: University of Chicago Press.

Mead, Andrew. 1999. “Bodily Hearing: Physiological Metaphors and Musical Understanding.” *Journal of Music Theory* 43: 1–19.

Merleau-Ponty, Maurice. 1963. *The Structure of Behavior*. Translated by Alden L. Fisher. Boston: Beacon Press.

———. 1964. *The Primacy of Perception*. Edited by James M. Edie. Evanston, IL: Northwestern University Press.

———. 1968. *The Visible and the Invisible*. Edited by Claude Lefort. Translated by Alphonso Lingis. Northwestern Studies in Phenomenology and Existential Philosophy. Evanston, IL: Northwestern University Press.

———. 2003. *Nature: Course Notes from the Collège de France*. Translated by Roger Vallier. Evanston, IL: Northwestern University Press.

———. 2012. *Phenomenology of Perception*. Translated by Donald A. Landes. London: Routledge.

Metheny, Pat. 2000. *Pat Metheny Song Book: The Complete Collection, 167 Compositions*. Milwaukee, WI: Hal Leonard.

Meyer, Leonard B. 1956. *Emotion and Meaning in Music*. Chicago: University of Chicago Press.

———. 1967. *Music, the Arts, and Ideas: Patterns and Predictions in Twentieth-Century Culture*. Chicago: University of Chicago Press.

———. 1973. “On the Nature and Limits of Critical Analysis.” In *Explaining Music: Essays and Explorations*, 3–25. Berkeley: University of California Press.

Milkowski, Bill. 1983. “The Frith Factor: Exploration in Sound.” *Downbeat* 50 (1): 22–25, 61.

Miller, Cherisse W. 2011. *Making Music with a Hearing Loss: Strategies and Stories*. Rockville, MD: AAMHL Publications.

Miner, Gregg. 2015. “What Is a Harp Guitar? The Definitive Organology of Historical and Modern Harp Guitars and Related Instruments.” http://www.harpguitars.net/history/org/hgorg.htm.

Missin, Pat. n.d. “So Just Who Was This Richter Guy and What Exactly Did He Invent?” www.patmissin.com/ffaq/q37.html.

Monelle, Raymond. 2006. *The Musical Topic: Hunt, Military and Pastoral*. Bloomington: Indiana University Press.

Montague, Eugene. 2012. "Instrumental Gesture in Chopin's Étude in A-Flat Major, Op. 25, No. 1." *Music Theory Online* 18. http://www.mtosmt.org/issues/mto.12.18.4/mto.12.18.4.montague.php.

Moseley, Roger. 2015. "Digital Analogies: The Keyboard as Field of Musical Play." *Journal of the American Musicological Society* 68: 151–227.

Mumford, Lewis. 1934. *Technics and Civilization*. New York: Harcourt, Brace.

Musicians Professional Resource. n.d. "Howard Levy Interview." *Musicians Professional Resource*. http://www.musicians-professional-resource.com/interview3.html.

Nahmias, Eddy. 2005. "Agency, Authorship, and Illusion." *Consciousness and Cognition* 14: 771–85.

Nattiez, Jean Jacques. 1990. *Music and Discourse: Toward a Semiology of Music*. Princeton, NJ: Princeton University Press.

Nettl, Bruno. 1992. *The Radif of Persian Music: Studies of Structure and Cultural Context in the Classical Music of Iran*. Rev. ed. Champaign, IL: Elephant & Cat.

Novembre, Giacomo, and Peter E. Keller. 2011. "A Grammar of Action Generates Predictions in Skilled Musicians." *Consciousness and Cognition* 20: 1232–43.

Overy, Katie, and Istvan Molnar-Szakacs. 2009. "Being Together in Time: Musical Experience and the Mirror Neuron System." *Music Perception* 26: 489–504.

Pacherie, Elisabeth. 2008. "The Phenomenology of Action: A Conceptual Framework." *Cognition* 107: 179–219.

Palisca, Claude V. 1961. "Scientific Empiricism in Musical Thought." In *Seventeenth-Century Science and the Arts*, edited by H. H. Rhys, 91–137. Princeton, NJ: Princeton University Press.

Palmer, Caroline, and Simone Dalla Bella. 2004. "Movement Amplitude and Tempo Change in Piano Performance." *Journal of the Acoustical Society of America* 115: 2590.

Palmer, Caroline, Erik Koopmans, Janeen D. Loehr, and Christine Carter. 2009. "Movement-Related Feedback and Temporal Accuracy in Clarinet Performance." *Music Perception* 26: 439–49.

Palmer, Caroline, and Rosalee K. Meyer. 2000. "Conceptual and Motor Learning in Music Performance." *Psychological Science* 11: 63–68.

Palmer, Carolyn F., Rebecca K. Jones, Beth L. Hennessy, Marsha G. Unze, and Anne D. Pick. 1989. "How Is a Trumpet Known? The 'Basic Object Level' Concept and Perception of Musical Instruments." *American Journal of Psychology* 102: 17–37.

Palombini, Carlos. 1998. "Technology and Pierre Schaeffer: Pierre Schaeffer's *Art-Relais*, Walter Benjamin's *technische Reproduzierbarkeit* and Martin Heidegger's *Ge-stell*." *Organised Sound* 3: 35–43.

Parry, Richard. 2007. "*Episteme* and *Techne*." *Stanford Encyclopedia of Philosophy*. http://plato.stanford.edu/entries/episteme-techne/.

Paulson, Marcy. 2009. "Is Transposing on a Diatonic Harmonica Possible?" http://www.suite101.com/content/transposing-on-a-diatonic-harmonica-a137825.

Peled, Avi, Assaf Pressman, Amir B. Geva, and Ilan Modai. 2003. "Somatosensory Evoked Potentials during a Rubber-Hand Illusion in Schizophrenia." *Schizophrenia Research* 64: 157–63.

Perrott, David, and Robert O. Gjerdingen. 2008. "Scanning the Dial: The Rapid Recognition of Music Genres." *Journal of New Music Research* 37: 93–100.

Pfordresher, Peter Q. 2005. "Auditory Feedback in Music Performance: The Role of Melodic Structure and Musical Skill." *Journal of Experimental Psychology. Human Perception & Performance* 31: 1331–45.

———. 2006. “Coordination of Perception and Action in Music Performance.” *Advances in Cognitive Psychology* 2: 183–98.
Pfordresher, Peter Q., and James T. Mantell. 2012. “Effects of Altered Auditory Feedback across Effector Systems: Production of Melodies by Keyboard and Singing.” *Acta Psychologica* 139: 166–77.
Pfordresher, Peter Q., and Caroline Palmer. 2002. “Effects of Delayed Auditory Feedback on Timing of Music Performance.” *Psychological Research* 66: 71–79.
———. 2006. “Effects of Hearing the Past, Present, or Future During Music Performance.” *Perception & Psychophysics* 68: 362–76.
Phillips-Silver, Jessica, and Laurel J. Trainor. 2005. “Feeling the Beat: Movement Influences Infants’ Rhythm Perception.” *Science* 308: 1430.
———. 2007. “Hearing What the Body Feels: Auditory Encoding of Rhythmic Movement.” *Cognition* 105: 533–46.
Pickering, Andrew. 2009. *The Cybernetic Brain: Sketches of Another Future*. Chicago: University of Chicago Press.
Pinch, Trevor, and Frank Trocco. 2002. “The Social Construction of the Early Electronic Music Synthesizer.” In *Music and Technology in the Twentieth Century*, edited by Hans-Joachim Braun, 67–83. Baltimore: Johns Hopkins University Press.
Polanyi, Michael. 1958. *Personal Knowledge: Towards a Post-Critical Philosophy*. Chicago: University of Chicago Press.
Reichardt, Jasia, ed. 1968. *Cybernetic Serendipity: The Computer and the Arts*. London New York: Studio International.
Repp, Bruno H. 1987. “The Sound of Two Hands Clapping: An Exploratory Study.” *Journal of the Acoustical Society of America* 81: 1100–1109.
———. 1999. “Effects of Auditory Feedback Deprivation on Expressive Piano Performance.” *Music Perception* 16: 409–38.
Ringer, Alexander L. 1953. “The *Chasse* as a Musical Topic of the 18th Century.” *Journal of the American Musicological Society* 6: 148–59.
Rings, Steven. 2011. *Tonality and Transformation*. Oxford Studies in Music Theory. New York: Oxford University Press.
———. 2012. “The Learned Self: Artifice in Brahms’s Late Intermezzi.” In *Expressive Intersections in Brahms: Essays in Analysis and Meaning*, edited by Heather Platt and Peter H. Smith, 19–50. Bloomington: Indiana University Press.
Riskin, Jessica. 2003. “The Defecating Duck, Or, The Ambiguous Origins of Artificial Life.” *Critical Inquiry* 29: 599–633.
Rizzolatti, Giacomo, and Corrado Sinigaglia. 2008. *Mirrors in the Brain: How Our Minds Share Actions and Emotions*. Translated by Frances Anderson. Oxford: Oxford University Press.
Rockwell, Joti. 2007. “Drive, Lonesomeness, and the Genre of Bluegrass Music.” PhD dissertation, University of Chicago.
———. 2009. “Banjo Transformations and Bluegrass Rhythm.” *Journal of Music Theory* 53: 137–62.
Rodby, Steve. 2008. *Imaginary Day Live*. DVD. Eagle Eye Media.
Rohrer, Tim. 2005. “Image Schemata in the Brain.” In *From Perception to Meaning: Image Schemas in Cognitive Linguistics*, edited by Beate Hampe and Joe Grady, 165–96. Berlin: Mouton de Gruyter.
Rosenwinkel, Kurt. 2007. “The Next Step—2001.” http://www.kurtrosenwinkel.com/archives/144.
Rothstein, Edward. 1991. “Yo-Yo Ma and His New ‘Hyper’ Cello.” *New York Times*, August 17. http://www.nytimes.com/1991/08/17/arts/review-music-yo-yo-ma-and-his-new-hyper-cello.html.

Rover, Christian. 2006. "Kurt Rosenwinkel: From a Guitarist's Perspective." http://www.christianrover.com/Englische%20Seiten/Rosenwinkelengl.html.

Rusconi, Elena, Bonnie Kwan, Bruno L. Giordano, Carlo Umiltà, and Brian Butterworth. 2006. "Spatial Representation of Pitch Height: The SMARC Effect." *Cognition* 99: 113–29.

Sacks, Oliver. 1989. *Seeing Voices: A Journey into the World of the Deaf*. Berkeley: University of California Press.

Saslaw, Janna. 1996. "Forces, Containers, and Paths: The Role of Body-Derived Image Schemas in the Conceptualization of Music." *Journal of Music Theory* 40: 217–43.

Schaeffer, Pierre. 1966. *Traité des objets musicaux*. Paris: Éditions du Seuil.

Schechner, Richard. 2013. *Performance Studies: An Introduction*. 3rd ed. London: Routledge.

Schindler, Anton F. 1841. *The Life of Beethoven*. Translated by Ignace Moscheles. Vol. 2. London: Henry Colburn.

———. 1966. *Beethoven as I Knew Him*. Edited by Donald W. MacArdle. Translated by Constance S. Jolly. Chapel Hill: University of North Carolina Press.

Schulz, Matthias, Bernhard Ross, and Christo Pantev. 2003. "Evidence for Training-Induced Crossmodal Reorganization of Cortical Functions in Trumpet Performance." *NeuroReport* 14: 157–61.

Schutz, Michael, David Huron, Kristopher Keeton, and Greg Loewer. 2008. "The Happy Xylophone: Acoustic Affordances Restrict an Emotional Palate." *Empirical Musicology Review* 3: 126–35.

Schutz, Michael, and Fiona Manning. 2012. "Looking Beyond the Score: The Musical Role of Percussionists' Ancillary Gestures." *Music Theory Online* 18. http://www.mtosmt.org/issues/mto.12.18.1/mto.12.18.1.schutz_manning.html.

Scruton, Roger. 1997. *The Aesthetics of Music*. New York: Oxford University Press.

Sebastian, John. 1992. *Blues Harmonica*. Woodstock, NY: Homespun Tapes.

Senna, Irene, Angelo Maravita, Nadia Bolognini, and Cesare V. Parise. 2014. "The Marble-Hand Illusion." *PLoS ONE* 9: e91688.

Serino, Andrea, Michela Bassolino, Alessandro Farnè, and Elisabetta Làdavas. 2007. "Extended Multisensory Space in Blind Cane Users." *Psychological Science* 18: 642–48.

Serré de Rieux, Jean de. 1734. *Les dons des enfans de Latone: La musique et la chasse du cerf*. Paris: Chés P. Prault. http://openlibrary.org/books/OL24194489M/Les_dons_des_enfanc_de_Latone.

Shaffer, Kris. n.d. "Overtones, Intervals, and Generative Transformations in György Ligeti's Hamburg Concerto." Unpublished manuscript. http://pushpullfork.com/media/ShafferHamburgConcertoPaper.pdf.

Shannon, Claude E. 1964. "The Mathematical Theory of Communication." In *The Mathematical Theory of Communication*, by Claude E. Shannon and Warren Weaver. Urbana: University of Illinois Press.

Sheets-Johnstone, Maxine. 2005. "What Are We Naming?" In *Body Image and Body Schema: Interdisciplinary Perspectives on the Body*, edited by Helena de Preester and Veroniek Knockaert, 211–32. Amsterdam: J. Benjamins.

Shikida, Leonardo K. 2007. "Honest Transcription, But No Style at All." Customer Review. *Amazon.com*. July 18. http://www.amazon.com/review/R2BYL49RBIQ1GA/ref=cm_cr_dp_title?ie=UTF8&ASIN=0825613418&nodeID=283155&store=books.

Sisman, Elaine R. 1993. *Haydn and the Classical Variation*. Studies in the History of Music 5. Cambridge, MA: Harvard University Press.

Solie, Ruth A. 2004. "'Girling' at the Parlor Piano." In *Music in Other Words: Victorian Conversations*, 85–117. Berkeley: University of California Press.

Spicer, Mark. 2011. "(Per)Form In(g) Rock: A Response." *Music Theory Online* 17. http://www.mtosmt.org/issues/mto.11.17.3/mto.11.17.3.spicer.html.

Sporns, Olaf. 2010. *Networks of the Brain*. Cambridge, MA: MIT Press.
Stewart, Lauren, Vincent Walsh, and Uta Frith. 2004. "Reading Music Modifies Spatial Mapping in Pianists." *Perception & Psychophysics* 66: 183–95.
Stiegler, Bernard. 1998. *Technics and Time, 1: The Fault of Epimetheus*. Translated by Richard Beardsworth and George Collins. Stanford, CA: Stanford University Press.
———. 2009. *Technics and Time, 2: Disorientation*. Translated by Stephen Barker. Stanford, CA: Stanford University Press.
———. 2011. *Technics and Time, 3: Cinematic Time and the Question of Malaise*. Translated by Stephen Barker. Stanford, CA: Stanford University Press.
Straus, Joseph N. 2003. "Uniformity, Balance, and Smoothness in Atonal Voice Leading." *Music Theory Spectrum* 25: 305–52.
———. 2011. *Extraordinary Measures: Disability in Music*. New York: Oxford University Press.
Sudnow, David. 1978. *Ways of the Hand: The Organization of Improvised Conduct*. Cambridge, MA: Harvard University Press.
Szendy, Peter. 2016. *Phantom Limbs: On Musical Bodies*. Translated by Will Bishop. New York: Fordham University Press.
Tallis, Raymond. 2003. *The Hand: A Philosophical Inquiry into Human Being*. Edinburgh: Edinburgh University Press.
Taub, Robert. 2002. *Playing the Beethoven Piano Sonatas*. Portland, OR: Amadeus Press.
Taylor, Timothy. 2001. *Strange Sounds: Music, Technology, and Culture*. New York: Routledge.
Temperley, David. 2007. "The Melodic-Harmonic 'Divorce' in Rock." *Popular Music* 26: 323–42.
Thakkar, Katharine N., Heathman S. Nichols, Lindsey G. McIntosh, and Sohee Park. 2011. "Disturbances in Body Ownership in Schizophrenia: Evidence from the Rubber Hand Illusion and Case Study of a Spontaneous Out-of-Body Experience." *PLoS ONE* 6: e27089.
Thayer, Alexander Wheelock. 1967. *Thayer's Life of Beethoven*. Edited by Forbes Elliot. Princeton, NJ: Princeton University Press.
Tresch, John, and Emily I. Dolan. 2013. "Toward a New Organology: Instruments of Music and Science." *Osiris* 28: 278–98.
Tsakiris, Manos, and Patrick Haggard. 2005. "The Rubber Hand Illusion Revisited: Visuotactile Integration and Self-Attribution." *Journal of Experimental Psychology: Human Perception and Performance* 31: 80–91.
Tucker, Mike, and Rob Ellis. 1998. "On the Relations Between Seen Objects and Components of Potential Actions." *Journal of Experimental Psychology: Human Perception and Performance* 24: 830–46.
———. 2001. "The Potentiation of Grasp Types During Visual Object Categorization." *Visual Cognition* 8: 769–800.
———. 2004. "Action Priming by Briefly Presented Objects." *Acta Psychologica* 116: 185–203.
Tuckwell, Barry. 2002. *Horn*. New ed. Yehudi Menuhin Music Guides. London: Kahn & Averill.
Tymoczko, Dmitri. 2011. *A Geometry of Music: Harmony and Counterpoint in the Extended Common Practice*. New York: Oxford University Press.
Varela, Francisco J., Evan Thompson, and Eleanor Rosch. 1991. *The Embodied Mind: Cognitive Science and Human Experience*. Cambridge, MA: MIT Press.
Verbalis, Jon. 2012. *Natural Fingering: A Topographical Approach to Pianism*. New York: Oxford University Press.

Vitale, Alessia Rita. 2008. “The Singing Lesson: Phenomenology of the Non-Verbal Dynamics Appearing in Studying the *Instrument-Voix*.” *Musicae Scientiae*, Special issue: “Narrative in Music and Interaction,” 111–28.

Waksman, Steve. 1999. *Instruments of Desire: The Electric Guitar and the Shaping of Musical Experience*. Cambridge, MA: Harvard University Press.

———. 2001. “Into the Arena: Edward Van Halen and the Cultural Contradictions of the Guitar Hero.” In *Guitar Cultures*, edited by Andy Bennett and Kevin Dawe, 117–34. Oxford: Berg.

Walser, Robert. 1993. *Running with the Devil: Power, Gender, and Madness in Heavy Metal Music*. Hanover, NH: University Press of New England.

Webb, Nicholas. 1985. “Pat Metheny Interview.” *Guitarist*, May. http://www.joness.com/gr300/metheny.htm.

Weber, Samuel. 1989. “Upsetting the Set Up: Remarks on Heidegger’s Questing after Technics.” *Modern Language Notes* 104: 977–92.

Wegman, Rob C. 1996. “From Maker to Composer: Improvisation and Musical Authorship in the Low Countries, 1450–1500.” *Journal of the American Musicological Society* 49: 409–79.

Wenzel, Haik, and Martin Häffner. 2006. *Legende Hohner Harmonika: Mundharmonika und Akkordeon in der Welt der Musik*. Bergkirchen: PPVMedien/Edition Bochinsky.

Wiener, Norbert. 1948. *Cybernetics; Or, Control and Communication in the Animal and the Machine*. New York: John Wiley & Sons.

Williams, Peter. 1981. “BWV565: A Toccata in D Minor for Organ by J. S. Bach?” *Early Music* 9: 330–37.

———. 1994. “Two Case Studies in Performance Practice and the Details of Notation: 2. J. S. Bach and Left-Hand–Right-Hand Distribution.” *Early Music* 22: 101–13.

———. 2004. *The Life of Bach*. Cambridge: Cambridge University Press.

Wiskus, Jessica. 2013. *The Rhythm of Thought: Art, Literature, and Music after Merleau-Ponty*. Chicago: University of Chicago Press.

Witt, Jessica K., and Michael A. Riley. 2014. “Discovering Your Inner Gibson: Reconciling Action-Specific and Ecological Approaches to Perception–Action.” *Psychonomic Bulletin and Review* 21: 1353–70.

Wolff, Christoph. 2000. *Johann Sebastian Bach: The Learned Musician*. New York: W. W. Norton.

Wu, Ling-ling, and Lawrence W. Barsalou. 2009. “Perceptual Simulation in Conceptual Combination: Evidence from Property Generation.” *Acta Psychologica* 132: 173–89.

Yamamoto, Shinya, and Shigeru Kitazawa. 2001. “Sensation at the Tips of Invisible Tools.” *Nature Neuroscience* 4: 979–80.

Yearsley, David. 2002. *Bach and the Meanings of Counterpoint*. Cambridge: Cambridge University Press.

———. 2012. *Bach’s Feet: The Organ Pedals in European Culture*. Cambridge: Cambridge University Press.

Yeh, Wenchi, and Lawrence W. Barsalou. 2006. “The Situated Nature of Concepts.” *American Journal of Psychology* 119: 349–84.

Yin, Henry H., and Barbara J. Knowlton. 2006. “The Role of the Basal Ganglia in Habit Formation.” *Nature Reviews Neuroscience* 7: 464–76.

Yung, Bell. 1984. “Choreographic and Kinesthetic Elements in Performance on the Chinese Seven-String Zither.” *Ethnomusicology* 28: 505–17.

Zanten, Wim van. 1986. “The Tone Material of the Kacapi in Tembang Sunda in West Java.” *Ethnomusicology* 30: 84–112.

Zarlino, Gioseffo. 1588. *Sopplimenti Musicali*. Venice: Francesco dei Franceschi Senese.
Zbikowski, Lawrence M. 2002. *Conceptualizing Music: Cognitive Structure, Theory, and Analysis*. AMS Studies in Music. New York: Oxford University Press.
———. 2010. "Music, Emotion, Analysis." *Music Analysis* 29: 37–60.
Zheng, Zane Z., Ewen N. MacDonald, Kevin G. Munhall, and Ingrid S. Johnsrude. 2011. "Perceiving a Stranger's Voice as Being One's Own: A 'Rubber Voice' Illusion?" *PLoS ONE* 6: e18655.

INDEX