Guitar Thinking

Perspectives from Music Theory and Cognitive Science

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WHAT DO YOU LEARN when you learn to play the guitar? Exercises and scales develop physical skills—for example, the ability to place fingers on the strings, to coordinate both hands, to play the right notes at the right time. Yet this practice is also a kind of ear training. With experience, the budding guitarist becomes aware of differences in chord quality, harmonic progression, meter, and texture. Even simple studies can build understanding of a musical language, whether common-practice tonality in Fernando Sor's études or more modern styles in Leo Brouwer's *Estudios sencillos*. These musicianship skills overlap with those of other instrumentalists. But in other respects, they are shaped by the possibilities and constraints of the guitar itself. Ultimately, you start to think like a guitarist. You start to conceptualize music—to know it, imagine it, or experience it—in new ways. The guitar, then, is not just a tool for making sounds. As it coordinates body, ear, and mind, the instrument also becomes a tool for musical thinking.

In my view, "musical thinking" is another name for music theory. That is, music theory is just a shared culture of musical thinking.[1] At a basic level, you can learn music theory through the guitar. But if the guitar can change how we think about and what we know about music, it can also change music theory itself. For example, consider baroque music for the Spanish-style guitar. *Rasgueado* dances such as the *folia*, *chacona*, and *zarabanda* were popular throughout seventeenth-century Europe. While keyboardists at the time thought more contrapuntally, strumming guitarists treated triads as objects. Perhaps surprisingly, a central construct of Western music theory first emerged from this tradition: the musical circle. The earliest circle of fifths was published in *Guitarra española* (1596) by Joan Carles Amat, a Catalonian physician and amateur guitarist. **Figure 1** reproduces Amat's circle, while **figure 2** provides a transcription by Thomas Christensen. The notes and letters within the grid are tablature for a five-course guitar, indicating chord shapes that are still common today. The top half of the diagram cycles through major triads, starting with E major on the far left; the bottom, minor triads, with E minor on the far right. Christensen

1 Lawrence M. Zbikowski, *Conceptualizing Music: Cognitive Structure, Theory, and Analysis*, AMS Studies in Music (New York: Oxford University Press, 2002), 106–19.

Figure 1 Circle of fifths in tablature from Joan Carles Amat, *Guitarra española* (1596).

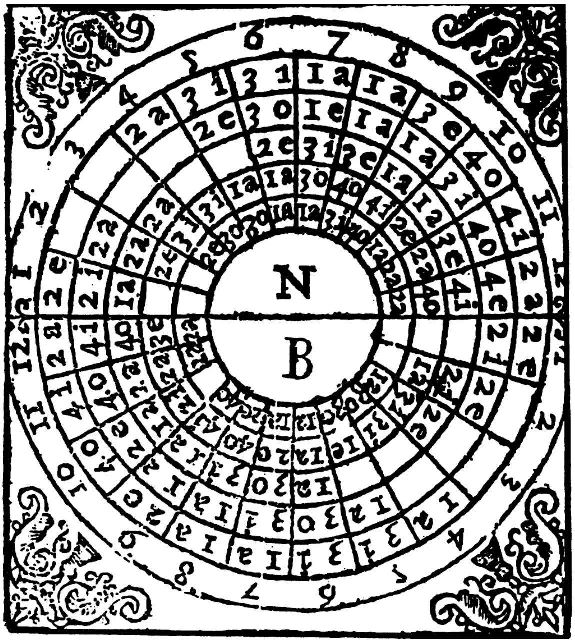


Figure 2 Transcription of Amat's musical circle (from Christensen, "The Spanish Baroque Guitar and Seventeenth-Century Triadic Theory," example 4).

has argued that Amat's manual and others "stake out a distinct theoretical perspective, one that was instinctively understood and more widely practiced by musicians of the time than the theory depicted in the learned, weighty tomes of their scholastic counterparts."[2] This perspective was grounded in guitar practice, but its implications went much further:

2 Thomas Christensen, "The Spanish Baroque Guitar and Seventeenth-Century Triadic Theory," *Journal of Music Theory* 36, no. 1 (1992): 11. Collections of lute pieces that explore all twenty-four major and minor keys also emerged around this time, facilitated by the fretboard and tablature (see Megan Kaes Long, "What Do Signatures Signify? The Curious Case of Seventeenth-Century English Key," *Journal of Music Theory* 64, no. 2 [2020]: 147–48, https://doi.org/10.1215/00222909-8550771).

> As unpretentious as *rasgueado* music was, its theoretical implications were profound: music was now conceived and taught as consisting of *chordal entities* that were self-sufficient and combinable in permutations independent of contrapuntal or modal control. Amat describes chords as "raw material" for the guitarist, comparable to "the colors of the painter, with which one can mix in any way and in whatever key, jumping from one to the other."[3]

The guitar's chordal possibilities, then, supported distinctive modes of musical thought, anticipating the chord-based tonal theory that would take hold later. Similarly, a set of instructional materials by the jazz guitarist Pat Martino, titled *The Nature of the Guitar*, anticipated ideas about chromatic harmony from contemporary music theory.[4] Where neo-Riemannian theory uses mathematics to model systematic relationships among triads, Martino started from fretboard shapes. In such cases, the guitar can be understood as a tool for musical thinking, an "instrument of music theory."[5]

More recently, guitars and guitar thinking have become objects of inquiry in music theory and cognitive science. This reflects a broader trend in academic music research. Traditionally, music has often been imagined as a form of text.[6] This view treated the performer as a relatively passive intermediary between composer and audience, whose duty was to faithfully realize musical works, without adding to them. By contrast, many twenty-first-century scholars insist that music is performance and that scores are best understood as scripts or recipes for performance.[7] Performance studies in music are highly interdisciplinary, drawing on anthropological, historical, and psychological methods, among others. They also develop dialogues between music analysts and performers.[8] More generally, this research can reveal distinctive aspects of instrumental thinking. So, how does guitar playing fit into this discourse? This article will examine several performance-based analyses of guitar music, culminating in analytical sketches for two of Brouwer's études. First, however, let's begin with broader cognitive and theoretical perspectives on guitar thinking.

3 Christensen, 8.

4 Guy Capuzzo, "Pat Martino's *The Nature of the Guitar*: An Intersection of Jazz Theory and Neo-Riemannian Theory," *Music Theory Online* 12, no. 1 (2006), http://www.mtosmt.org/issues/mto.06.12.1/mto.06.12.1.capuzzo.pdf.

5 Alexander Rehding, "Instruments of Music Theory," *Music Theory Online* 22, no. 4 (2016), http://mtosmt.org/issues/mto.16.22.4/mto.16.22.4.rehding.html.

6 Nicholas Cook, *Beyond the Score: Music as Performance* (New York: Oxford University Press, 2013).

7 For example, see Jonathan Dunsby, *Performing Music: Shared Concerns* (Oxford: Oxford University Press, 1995); Christopher Small, *Musicking: The Meanings of Performing and Listening* (Middletown, CT: Wesleyan University Press, 1998); John Rink, ed., *Musical Performance: A Guide to Understanding* (Cambridge: Cambridge University Press, 2002).

8 Daphne Leong, *Performing Knowledge: Twentieth-Century Music in Analysis and Performance*, Oxford Studies in Music Theory (New York: Oxford University Press, 2019).

Guitar Psychology

For performers, music is not only a sonic phenomenon; music involves both sound and action. Instrumental practice develops particular, two-way connections between auditory and motor domains. Because of this, an expert guitarist might imaginatively "hear" the chords in handshapes made away from the instrument. Conversely, the guitarist might imaginatively "feel" performative gestures while listening to guitar music. These links between the ears and the hands often color musicians' experiences. But they are also evident in neuroscientific studies that show learned patterns of auditory-motor coactivation in instrumentalists' brains. When listening to music for one's instrument, there is activity in motor areas (even if the player stays still); when making performative gestures, there is activity in auditory areas (even when no music can be heard).[9] These neural connections, produced by extensive training, help to explain how instrumentalists come to hear movements and feel sounds.

Yet, as I argue in my book *Music at Hand*, this process depends on instruments.[10] If instruments do not consistently link action and sound, this multisensory coupling does not emerge. An experiment by Marc Bangert and Eckart Altenmüller demonstrates this nicely.[11] In the study, participants without prior musical training received ten weeks of piano lessons. One group played a regular keyboard; the other played a randomized keyboard, where pitch locations frequently changed. Neuroimaging showed that the first group quickly developed patterns of auditory-motor coactivation, which resembled the brain activity of expert pianists. With the random-keyboard group, however, these associations never developed, despite weeks of practice. The link between ear and hand, then, requires an instrument with stable affordances.

9 Marc Bangert, Udo Haeusler, and Eckart Altenmüller, "On Practice: How the Brain Connects Piano Keys and Piano Sounds," *Annals of the New York Academy of Sciences* 930 (June 1, 2001): 425–28, https://doi.org/10.1111/j.1749-6632.2001.tb05760.x; Jens Haueisen and Thomas R. Knösche, "Involuntary Motor Activity in Pianists Evoked by Music Perception," *Journal of Cognitive Neuroscience* 13, no. 6 (2001): 786–92, https://doi.org/10.1162/08989290152541449; Martin Lotze, Gabriele Scheler, Heng-Ru May Tan, Christoph Braun, and Niels Birbaumer, "The Musician's Brain: Functional Imaging of Amateurs and Professionals During Performance and Imagery," *NeuroImage* 20, no. 3 (2003): 1817–29, https://doi.org/10.1016/j.neuroimage.2003.07.018; Ulrich C. Drost et al., "Action-Effect Coupling in Pianists," Psychological Research 69, no. 4 (2005): 233–41, https://doi.org/10.1007/s00426-004-0175-8; Amir Lahav et al., "The Power of Listening: Auditory-Motor Interactions in Musical Training," *Annals of the New York Academy of Sciences* 1060, no. 1 (December 1, 2005): 189–94, https://doi.org/10.1196/annals.1360.042; Elizabeth Hellmuth Margulis et al., "Selective Neurophysiologic Responses to Music in Instrumentalists with Different Listening Biographies," *Human Brain Mapping* 30, no. 1 (2009): 267–75, https://doi.org/10.1002/hbm.20503; Joyce L. Chen, Charlotte Rae, and Kate E. Watkins, "Learning to Play a Melody: An FMRI Study Examining the Formation of Auditory-Motor Associations," *Neuroimage*, 2011, https://doi.org/10.1016/j.neuroimage.2011.08.012.

10 Jonathan De Souza, *Music at Hand: Instruments, Bodies, and Cognition*, Oxford Studies in Music Theory (New York: Oxford University Press, 2017).

11 Marc Bangert and Eckart O. Altenmüller, "Mapping Perception to Action in Piano Practice: A Longitudinal DC-EEG Study," *BMC Neuroscience* 4 (2003): 26, https://doi.org/10.1186/1471-2202-4-26.

The term *affordance* comes from J. J. Gibson, the founder of ecological psychology.[12] An object's affordances are its possibilities for action. For example, a guitar affords playing, and a chair affords sitting. Of course, they have other affordances too: I could also stand on the chair, use it to prop up my sheet music, and so forth. All of these possibilities depend on the object's properties and also my abilities. The chair does not afford sitting for a newborn baby, and the guitar is not playable for a goldfish. Affordances, then, are fundamentally relational. Some affordances are based on physics, while others are culturally or technologically produced. The guitar affords harmonics at particular locations, which are determined by the behavior of vibrating strings. Guitar tuning is fairly regular too, but this relies on convention rather than nature. Either way, these affordances are relatively predictable. When the string gets shorter or tighter, its pitch gets higher. Such invariance grounds perception of affordances and is essential for instrumental expertise.

In another experiment, Ulrich C. Drost, Martina Rieger, and Wolfgang Prinz investigated expert musicians' relation to instrumental affordances.[13] Guitarists were shown an onscreen prompt—"A" or "Am"—and were asked to finger the corresponding chord on a guitar fretboard. When they saw the prompt, they also heard a chord that might or might not match the chord symbol. When a mismatched chord had the timbre of a piano, organ, flute, or voice, it did not significantly affect participants' response time. But when the mismatched chord sounded like a guitar, they were significantly slower to respond. When these researchers did the same experiment with pianists, the participants' performance was compromised by piano and organ sounds. This suggests that pianists were responding not only to a familiar timbre but to the affordances of the keyboard in general. In both cases, musicians were able to ignore distractor sounds that were made by instruments that they did not play. They had a distinctive connection to music for their own instrument, which the researchers described in terms of affordances.

That study used familiar chord shapes, and familiarity is important here. Keith Phillips, Andrew Goldman, and Tyreek Jackson have examined this by using altered auditory feedback.[14] Studies with altered auditory feedback are well established in music psychology, but previous research in this area has focused on the piano.[15] Phillips and colleagues, by contrast, used chord shapes on the guitar. Guitarists would play two versions of the same voicing—one with a familiar shape and one

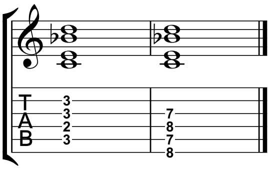
12 James J. Gibson, "The Theory of Affordances," in *Perceiving, Acting, and Knowing: Toward an Ecological Psychology*, ed. Robert Shaw and John Bransford (Hillsdale, NJ: Erlbaum, 1979), 67–82.

13 Ulrich C. Drost, Martina Rieger, and Wolfgang Prinz, "Instrument Specificity in Experienced Musicians," *Quarterly Journal of Experimental Psychology* 60, no. 4 (2007): 527–33, https://doi.org/10.1080/17470210601154388.

14 Keith Phillips, Andrew Goldman, and Tyreek Jackson, "Hand Shape Familiarity Affects Guitarists' Perception of Sonic Congruence," *Auditory Perception & Cognition* 2, nos. 1–2 (2019): 82–97, https://doi.org/10.1080/25742442.2019.1684164.

15 For research on altered auditory feedback, see Peter Q. Pfordresher, *Sound and Action in Music Performance* (Cambridge, MA: Academic Press, 2019).

Figure 3 Familiar and less familiar fretboard shapes for the same voicing of a C9 chord (from Phillips, Goldman, and Jackson, "Hand Shape Familiarity Affects Guitarists' Perception of Sonic Congruence").



with a relatively unfamiliar shape.[16] **Figure 3** presents two chord shapes from the study. As the notation above the tablature indicates, they produce the same pitches, but the first version is more familiar for most players. In half of the trials, the auditory feedback was altered, so the participants did not hear the exact chord that they were playing. They found it much easier to identify this mismatch between sound and action when the chord shape was familiar. This suggests that some chord shapes had stronger perception-action coupling than others, that less familiar chord shapes are not as closely associated with an auditory image. So, style and habit are important for auditory-motor coupling. A classical guitarist, a rock guitarist, and a jazz guitarist will share some knowledge of their common instrument, but their know-how will not be identical. Instrumental expertise is shaped by a specific cultural context.

Guitarists experience chord shapes in terms of physical action or feel, as well as sound. But hand shapes on the fretboard are also visible.[17] Visual associations are often tested via a Stroop task. The classic Stroop task involves words, written in color. Participants are supposed to ignore the words and name the color, but this is difficult when the words spell out other color names (e.g., when the word "red" is written in blue). The paradigm has been expanded in many ways: for example, in one Stroop-like sight-reading task, pianists find it almost impossible to ignore nonsensical finger markings in their music.[18] Matthew J. C. Crump, Gordon D. Logan, and Jerry Kimbrough used a similar approach to study visual aspects of guitarists' expertise.[19] They focused on common CAGED-system chords, which were visually represented with photographs of a guitarist's hand on the fretboard. These photographs were

16 James Renwick has systematically investigated fretboard shapes that produce the same voicing (see James Renwick, "Pitch, Voicings, and Fretboard Transformations in Tōru Takemitsu's 'Rosedale'" [presentation, Annual Meeting of the Society for Music Theory, November 7, 2021]).

17 Of course, vision plays many roles in guitar performance. For example, expert guitarists often look ahead to fretboard locations (before moving or placing the left hand), or speak of visual patterns for chords or scales "lighting up" on the fretboard. Amy Brandon and David Westwood, "How the Guitar Shapes Us," part 1, *Soundboard* 45, no. 1 (2019): 40.

18 Lauren Stewart, Vincent Walsh, and Uta Frith, "Reading Music Modifies Spatial Mapping in Pianists," *Perception & Psychophysics* 66 (2004): 183–95.

19 Matthew J. C. Crump, Gordon D. Logan, and Jerry Kimbrough, "Keeping an Eye on Guitar Skill: Visual Representations of Guitar Chords," *Music Perception: An Interdisciplinary Journal* 30, no. 1 (2012): 37–47.

combined with sounds to create congruent or incongruent pairs. The pairs were presented in the experiment, and guitarist and non-guitarist participants were asked to identify the visual or auditory information as quickly as possible. Once again, the guitarists were unable fully to ignore the incongruent pairs, and their response time was significantly slower for them. This demonstrates visual aspects of guitar knowledge and indicates that the instrument-based connection between sight, sound, and action is automatic. Because of this (and because guitar lessons typically involve watching and imitating others), cognitive neuroscientists have also used guitar learning to investigate mirror neurons and the brain's action-observation network.[20]

To play an instrument, then, a musician must recognize its sound-making affordances. And these affordances expand as a player develops new bodily skills and neural connections. This also supports distinctive perceptual habits, different ways of knowing. Musical instruments, then, are not just tools for making sound. They are also cognitive tools or "epistemic tools," which produce musical knowledge.

Fretboard Theory

Like psychologists, music theorists have begun to consider guitar playing. Traditionally, theory has examined various musical objects, from individual pitch classes to intervals to harmonic progressions to large-scale formal templates. And across these different levels, it has typically valued abstraction. This approach has produced many useful insights, and some degree of abstraction is needed to draw connections between different moments or pieces. Abstract theoretical models tend to downplay performance, yet they might still rely on instrumental knowledge. Arguably, they have implicitly privileged the piano: they imagine pitch space in terms of a keyboard, where each note appears in a single place, ordered in terms of a single dimension, where the natural notes of C major form a referential collection (and other notes require accidentals), where the repeating structure of every octave highlights pitch-class relations.[21] The fretboard, by contrast, presents a very different kind of space, and this has proved useful for scholars who wish to consider how musical organization might be conditioned by players' bodies and musical instruments.

Already in the early 1990s, the ethnomusicologists John Baily and Peter Driver used guitar playing to investigate musical structure and human movement. They considered the fretboard as "a framework within which actions are planned and executed."[22]

20 Giovanni Buccino et al., "Neural Circuits Underlying Imitation Learning of Hand Actions: An Event-Related FMRI Study," *Neuron* 42, no. 2 (April 22, 2004): 323–34, https://doi.org/10.1016/S0896-6273(04)00181-3; Tom Gardner, Aidas Aglinskas, and Emily S. Cross, "Using Guitar Learning to Probe the Action Observation Network's Response to Visuomotor Familiarity," *NeuroImage* 156 (August 1, 2017): 174–89, https://doi.org/10.1016/j.neuroimage.2017.04.060.

21 Alexander Rehding, "Three Music-Theory Lessons," *Journal of the Royal Musical Association* 141, no. 2 (2016): 251–82.

22 John Baily and Peter Driver, "Spatio-Motor Thinking in Playing Folk Blues Guitar," *World of Music* 34, no. 3 (1992): 61.

While their main examples came from folk-blues and rock, they were thinking about fretboard space in general, and this article built on Baily's earlier research on long-necked lutes in Afghanistan. For Baily, the guitar, with its six adjacent strings, forms a "tiered array."[23] On the guitar, the Afghan rebab, or many other instruments, the fretting hand can move along the strings or across them. The fretboard, then, has two basic dimensions, and music for it often reveals a "kind of spatial logic."[24]

This line of thinking was taken up by music theorists in the twenty-first century. Where Baily and Driver theorized the fretboard's dimensionality, Timothy Koozin examined guitarists' hand shapes. He developed a new theoretical construct—the "fret-interval type"—as "a measure of fretboard hand position."[25] Each fret-interval type is a vector with six values, ordered by string number (from 6 to 1). For example, <133211> indicates the standard shape for an F-major barre chord. It's important to note that the numbers in the vector refer to relative fret positions, so that 1 represents the lowest position in the shape, not the first fret. As Koozin explained, "this is like a guitar chord tab, with fret numberings reduced by the factor that will represent the lower boundary or barre as 1."[26] In other words, the fret-interval type <133211> stands not only for an F barre chord but also for any barre chord with that shape. Koozin also used the fret-interval type melodically, to represent common scalar shapes. This theoretical tool adds a performance-based element to Koozin's analyses, which consider hand shapes alongside tonal progressions, lyrics, and other musical features.

While the fretting hand forms melodic or chordal shapes on the fretboard, the picking or plucking hand typically activates the sound. Joti Rockwell analyzed fingerpicking patterns in an article on bluegrass banjo.[27] To do so, he connected banjo performance to transformational theory. Before discussing Rockwell's analysis, then, let me offer a brief introduction to this music-analytical method.

Transformational theory was developed by David Lewin in the 1980s.[28] It models various musical "spaces," and also moves or shapes within them. These spaces might involve pitches and pitch classes, chords or tone rows—but also rhythmic patterns, the arrangement of parts in invertible counterpoint, timbres, or other musical elements. Each of these spaces, however, will be represented by a mathematical group.

23 John Baily, "Movement Patterns in Playing the Herati Dutar," in *The Anthropology of the Body*, ed. John Blacking (London and New York: Academic Press, 1977), 310.

24 John Baily and Peter Driver, "Spatio-Motor Thinking in Playing Folk Blues Guitar," *World of Music* 34 (1992): 67.

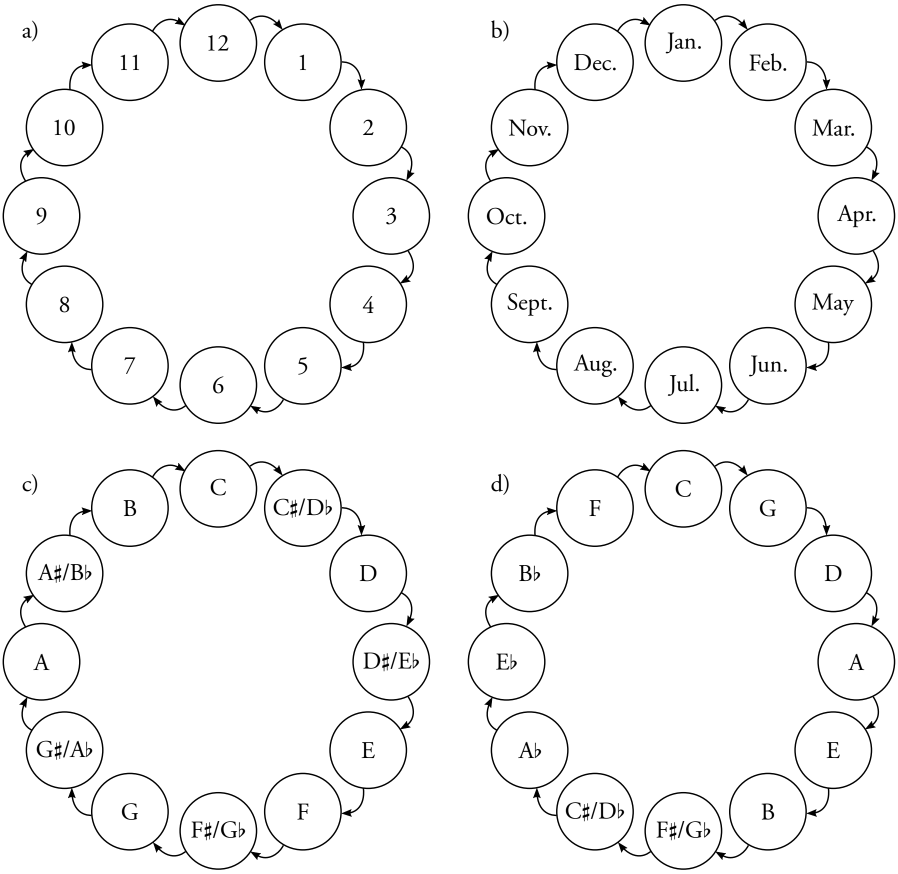
25 Timothy Koozin, "Guitar Voicing in Pop-Rock Music: A Performance-Based Analytical Approach," *Music Theory Online* 17, no. 3 (2011): para. 2, http://www.mtosmt.org/issues/mto.11.17.3/mto.11.17.3.koozin.html.

26 Ibid.

27 Joti Rockwell, "Banjo Transformations and Bluegrass Rhythm," *Journal of Music Theory* 53, no. 1 (2009): 137–62.

28 David Lewin, *Generalized Musical Intervals and Transformations* (New Haven: Yale University Press, 1987). For accessible introductions, see Ramon Satyendra, "An Informal Introduction to Some Formal Concepts from Lewin's Transformational Theory," *Journal of Music Theory* 48, no. 1 (2004): 99–141, https://doi.org/10.1215/00222909-48-1-99; Steven Rings, *Tonality and Transformation*, Oxford Studies in Music Theory (New York and Oxford: Oxford University Press, 2011), chap. 1.

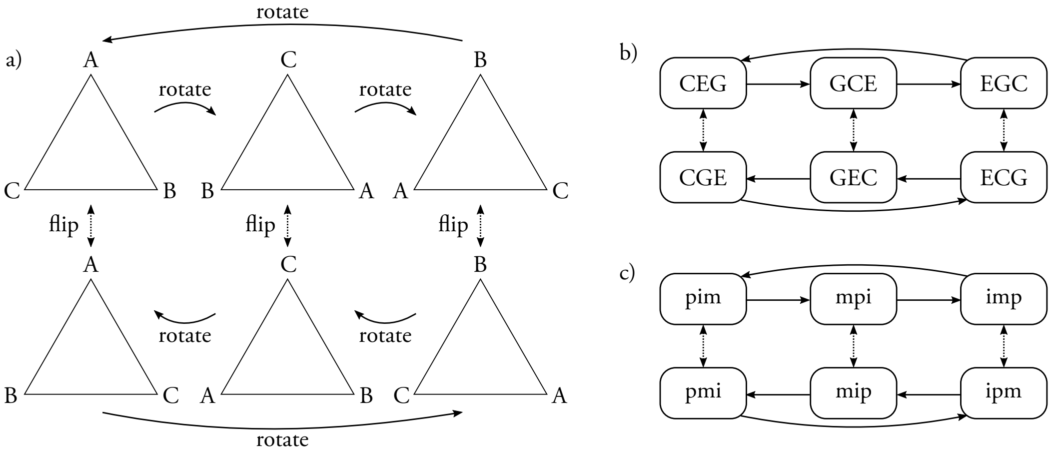
Figure 4 A cyclic group with twelve elements can model (a) the hours on a clockface, (b) the months of the year, (c) the chromatic scale, or (d) the cycle of fifths.



At a basic level, a mathematical group involves a set of related elements. For example, the numbers on a clockface form a group with twelve elements. This same group can be used to model the months of the year, the pitch classes of the chromatic scale, or the cycle of fifths. Figure 4 visualizes these spaces through transformation networks, where each node includes an element, and each arrow represents a relation. If you start at any element and move, say, "two steps clockwise," you will find yourself at another element in the group. That move can be repeated or combined with other moves: "two steps clockwise" plus "one step clockwise" takes you to the same place as "three steps clockwise." The move can also be reversed, so that "two steps counter-clockwise" takes you back to your starting point. Importantly, transformations do not only apply to individual elements. They can also affect sets or shapes with multiple elements. As Lewin puts it, transformations let you change one gestalt into another gestalt "as regards content, or location, or anything else."[29] Though this method of analysis is

29 David Lewin, *Generalized Musical Intervals and Transformations* (New Haven: Yale University Press, 1987), 159.

Figure 5 The rotations and flips of an equilateral triangle (a) also form a mathematical group, which corresponds to the permutations of a triad (b) and banjo fingerpicking patterns (c).



highly formalized, Lewin wanted to cultivate a view from "inside" the music, taking a performer's perspective.[30]

Bluegrass banjo picking uses the thumb and two fingers, and this is reflected in the group that underlies Rockwell's analysis. **Figure 5a** imagines this group in terms of a triangle with equal sides. If you always keep one corner pointing up, there are six different ways of placing the triangle. The arrows in the figure show how these positions relate to each other by rotating and flipping. This group has been used to analyze triadic permutations (as in **figure 5b**), chromatic chord progressions, and invertible counterpoint in J. S. Bach's three-part sinfonias.[31] Yet, as Rockwell showed, these triangles also correspond to the three-finger "rolls" that are foundational to bluegrass banjo picking, such as the forward roll (p, i, m) and the backward roll (m, i, p) (see **figure 4c**). He analyzed these physical patterns and considered how they create cross rhythms—groups of three eighth notes within common time, which create syncopation—and contribute to a sense of drive.

Related fingerpicking patterns can be found in classical guitar repertoire. **Figure 6** presents the opening of Sor's Étude in E minor, op. 6, no. 11. Here Andrés Segovia's edition indicates a repeating cycle, involving the index, middle, and ring fingers (although Sor himself likely played this pattern with thumb, index, and middle fingers).[32] The triplets fit the metrical structure, unlike the cross rhythms that Rockwell analyzes.

30 For discussion of theory and performance, see David Lewin, "Music Theory, Phenomenology, and Modes of Perception," *Music Perception* 3 (1986): 327–92.

31 Daniel Harrison, "Some Group Properties of Triple Counterpoint and Their Influence on Compositions by J. S. Bach," *Journal of Music Theory* 32 (1988): 23–49; De Souza, *Music at Hand*, chap. 5.

32 On Sor's fingering, see David Tanenbaum, *The Essential Studies: Fernando Sor's 20 Estudios* (San Francisco: Guitar Solo, 1991, 52.

Yet the finger cycle does not necessarily begin on the beat. It is possible to imagine this as an (a, i, m) cycle, starting on the second beat. But it can also be imagined as a kind of forward roll, a repeating (i, m, a) cycle. This physical cycle would start just after each beat, on the second triplet, and lead into the next beat (much as the melody's first three notes lead to the E on the downbeat of m. 2). In this way, the performative pattern might again subtly push against the meter and contribute to a certain sense of forward motion or drive. Similarly, in the second section of Benjamin Britten's *Nocturnal after John Dowland*, op. 70, Julian Bream's fingering begins with a three-finger cycle (a, i, p) that resembles the backward roll (see **figure 7**). Here, at the last note of m. 1, the fingers reverse: the thumb, which previously came before the ring finger, now comes after it (a, p). Of course, where banjo players typically use three fingers, guitarists typically use four. With this in mind, Nathan Smith has recently extended Rockwell's transformational model by using a larger four-element group to represent finger patterns.[33] For example, this allows for formal analysis of the right hand in Brouwer's sixth simple study. The étude's opening appears in **figure 8**. In mm. 1–22, (p, a, m, i) is always followed by two (a, m, i, p)s. Note that the first group (p, a, m, i) is a rotation of the second (a, m, i, p), and the second is a kind of four-finger backwards roll.

In Brouwer's study, the order of the right-hand fingers initially corresponds to the notes' order in pitch space. The thumb plays the lowest note, and so on. In mm. 13–14, however, the index finger plays a note that is higher than the middle finger's note. (This foreshadows the relation between plucking and pitch contour in mm. 23–30, where the meter shifts from 3/4 to 2/4 and the (p, a, m, i) motion continues throughout.) Similarly, in Britten's opening, the highest string in the passage plays the middle note, so that the descending contour in finger space or cross-string space corresponds to a wavelike melodic shape. Again, this is possible because of the guitar's affordances, because of the structure of its musical space.

My 2018 article "Fretboard Transformations" examined the instrument as a musical space and analyzed shapes within it.[34] This theoretical model does not analyze pitches directly. After all, many pitches can be played in multiple places on the fretboard, and their locations can change with altered tuning.[35] And, as the Britten example in **figure 7** shows, lower notes can appear on higher strings (and vice versa). Instead, I focused on fretboard locations. Every spot on the fretboard can be represented by a pair of numbers, where the first number labels the fret and the second number

33 Nathan Smith, "Formalizing the Fretboard's Phantasmic Fingers" (presentation, The 21st-Century Guitar Conference, Universidade Nova de Lisboa, Portugal, March 24, 2021), http://www.21cguitar.com/livestream.

34 Jonathan De Souza, "Fretboard Transformations," *Journal of Music Theory* 62, no. 1 (2018): 1–39.

35 With unfamiliar altered tunings, fretboard locations might be more salient than pitches. For example, as I've discussed elsewhere, the jazz guitarist Kurt Rosenwinkel disrupts his habits by using unusual tunings, so he does not consciously know what the notes are (De Souza, *Music at Hand*, chap. 4; see also Jonathan De Souza, "Instrumental Transformations in Heinrich Biber's Mystery Sonatas," *Music Theory Online* 26, no. 4 [2020], https://doi.org/10.30535/mto.26.4.1).

Figure 6 Fernando Sor, Étude in E minor, op. 6, no. 11, mm. 1–2, edited by Andrés Segovia.

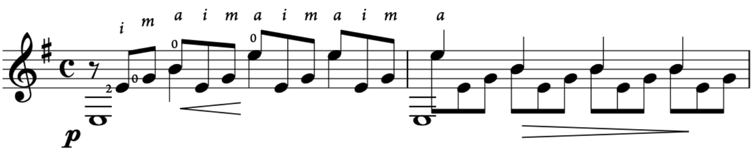


Figure 7 Benjamin Britten, *Nocturnal after John Dowland*, op. 70 (1963), second movement, mm. 1–2.

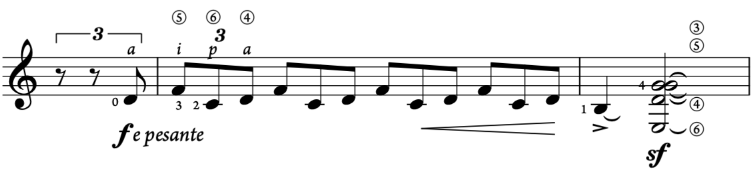
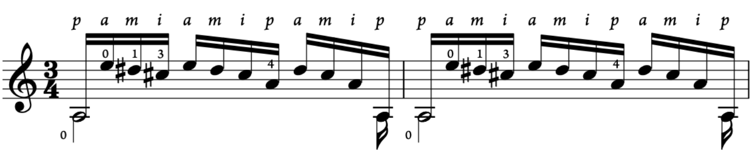


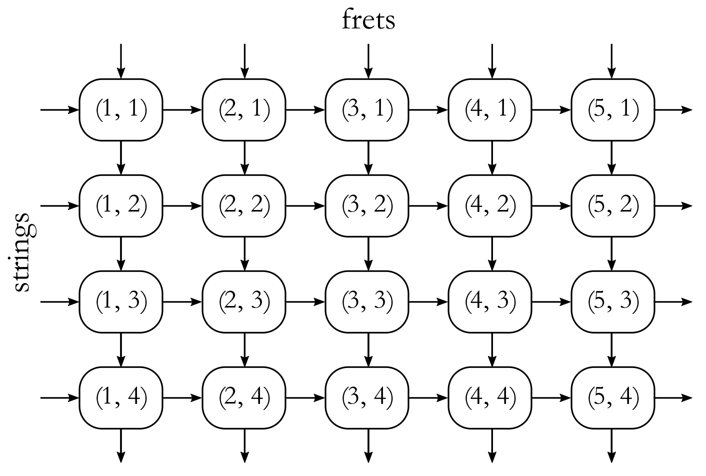
Figure 8 Leo Brouwer, *Estudios Sencillos*, no. 6 (1972), mm. 1–2.



labels the string. For example, the second note in that Britten example appears at the eighth fret on the fifth string, (8, 5). The subsequent note is at the eighth fret on the sixth string, (8, 6). The transformation (0, +1) takes one to the other, staying at the same fret but moving down one string. **Figure 9** maps the underlying space here, which resembles a Cartesian plane with *x*, *y* coordinates. Its two dimensions, already identified by Baily and Driver, allow for movement along and across the strings.

My transformational model offers new ways to measure distances in fretboard space. Nicholas Shea used this in a recent corpus study of pop-rock guitar music. Corpus analysis is increasingly common in twenty-first-century music theory. Instead of analyzing individual pieces or performances, it engages a larger body (i.e., "corpus") of works. This can reveal stylistic norms and statistically significant trends. Shea analyzed nearly five hundred pop and rock songs from 1954 to 2019. One of his key questions involved fretboard space and musical form. In guitar music, a formal section might be associated with a particular zone on the fretboard. In such cases, the transitional move that sets up a new section might be larger than the moves within a section. Of course, this might also involve a change in register. So, are formal transitions predicted by fret distances, pitch distances, or both? In Shea's statistical analysis, both fret distances and pitch distances were highly significant, yet the fret

Figure 9 Any point on the fretboard can be labeled with a fret number and string number, which creates a two-dimensional space.



distances had a larger effect. These results suggest that "performative transitions on an instrument potentially have greater bearing on formal organization and segmentation than pitch data."[36] This supports Shea's broader argument that the structure of pop-rock music is influenced by the affordances of the guitar.

Transformational theory also goes beyond measurements. It is possible to transpose fretboard shapes along or across the strings (as discussed in my analysis of Eddie Van Halen's solo piece, "Cathedral").[37] It is also possible to invert fretboard shapes in either dimension. For example, common fretboard shapes for D and D7 are related by along-string inversion. But the possibilities for transforming shapes are endless. For example, custom transformations have been used to analyze pivoting gestures by the jazz guitarist Kurt Rosenwinkel and expanding/contracting gestures in a mandolin part by Mark O'Connor.[38] New fretboard transformations can be created as needed, to change one gestalt into another.

As an example, let's return to Joan Carles Amat's musical circle from *Guitarra española*. On an abstract level, it corresponds to a series of major and then minor triads, related by falling perfect fifths. Yet it also enacts a transformational process involving fretboard shapes. Every shape involves all five courses of the baroque guitar. **Figures 10a** and **10b** show two ways of representing this transformation. For convenience, we can call it "J" (transformations can be labeled with letters or names, and in this case, "J" might stand for Joan). With this transformation J, most fret positions move to the next highest string. The fret on the highest string wraps around to the lowest, and this is shown by a dotted arrow in the figure. At the same time, when the

36 Nicholas J. Shea, "Ecological Models of Musical Structure in Pop-Rock, 1950–2019" (ProQuest Dissertations, 2020), 122, https://search.proquest.com/docview/2489204736.

37 Van Halen's "Cathedral" is a canon for electric guitar and delay pedal. See De Souza, "Fretboard Transformations," 16–25.

38 See De Souza, *Music at Hand*, 88–97; "Fretboard Transformations," 31–35.

fret on the third string moves to the second string, it increases by one (to account for the major third between those strings). The figure shows this departure with a dashed arrow. Overall, then, the fretboard shape nearly rotates in across-string space.[39] The J transformation accounts for every transition in the top and bottom half of figure 1. Amat applies this transformational process to two familiar chord shapes for E major and E minor (see **figures 10c** and **10d**, respectively). But in principle, any fretboard shape could serve as a starting point.[40] For example, **figure 10e** launches the same process from the dominant seventh E7. Because each iteration of J increases a single fret position by one, the entire shape is transposed up one fret along the string after five repetitions (e.g., $J^5 = (+1, 0)$). From this point onward, all of the open strings will have disappeared, and the remaining voicings will repeat the first five shapes as barré chords. After eleven iterations, every triad has been presented once (and because the fretboard positions are not marked with sharps or flats, there is no spot where enharmonic equivalence is explicitly invoked). The twelfth step in the process would return to E but with a different voicing.[41] Of course, this process could continue indefinitely, creeping up the fretboard. Ultimately, Amat's diagram reveals a dual awareness involving sounding chords and also interrelated fretboard shapes—a kind of awareness that is still familiar to guitarists more than four centuries later. And while earlier music theorists might have focused on the harmonic aspects of Amat's groundbreaking musical cycle, music theorists today are increasingly curious about its guitaristic features too.

Two Simple Studies

For a final case study, let's return to Brouwer's *Simple Studies*. "It's not the music which is simple," the composer explains. "I always have a complicated harmony or meaning or lines or broken figures in the music, which is not simple. What is simple is the way to play. Simplicity for fingers; complexity for ear."[42] The pieces are complex for the

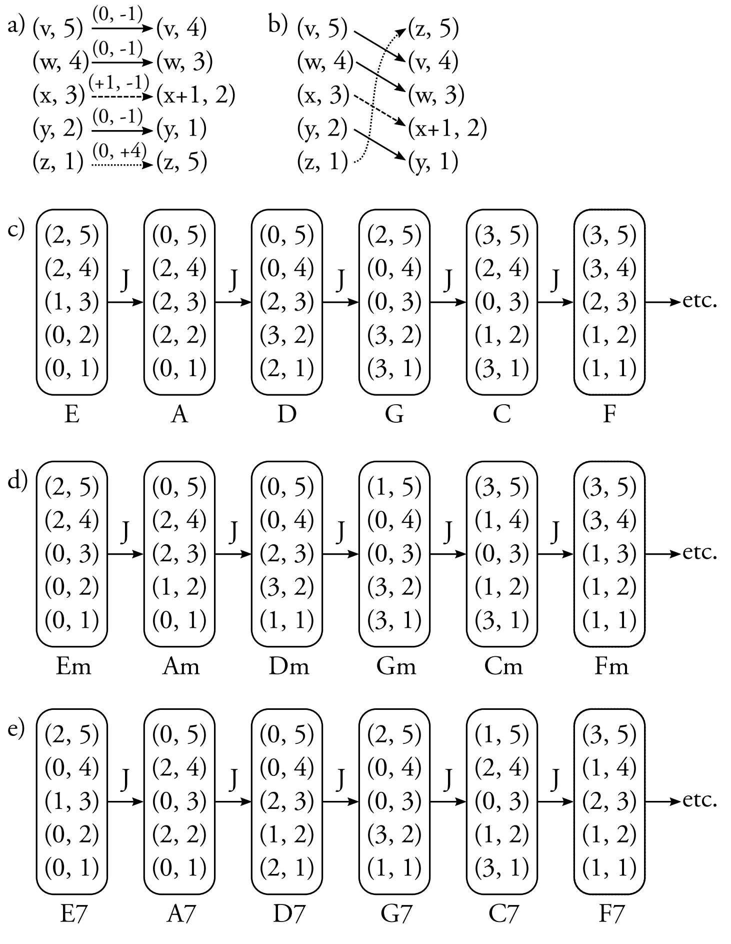
39 In "Fretboard Transformations" (7n9), I doubted the value of a rotational perspective on the fretboard. Thanks to Mark Simos for a conversation that helped me to change my mind.

40 At the same time, Amat's starting point is not arbitrary. This becomes clear when we reverse the process. To undo the transformation J, the shape would rotate from higher to lower strings, and the fret value that goes from the second to third strings would decrease by 1. Mathematically, this inverse of J would be labeled with a negative exponent, J^{-1}. When J^{-1} is applied to either major or minor starting chords, the open B string moves to fret −1 on the G sstring! Obviously, this fretboard shape is unplayable, even though it's theoretically conceivable.

41 My transformational model can help us answer various theoretical questions about this process. For example, when will E reappear with a higher version of the first shape? Remembering that $J^5 = (+1, 0)$, we can calculate the answer: $(+12, 0) = J^{60}$. To take the original shape up an octave (twelve frets), Amat's transformation must be repeated sixty times. That is, the original shape for E won't reappear until all twelve triads have taken all five fretboard shapes (12 triads × 5 shapes = 60).

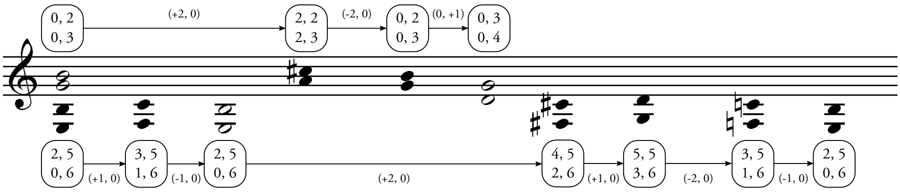
42 Leo Brouwer, "Leo Brouwer Teaches 'Estudios Sencillos,'" YouTube video, *Tonebase Guitar*, December 2, 2018, https://youtu.be/2IWN8NWflZA.

Figure 10 The transformation J nearly rotates a fretboard shape across the strings: (a) and (b) illustrate the mapping; (c), (d), and (e) start this process with a major, minor, and dominant seventh chord, respectively.



eye as well as the ear. And what about the mind? It is possible to construct a complex analysis of these pieces, focusing on the harmonic and contrapuntal challenges of their modern musical idiom. But if the mind follows the fingers, the études are much more simple. The fingers reveal when two apparently different moments are based on the same gesture. Conversely, they also help us understand when a musical element that is apparently the same is, in fact, produced in a different way. Take the interval between E2 and B2. According to traditional theory, this is simply a perfect fifth. But on a guitar in standard tuning, there are two distinct realizations: this fifth spans from (0, 6) to (2, 5), corresponding to the fretboard transformation (+2, −1) (i.e., up two frets and up one string); it also appears from (0, 6) to (7, 6), moving up seven frets along the same string (+7, 0). Though they sound the exact same pitches, Brouwer's études show that these fretboard intervals are not interchangeable for the fingers, even if they are equivalent for the ears.

Figure 11 Pitch reduction and fretboard transformations for Brouwer, *Estudios sencillos*, no. 1, mm. 5–15.



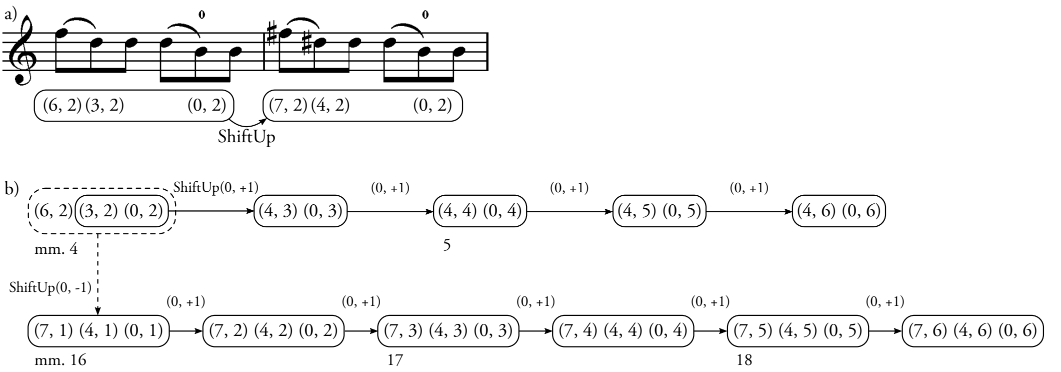
The cross-string perfect fifth (2, 5)–(0, 6) features in the set's first étude. This étude begins with a melody in the bass, interlocking with a repeated third on the open G and B strings. The perfect fifth first appears in the accented pickup to m. 3, at the end of the initial phrase. It emerges as a motif in the étude after that melody's echo. **Figure 11** traces Brouwer's use of this fifth throughout the piece, combining transformational networks with a pitch reduction. In mm. 5, it shifts up one fret, while the pulsing open strings continue, and this back-and-forth continues through m. 9. In m. 11, the open-string pair shifts down one string by (0, +1)—the sounding major third becomes a perfect fourth, though the performance gesture is almost identical. Next, Brouwer returns to the cross-string fifth: in mm. 12–14, it shifts up two frets, then one fret. The process reverses, shifting down two frets and finally—after a delay that intensifies the climactic return—down one more fret. Note how the fretboard moves are inverted here: (+2, 0), (+1, 0) turns into(−2, 0), (−1, 0). The original fifth arrives at the end of m. 15, played fortissimo and *marcato*. This motivic fifth always involves the fifth and sixth strings.

In terms of fret distance, this cross-string fifth has a kinship with the (±2, 0) gestures that appear throughout the étude. This two-fret whole tone is especially emphasized in mm. 9–10 (shown above the staff in figure 11). But this might also explain why the melodic echo in mm. 3–4 replaces C (3, 5) with C♯ (4, 5). With this adjustment, the fingering on the A string matches the earlier pattern on the D string, which was also built from (±2, 0)s. In that echo, all of the fret numbers are even. That C♯, two frets above the top note of the fifth, also features in the brief retransition (mm. 16–17), which connects the *marcato* fifth with the reprise in m. 18.

Étude 7, by contrast, highlights the along-string version of the E2–B2 fifth: this interval is repeated in m. 13, at the étude's midpoint (the entire piece is 26 measures long). In my view, it derives from the opening gesture. This ascending gesture juxtaposes an across-string C-minor triad and an along-string B-diminished triad. In m. 4, the diminished triad is inverted, setting off a descent in which a third repeats above each open string. **Figure 12a** illustrates a relevant transformation that I call ShiftUp.[43] ShiftUp holds open strings in place and moves all other frets up by one. **Figure 12b** shows how ShiftUp is applied to the end of the diminished triad, generating

43 De Souza, "Fretboard Transformations," 27–29.

Figure 12 (a) The transformation ShiftUp holds open strings in place and moves all other fret positions up by 1; (b) transformation network for along-string gestures in Brouwer, *Estudios sencillos*, no. 7, mm. 4–5 and 16–18.



the major thirds that descend across the strings. The bottom half of that network charts an expanded version of this descent (mm. 16–18), in which the entire diminished-triad gesture is changed into a major triad via ShiftUp. From this perspective, the central motif might be less about diminished versus major triads, and more about a fingered minor third somewhere above an open string. The repeated fifth at the midpoint emerges from this motif too: it is preceded by the (4, 6), which grounds a chromatically filled-in minor third between G♯2 and B2. The underlying ((4, 6), (7, 6), (0, 6)) here is a rotated and flipped version of the pattern from the end of m. 18. The piece's final section splits the minor third, where both notes are fingered, and the major third, where the lower note is an open string. The ringing major seventh that punctuates (and closes) the étude provides contrast. But the interval from the low open E to that seventh's top note is a compound perfect fifth, E2–B4, and it again spans seven frets, (+7, −5). In that sense, this contrasting element again relates to the along-string fifth, (+7, 0).

In these études, Brouwer's motifs combine both fingering patterns and sounding patterns. This can create a tension between performers' and listeners' experience, making the pieces sound more complex than they feel. Yet it also raises questions about performance and composition, which Brouwer discussed at the 2018 GFA Convention:

> He talked about the importance of composing away from the guitar. He mimed picking up a guitar and fingering a chord: "It sounds marvelous!" Then he mimed sliding the chord shape higher up the fingerboard: "Marvelous again!" Then he mimed moving it again: "Still marvelous!" Then came the critique: "But who is composing? You or the guitar?"[44]

44 Jonathan Leathwood, personal communication, October 26, 2020.

You *or* the guitar? Why not both? Of course, the guitar doesn't compose independently. But, in a sense, neither does the composer. Even when Brouwer composes on paper, he draws on lifelong experience with the instrument. On some level, he still thinks like a guitarist. This doesn't mean that Brouwer's creative work is determined by the instrument. Not at all! Rather, it suggests that composition is relational. His compositions reflect his embodied relationship with and knowledge of the instrument. As I wrote in *Music at Hand*, "The instrument might not be an autonomous agent—but, in a sense, neither am I. My own embodied agency is distributed; my actions respond to the instrument's call."[45]

Conclusions

Amat's sixteenth-century musical circle shows how the guitar has influenced music theory. Yet the guitar and guitar playing have also emerged as topics for theoretical and scientific research in the twenty-first century. Psychological studies of guitar playing explore affordances, bodily skills, perception, and cognition. These topics have implications for our understanding of the brain, performance, and imagination. Meanwhile, music theorists have considered ways in which the structure of the guitar affects musical organization and players' experience. Drawing on transformational theory and other methods, they have analyzed hand shapes, fingerpicking patterns, and the fretboard as a musical space.

In both cognitive science and music theory, there is still much to be learned. For example, my colleagues and I are preparing an experiment that will compare responses to idiomatic chord voicings and voicings that are impossible to play on a guitar in standard tuning. MIDI guitar technology will also make it easier to adapt keyboard-based experiments, involving altered auditory feedback or other paradigms, to guitar research. To date, much of the music-theoretical research on the guitar has focused on rock and other popular genres. New insights will emerge from performance-based analysis of classical guitar repertoire but also of non-Western music for guitar and other fretted instruments. A recent contribution here is Toru Momii's analysis of contemporary music for shamisen, a three-stringed lute-like instrument from Japan.[46] While it draws on transformational theory, this work also engages with Japanese theoretical perspectives. For example, shamisen players' concept of *te* describes "recurring melodic patterns and their characteristic fingerings, hand positions, and performance techniques." As Momii shows, music theorists must work to overcome the discipline's traditional biases—and will benefit from greater dialogue with performers. Similarly, Daphne Leong's *Performing Knowledge*—which

45 De Souza, *Music at Hand*, 80–81. For a discussion of instrumental composition and Bach's lute music, see ibid., chap. 5.

46 Toru Momii, "Performing *Te*: Gesture, Form, and Interculturality in Dai Fujikura's *neo* for Solo Shamisen" (presentation, Annual Meeting of the Society for Music Theory, November 7, 2020).

includes a chapter on Elliott Carter's *Changes* (1983), cocreated with Jonathan Leathwood—points toward a more collaborative future for music-theoretical research.[47]

This work could have practical implications too, informing pedagogy, the process of learning or memorizing new pieces, or composing for the guitar. For example, thinking in terms of fretboard transformations might be especially useful when alternate tunings disrupt the familiar mapping between fret locations and pitches. But this perspective is not new. As Amat's tablature indicates, guitarists have understood this, implicitly or explicitly, for centuries.

Ultimately, music is not just sound. For any instrumentalist, music also involves physical actions, instrumental affordances, and visual patterns. For a guitarist, these are grounded in the two-dimensional matrix of the fretboard. Of course, this does not mean that all guitarists think the same way. Style matters. Classical, jazz, and rock guitarists focus on different instrumental possibilities and cultivate different techniques and habits. And many guitarists have other musical skills (related to composition, keyboard, singing, etc.), which offer other ways of experiencing and thinking about music. All the same, any guitarist has access to a kind of musical experience that is only made possible by the instrument. In my view, that's what it means to be a guitarist—to know music in a way that is deeply embodied and deeply influenced by this incredible musical technology.

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47 Leong, *Performing Knowledge*, chap. 8.

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