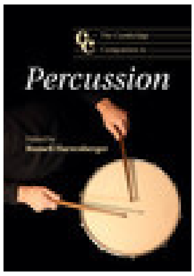


The Cambridge Companion to Percussion

Edited by Russell Hartenberger

Book DOI: http://dx.doi.org/10.1017/CBO9781316145074

Online ISBN: 9781316145074

Hardback ISBN: 9781107093454

Paperback ISBN: 9781107472433

Chapter

20 - Lessons from the laboratory: the musical translation of scientifi

c research on movement pp. 267-280

Chapter DOI: http://dx.doi.org/10.1017/CBO9781316145074.021

Cambridge University Press

# 20 Lessons from the laboratory

## The musical translation of scientific research on movement

MICHAEL SCHUTZ

From our first lessons focusing on the direct relationship between movement and sound quality to explorations of gestures' theatrical possibilities, physical movements have long fascinated percussionists. Scientific study of the topic has recently shed light onto the psychological underpinnings' of movement's musical uses. Although I now recognize this research's clear practical value, in my student days I mistakenly viewed "music research" as largely disconnected from my goals as a percussionist. My initial experiences in graduate school did little to challenge this perspective, with mandatory courses on library usage and lengthy written exams covering topics seemingly removed from my interests as a performer. However, a project focused on the perceptual implications of marimbists' physical movements challenged my perspective, dramatically changing my performing, teaching, and even thinking about music. Consequently, I began striving to balance my time between research and performance, finding that my efforts in one area informed and improved my work in the other.

Throughout this chapter, I will discuss scientific research on musical movement – with a particular focus on movements lacking acoustic consequences. While these studies vary in the immediacy of their application, all ultimately provide valuable insight. In this sense, the study of music cognition is analogous to that of music history: although some aspects are less immediately applicable, a broad understanding is helpful in becoming a well-rounded musician.[1] My specific aims in writing this chapter are twofold: first to emphasize technical scientific studies' practical value for performing musicians, and second to encourage musicians to think about new research questions and topics growing organically out of their personal experiences. As powerful research tools become increasingly widespread, the potential for harnessing their use grows dramatically. Consequently, there has never been a better time for curious musicians to begin exploring the psychological basis of our art.

## Music and body movement

As percussionists, we regularly face the importance of understanding physical movement. Renowned timpanist Fred Hinger's emphasis on the relationship between physical movement and sound quality[2] continues to influence many of today's leading percussionists. In addition to small movements of fingers and wrists, larger motions are required when playing drum set, marimba, timpani, and multiple percussion – not to mention merely arriving at the proper instrument in complex setups! Some composers have elevated physical movement to an art in its own right. Jennifer Stassack explores silent movements in her marimba solo *Six Elegies Dancing* (1987), and Thierry de Mey employs them to great artistic effect in *Musique de Table/Table Music* (1988). This issue is far from "new" – John Cage's *Living Room Music* (1940) touches on these issues to some extent by encouraging performers to creatively employ a variety of movements for reasons extending beyond their acoustic consequences. However, recent interest in "theatrical percussion" takes this relationship to a new level and is discussed at length in Aiyun Huang's article, "*Percussion* theater; the drama of performance" (Chapter 9 in this volume). My chapter supplements growing musical interest in this topic by exploring its scientific roots – *how and why* silent movements shape the musical experience. I am focusing on silent movements in particular as their role is counterintuitive, and also as acoustically consequential movements have understandably received more previous attention.[3]

Although rarely discussed in scientific terms, performers have long intuitively recognized movement's importance independent of its acoustic consequences. Steven Schick noted aptly that "physicality and gesture in percussion music are powerful tools of communication" and that "anyone who has ever attended a percussion concert can tell you that the experience of percussion music involves the eyes as well as the ears."[4] Although percussionists perhaps deal most directly with the consequences of extra-acoustic gestures, we are not alone in this matter. Composer Robert Schumann once famously remarked of a well-known pianist that "he must be heard – and also seen; for if Liszt played behind the screen, a great deal of poetry would be lost."[5]

Here I will summarize the latest scientific research on musical movement in two distinct sections. The first focuses on implications of *feeling our own* movements with respect to our perception of timing. The second explores the results of *seeing others' movements* when evaluating performances. Together, I hope this discussion will provide insights for composers, teachers, and performers. Although my focus is primarily on work relevant to percussionists, many of these issues apply equally as well to other musicians.

## Feeling movement: moving to the beat affects timing perception

When I first joined the percussion faculty at Longwood University in rural Farmville, VA, I frequently found myself coaching students through challenging repertoire by demonstrating the movements I would use to perform certain passages. Initially intended merely to provide a demonstration, dialogue about why I used certain movements led to some interesting introspection. On more than one occasion, I found myself unconsciously using gestures that were not strictly "necessary" for sound production. These movements were spontaneous, and although they "seemed helpful" I began wondering if this were actually the case – after all, at one point using a death grip to ensure my mallets didn't slip "seemed helpful." Many musicians move to the beat while playing or even listening – are such non-sound-producing movements musically useful? Musicians have recognized links between movement and rhythm for generations, and scientists have recently begun explaining the psychological and neurological bases for this connection.

One study presented participants with a six-beat sequence of snare drum and slapstick notes. Lacking accents, the sequence was created to be metrically ambiguous and could be interpreted as being in either 3/4 or 6/8 time. While listening, participants mimicked the bouncing motions of an experimenter moving either two or three times per grouping. When bouncing three times, participants were essentially moving in 3/4; when bouncing twice, they were moving in 6/8. Subsequent evaluations with acoustic accents added on every second or third note sounded more similar to the ambiguous rhythm when it *aligned with their previous movements*. In other words, moving while listening altered their understanding of the sequence's structure.[6] Although movement's effect could in theory reflect culture-specific associations, a parallel study using seven-month-old infants suggests it is innate.[7] Head movement, rather than movement of other body parts, is the essential driving force.[8]

This documentation of links between movement and timing perception complements parallel explorations of brain structure. Neural areas tasked primarily with motor control respond when listening to rhythms – even when the listener is not moving.[9] While neuroanatomy is "compartmentalized" with certain areas more active in some tasks than others, the degree of cross talk between distinct areas is significant. It is no more possible to ignore the feel of one's movement when listening than to read the letters D-O-G without recognizing they refer to man's best friend. Movement's effects on our perception of ambiguous stimuli raises intriguing questions as to whether we can use such findings strategically. Although body movement *changes* our interpretation, can it *improve* our listening abilities?

**Movement improves timing perception**

To explore whether movement can be "helpful," researchers created a series of simple metronome-like sequences lacking metrical context (i.e., a stream of quarter notes with no rhythmic variation). They then removed certain notes to make the underlying pulse ambiguous. All participants moved their fingers while listening to this ambiguous sequence, but half were asked to tap their feet prior to this finger movement (the others listened without first tapping their feet). Foot tapping aided extraction of the underlying pulse, presumably by clarifying the tapper's perception of the beat within ambiguous sequences.[10] This suggests that movement may be helpful when extracting pulse from rhythmically complex passages. It also raises an intriguing question – beyond assisting with a subjective task such as beat extraction, can body movement *objectively improve* our listening abilities?

To explore this question, Fiona Manning (one of my graduate students) is working with a paradigm designed to quantitatively measure movement's effect on perception. Our approach uses customized software producing MIDI sequences while simultaneously recording participants' tapping on electronic drum pads. The task involves listening to a simple five-measure pattern with three measures of quarter notes in 4/4 time followed by a measure of silence. Participants then hear a *probe tone* on the downbeat of the fifth measure, "probing" their perception of the downbeat. The probe tone occurs at the correct time (i.e., right on the beat) on half of the trials and is off by a slight amount on the other half – roughly a sixteenth note or thirty-second note early/late. Participants indicate whether this tone is correct and tap on half of the trials. We ask them to listen without moving for the rest. Participants are better at detecting the probe tone's timing when tapping along as opposed to listening without movement.[11] This demonstrates that movement can objectively improve rhythm perception. Although intriguing, we then began wondering whether it is the movement itself that improves rhythm perception or instead the *acoustic results* of the movement (i.e., hearing one's own taps).

Pinpointing the exact source of movement's improvement required separating the feel of tapping from its acoustic consequences. However, as anyone who has attempted to silently pick up/set down a tambourine during quiet passages recognizes, silent movements are not always feasible! Unable to make the taps "silent," we masked their sound using white noise – the static heard when tuning a radio between stations. Additionally, participants wore foam earplugs inside their headphones, blocking the sound of their tapping without obfuscating the MIDI woodblock sequence. Although they performed better when hearing as well as feeling their taps, the movement benefit persisted even when the taps were masked.[12] This shows that movement alone can improve rhythm perception, an insight useful when performing and/or listening to rhythmically intricate percussion music. The effects of movement documented in these studies were found in participants who were not selected for musical training, consistent with the idea that auditory-motor connections are innate or "hardwired." Nonetheless, the role of training is an important one to consider, and it consequently compelled a series of studies involving percussionists.

Our interest in training's effect arose in part from the opportunity to work with the percussion ensemble TorQ in preparation for the 2012 McMaster University *Neuromusic Conference*. As the event alternated between discussions of my team's research and TorQ's energetic performances, we tested the ensemble prior to the concert and showed their results as part of the event. Unsurprisingly, they were excellent tappers! Their performance in the experiment raised questions regarding the role of percussion training in auditory-motor interactions, and consequently Manning brought a team of students to the University of Toronto and University of Western Ontario to test their percussion studios. Additionally, through a partnership with the PAS Scholarly Research Committee and with funding from the Petro Canada *Young Innovator Award*, we were able to bring the MAPLE Lab to PASIC in 2013 and 2014, testing over one hundred percussionists in a series of experiments. These studies revealed that percussionists benefit more from movement than those without musical training.[13] To some extent, this reflects that percussionists are (predictably) good tappers. Curiously, however, percussionists did not outperform non-percussionists in the *absence of movement* – a surprising finding whose potential implications are currently being explored.

## Seeing movement: silent movements affect musical evaluations

In addition to listeners' movements affecting their own perception, the movements seen by audiences can affect their hearing of the music – even when acoustically irrelevant. Scholars formally exploring performers' movements distinguish between two broad categories of gestures: *effective* and *ancillary*. Effective gestures are required for sound production – such as the downward motion used in striking a drum. Their acoustic relevance distinguishes them from ancillary gestures – movements more excessive than acoustically required. Elaborate sweeps of the arm after striking an instrument, head movements assisting with timekeeping in complex passages, and even rhythmic breathing are, in an acoustic sense, "unnecessary."[14] Yet, they are regularly employed in performances, often to great effect.

Research on musical movement has blossomed in recent years, to the point where it is possible to synthesize multiple findings through a technique known as a "meta-analysis." This approach aggregates disparate results to summarize a large body of work. A meta-analysis including fifteen studies exploring visual influences on ratings of "overall quality," "liking," and "overall impression for performance evaluation" found that watching a performer's body movements had a consistent influence on ratings of their performances.[15] This formal quantification complements other reviews of the many ways in which vision affects evaluations of musical expressiveness,[16] which range from high-level attributes such as "performance quality" down to low-level properties such as timbre, pitch relationships, and volume.[17]

One challenge inherent in understanding the psychological basis for ancillary gestures' effects is designing studies capturing the full complexity of musical performances while yielding strong conclusions. One of music's endearing qualities is its complexity and variation, and no two performances are exactly the same. Although this variation makes music interesting, it poses unfortunate challenges for reproducibility and control – factors crucial for scientific progress. Simplifications of musical material can be helpful in designing experiments affording strong conclusions. However, this approach can make it challenging to determine whether conclusions drawn from such passages apply to realistic musical material. Therefore, a full understanding of performers' ancillary gestures requires a range of studies employing multiple approaches. In some cases, experiments conducted in realistic circumstances provide provocative suggestions, even if they defy clear conclusions. Alternatively, studies using constrained excerpts can be helpful as they offer convincing demonstrations of particular phenomena. Personally, I have found both approaches helpful in clarifying my understanding of how music "works." And in fact, it was through discussion of this kind of issue that I began my own journey into exploring music's psychological basis.

**Hearing gestures, seeing music**

During one of my lessons as a graduate student at Northwestern University, Professor Michael Burritt suggested I use more demonstrative motions in order to "shape the audience's listening experience." I naively protested that such movements were not part of the "true music" as they play no role in audio recordings. (I had not yet learned about research on ancillary gestures!) After all, this use of acoustically inconsequential motions seemed curious given our typical fixation on economizing motion. Upon further reflection, I began wondering if certain movements could be musically relevant despite lacking acoustic consequences. After all, "unnecessary" movements are pervasive. In fact, videos of my own playing documented that I myself frequently employed such gestures – despite my protests at the time as to their musical relevance! To clarify, I began a "controlled" project based on recordings of attempts to create marimba notes differing in duration. While single-note excerpts are a far cry from most recitals, this constrained scenario afforded exploration of a long-running musical debate: whether it is possible to create "long" and "short" notes on the marimba.

This experiment featured renowned marimbist Michael Burritt, who employed both "long" and "short" striking motions. His long gestures featured a flowing movement with a graceful "bounce" after impact, whereas short gestures ended abruptly.[18] My colleagues and I then asked musically trained participants to judge the durations of the resulting notes. Our key manipulation was switching the notes in half of the videos, pairing the long striking motion with the sound produced by the short motion, and vice versa. Despite instructions to judge the duration of the sound alone, visible gesture length significantly altered duration ratings. Furthermore, when judged in the absence of the gestures, evaluations of the notes produced by long and short gestures were indistinguishable. This documents that although long and short gestures do not affect the sound of notes produced on the marimba, they do affect *the way these notes sound* within the mind of the listener.[19] Subsequent studies demonstrate that it is specifically the post-impact motion that controls an audiences' perception of musical note duration[20] and that this illusion is similar even in those without musical training.[21] I described the psychological processes giving rise to this illusion in my first *Percussive Notes* article on this project[22] and the specifics of the motions involved in my second.[23] Videos from these experiments are also available freely in a review published in *Music Theory Online*.[24]

I chose a "controlled" approach to exploring the role of gestures in order to arrive at strong conclusions regarding vision's influence on music perception. While this approach holds many benefits, it is admittedly based on simplified musical material – a single note! Therefore, I see it as complementing other approaches using recordings of complete compositions or at least prolonged passages. One such study used silent videos of a percussionist playing Goldenberg's *Melodic Study in Sixteenths*[25] – aptly identified by researchers as "neutral in emotional nature." The marimbist attempted to convey four different emotional intentions: anger, happiness, sadness, and fear. Participants watching silent videos depicting the movements without sound were able to consistently discern the performer's


**Figure 20.1** Time-lapsed images from Schutz and Lipscomb study showing long and short striking motions. Captured 200 milliseconds apart, the images show that acclaimed percussion soloist Michael Burritt's striking mallet (held in his right hand) continues moving for longer after impact when using a "long" flowing gesture (top) than a "short" choppy gesture (bottom). This difference in post-impact motion changes our *perception* of the tone's duration, even though it does not affect the tone's *acoustic* duration. To see an animated version of this figure (and download demonstrations for personal/educational use), please visit www.maplelap.net/illusion.

emotional intentions. Manipulations using only portions of the video (i.e., removing the hands, showing only the head) were generally also sufficient. However, removing head movements reduced recognition of the performer's emotional intentions.[26] Although this approach establishes that vision is capable of *conveying meaningful information*, it does not comment on whether this information *affects auditory evaluations*. However, this kind of question has been explored by percussionist/psychologist Dr. Mary Broughton.

Broughton is a professional percussionist who also earned a PhD in Experimental Psychology and now draws on this dual background to formally study marimbists' body movements. One of her investigations involved asking participants to rate their level of interest and the level of "expressivity" exhibited in excerpts of popular solos such as *Marimba Dances* (Edwards), *Suite for Marimba* (Yoshioka), *Nancy* (Séjourné), and *Merlin* (Thomas). Broughton recorded these excerpts in two styles – either "expressive" (similar to an actual performance) or "deadpan" (with expressive aspects kept to a minimum). Participants rated these performances after hearing either audio-visual or audio-alone versions. They were in fact adept at detecting the expressive versus deadpan performance styles – however, only when watching as well as listening.[27]

This type of approach involving multiple performances of basic repertoire offers a "realistic" exploration of performance practices. Furthermore, it shows that differences in intention are both visible and can affect ratings of audio-visual performances.[28] As such, this design provides insight into ancillary gestures' effects on musical evaluations. At the same time, it does not afford disambiguation of the different performance intentions' visual and acoustic consequences. The expressive and deadpan conditions differ with respect to both body movements and the acoustic results of these movements (i.e., both effective and ancillary gestures). Consequently, other studies using tightly constrained excerpts provide an important complement to these approaches as they afford stronger conclusions.

One such investigation explores whether vocalists' facial expressions affect audience perception of their singing. Here, participants rated silent videos of a professional vocalist singing intervals ranging from a minor second to an octave. Participants were able to correctly recognize the relative sizes of the sung intervals from merely watching these soundless excerpts.[29] Subsequent studies built on this result by including an auditory component, pairing the facial expressions with different pairs of sung notes – either major or minor thirds. Here, rather than interval size, participants judged their emotional quality, building on differences in the emotional connotations of major and minor thirds in Western music. Singers' facial expressions changed evaluations of their sung intervals, providing strong evidence that they not only convey musically relevant information, but this information *affects evaluations* of sound.[30]

This work involving pairs of sung notes bears similarity to my own involving single marimba notes – both use constrained musical examples and tightly controlled procedures to arrive at strong conclusions. As musical performances generally involve more complex material, other approaches using longer excerpts hold certain advantages. Yet, the complexity of using "realistic" videos simultaneously precludes the manipulations of auditory and visual components required to reach unambiguous outcomes. Eliminating sound entirely allows for the use of more involved examples,[31] but introduces different challenges with respect to practical applications. Fortunately, methodological diversity is a bedrock principle of scientific exploration, as examination from multiple points of view helps in triangulating truth. And curiously, recent technological developments build on and affirm both approaches by using alternative representations of human movement affording new explorations.

**Threading the needle: new approaches to balancing realism and control**

Humans are adept at recognizing complex movements from surprisingly sparse representations. White dots tracking key locations (i.e., shoulder, elbow, hand, foot) against black backgrounds are effective at modeling many complex movements. In fact, movies such as *Avatar* use this approach to create compelling models of human motion. These models


http://dx.doi.org/10.1017/CBO9781316145074.021

appear curiously "realistic" given that they portray fictitious creatures never previously seen! In addition to their use in entertainment, these displays have a long history of aiding movement research,[32] including explorations of music[33] and dance.[34] I used a variation of this technique to create a "virtual marimbist," which served as an eerily accurate surrogate for an actual performer in some of my previous work.[35]

New extensions to this well-established technique offer powerful opportunities for balancing realism and control, as the sparse nature of point light representations affords manipulations preserving natural appearances. For example, "time warping" involves subtle changes in movements, allowing for rendering different versions of human avatars that remain realistic in appearance. In one intriguing approach, pianists played Chopin's *Prelude in E minor* with different degrees of expression – including "deadpan" (i.e., reduced expressivity), "normal" (i.e., typical expressive), and "exaggerated" (i.e., maximum possible expressivity). Pairing each time-warped movement sequence with each audio recording created visually identical but acoustically distinct (as well as acoustically identical but visually distinct) audio-visual performances.[36] Experiments using these hybrid audio-visual excerpts demonstrated a clear visual influence on performance evaluations of musical expressivity.[37] Because these animations used acoustically identical passages paired with different motions, they provide strong evidence that ancillary aspects of gestures can *alter evaluations* of concurrent acoustic information.

In an approach equally relevant to performing musicians, a different study explored the degree to which body movements provide insight into the winners of prestigious musical competitions. Six-second videos of finalists' performances were presented as either audio-visual, video-alone, or audio-alone clips. These excerpts showed violinists and pianists performing in high-stakes venues such as the Van Cliburn International Piano Competition and the International Tchaikovsky Competition. The overall level of playing was extremely high, and participants in the audio-alone and audio-visual conditions failed to perform better than chance at identifying competition winners. Curiously, only those watching *silent videos* performed better than chance! These results were robust across different assessments, and replicated even when using highly trained musicians as evaluators.[38]

Although many visual clues were available in videos, follow-up studies suggest that gross body movements played a crucial role. Silhouettes obfuscating facial features and smaller movements while preserving larger gestures again afforded predictions of the ultimate winners; however, still images did not.[39] Extensions of this paradigm involving ensemble performances in the Saint Paul String Quartet Competition and Fischoff

Competition suggest this phenomenon is not limited to solo performances.[40] Although further research is needed to determine the precise aspects of the performers' gestures contributing to this outcome (i.e., ancillary vs. effective), the use of material from important competitions means these results hold significant practical implications.

## Concluding thoughts and future opportunities

I have summarized a variety of movement studies pertinent to our work as musicians. My hope is that this knowledge will not only help performers, teachers, and composers, but that it might also encourage musicians to propose and pursue new research questions. Given the growth in tools and training programs, there is now tremendous potential for curious musicians to make important discoveries. Personally, I have found insights from this research not only fascinating, but also musically useful. When students in my percussion ensemble are struggling with certain rhythmically intricate passages, I am able to explain to them that moving while performing can help their efforts to keep time. Additionally, arranging setups so that my students can see one another often helps them to better align their performances. When puzzling through transcribing or simply listening to complex rhythms, I now tap along, improving my ability to extract the beat and recognize rhythms.

Knowledge of how performers can shape an audience's listening experience through the proper use of ancillary gestures is invaluable in striving to ensure they contribute toward our musical goals. Such movements can be helpful communicative tools in recitals and competitions, unscreened orchestral auditions, and live performances in a variety of ensembles – as audiences' attention is often disproportionately drawn to the percussion section (and for good reason!). I also find knowledge of gestures' perceptual effects helpful in explaining to students that effective performance is less about technical flash and faster tempos than the communication happening between performer and audience.

Scientific studies of musical communication can be pursued in a variety of different manners. After completing my Master of Music in Percussion Performance, I took the somewhat unusual step of pursuing a PhD in Experimental Psychology rather than the more typical path of enrolling in a Doctor of Musical Arts program. This decision helped me to develop the skills required for running my own research laboratory – which now allows me to explore a variety of musical issues. However, this is not the only way to become involved in scientific research on music, as scientists are often eager to collaborate on projects of mutual interest.

For example, Roger Chaffin's group at the University of Connecticut has pursued novel explorations of practice and memorization techniques employed by professional pianist Gabriela Imreh.[41] This partnership proved quite fruitful, and he subsequently studied issues of memory in realistic practice and performance scenarios through partnerships with cellist Tânia Lisboa[42] and vocalist Jane Ginsborg.[43] Both Lisboa and Ginsborg now blend performance and research activities as part of their professional portfolios. Therefore, collaborations hold great potential for enhancing dialogue between the artistic and scientific communities and represent the epitome of interdisciplinary research trumpeted by universities. Musicians interested in exploring such opportunities may wish to consult the Society for Music Perception and Cognition map of researchers and facilities at http://musicperception.org/smpc-resources.html.

In conclusion, there are many ways in which psychological research can inform and inspire musical activities. I believe the importance of understanding music cognition parallels the importance of understanding more traditional subjects included in music curricula, such as musical harmony. A firm understanding of basic principles of music theory as presented in undergraduate textbooks provides useful insight into the structure of actual symphonies and solos – even though in practice "rules" are not always followed as cleanly as in the classroom. Similarly, controlled studies can be helpful in probing the general principles employed in processing more complex musical material. Although it is possible to recognize "moving to the beat" helps timekeeping without knowledge of the cognitive basis for this insight or that ancillary gestures on stage affect performance evaluations without an understanding of cross talk between neural areas processing sight and sound, understanding the cognitive basis for these phenomena only improves our understanding of music – and the musicians giving it life. Sound only becomes music within the mind of the listener, and consequently understanding music's psychological basis provides significant benefits for all who perform, teach, compose, and enjoy this important human endeavor.

As the field of music cognition grows, I am excited about the possibility of experimental psychology's powerful techniques to explore musically motivated questions, complementing music cognition's traditional focus on using music to explore psychologically motivated questions. As musicians, we possess finely tuned intuitions cultivated from a wide array of musical experiences, which hold the potential to lead organically to exciting new research questions. Such interdisciplinary explorations hold significant and far-reaching benefits, helping us inch closer to a fuller understanding of the surprising ways movement can be used to create more effective musical performances.

## Notes

1. Those interested in the brain's processing of music are encouraged to read John Iversen's article on the neural processing of rhythm, Chapter 21 in this volume.
2. F. Hinger, *Technique for the Virtuoso Timpanist* (Hackensack, NJ: Jerona Music, 1981).
3. S. Dahl, "Striking Movements: A Survey of Motion Analysis of Percussionists," *Acoustical Science and Technology*, 32 (2011), 168–73.
4. S. Schick, *The Percussionist's Art: Same Bed, Different Dreams* (University of Rochester Press, 2006).
5. S. Morgenstern, *Composers on Music* (London: Faber & Faber, 1958), p. 156.
6. J. Phillips-Silver and L. J. Trainor, "Hearing What the Body Feels: Auditory Encoding of Rhythmic Movement," *Cognition*, 105 (2007), 533–46.
7. Phillips-Silver and Trainor, "Feeling the Beat: Movement Influences Infant Rhythm Perception," *Science*, 308 (2005), 1430.
8. Phillips-Silver and Trainor, "Vestibular Influence on Auditory Metrical Interpretation," *Brain and Cognition*, 67 (2008), 94–102.
9. J. A. Grahn and M. Brett, "Rhythm and Beat Perception in Motor Areas of the Brain," *Journal of Cognitive Neuroscience*, 19 (2007), 893–906.
10. Y. H. Su and E. Pöppel, "Body Movement Enhances the Extraction of Temporal Structures in Auditory Sequences," *Psychological Research*, 76 (2012), 373–82.
11. F. Manning and M. Schutz, "'Moving to the Beat' Improves Timing Perception," *Psychonomic Bulletin & Review*, 20 (2013), 1133–39.
12. Manning and Schutz, "Movement Enhances Perceived Timing in the Absence of Auditory Feedback," *Timing & Time Perception*, 3 (2015), 3–12.
13. Manning and Schutz, "Trained to Keep a Beat: Movement-related Enhancements to Timing Perception in Percussionists and Non-percussionists," *Psychological Research* (in press), 1–22.
14. M. Nusseck, M. and M. M. Wanderley, "Music and Motion – How Music-related Ancillary Body Movements Contribute to the Experience of Music," *Music Perception: An Interdisciplinary Journal*, 26 (2009), 335–53; Wanderley, B. W. Vines, N. Middleton, C. McKay, and W. Hatch, "The Musical Significance of Clarinetists' Ancillary Gestures: An Exploration of the Field," *Journal of New Music Research*, 34 (2005), 97–113.
15. F. Platz and R. Kopiez, "When the Eye Listens: A Meta-analysis of how Audio-visual Presentation Enhances the Appreciation of Music Performance," *Music Perception: An Interdisciplinary Journal*, 30 (2012), 71–83.
16. W. F. Thompson, P. Graham, and F. A. Russo, "Seeing Music Performance: Visual Influences on Perception and Experience," *Semiotica* 156 (2005), 203–27.
17. Schutz, "Seeing Music? What Musicians Need to Know about Vision," *Empirical Musicology Review*, 3 (2008), 83–108.
18. Samples of these videos are available online at www.maplelab.net/illusion.
19. Schutz and S. Lipscomb, "Hearing Gestures, Seeing Music: Vision Influences Perceived Tone Duration," *Perception*, 36 (2007), 888–97.
20. J. A. Armontrout, Schutz, and M. Kubovy, "Visual Determinants of a Cross-modal Illusion," *Attention, Perception, & Psychophysics*, 71 (2009), 1618–27.
21. Schutz and Kubovy, "Causality and Cross-modal Integration," *Journal of Experimental Psychology: Human Perception and Performance*, 35 (2009), 1791–1810.
22. Schutz, "The Mind of the Listener: Acoustics, Perception, and the Musical Experience," *Percussive Notes* vol. 47 (2009), 22–8.
23. Schutz and Manning, "Effectively using Affective Festures: What Percussionists Need to Know about Movement and Perception," *Percussive Notes* vol. 51, no. 2 (2013), 26–31.
24. Schutz and Manning, "Looking Beyond the Score: The Musical Role of Percussionists' Ancillary Gestures," *Music Theory Online*, 18 (2012), 1–14.
25. M. Goldenberg, *Modern School for Xylophone, Marimba, Vibraphone* (New York: Chapell, 1950).
26. Dahl and A. Friberg, "Visual Perception of Expressiveness in Musicians' Body Movements," *Music Perception: An Interdisciplinary Journal*, 24 (2007), 433–54.
27. M. Broughton and C. Stevens, "Music, Movement and Marimba: An Investigation of the Role of Movement and Gesture in Communicating Musical Expression to an Audience," *Psychology of Music*, 37 (2009), 137–53.
28. Subsequent investigations explore formal coding and analysis of movement types using the Laban movement system [Broughton and Stevens,"Analyzing Expressive Qualities in Movement and Stillness: Effort-shape Analyses of Solo Marimbists' Bodily Expression," *Music Perception*, 29 (2012), 339–57] and examine

individual differences in their detection [Broughton and J. W. Davidson, "Action and Familiarity Effects on Self and other Expert Musicians' Laban Effort-shape Analyses of Expressive Bodily Behaviors in Instrumental Music Performance: a Case Study Approach," *Frontiers in Psychology*, 5 (2014), 1201].

29. Thompson and Russo, "Facing the Music," *Psychological Science*, 18 (2007), 756–57.

30. Thompson, Russo, and L. Quinto, (2008), "Audio-visual Integration of Emotional Cues in Song," *Cognition and Emotion*, 22 (2008), 1457–70.

31. Dahl and Friberg, "Visual Perception," 433–54.

32. G. Johansson, "Visual Perception of Biological Motion and a Model for its Analysis," *Perception & Psychophysics*, 14 (1973), 201–11.

33. Davidson, "Visual Perception of Performance Manner in the Movements of Solo Musicians," *Psychology of Music*, 21 (1993), 103–13.

34. P. Toiviainen, G. Luck, and Thompson, "Embodied Meter: Hierarchical Eigenmodes in Music-induced Movement," *Music Perception: An Interdisciplinary Journal*, 28 (2010), 59–70.

35. Schutz and Kubovy, "Deconstructing a Musical Illusion: Point-light Representations Capture Salient Properties of Impact Motions," *Canadian Acoustics*, 37 (2009), 23–8.

36. These approaches built upon earlier work examining the body movements of pianists as they relate to desired manipulations of expression by Thompson and Luck, "Exploring Relationships Between Pianists' Body Movements, their Expressive Intentions, and Structural Elements of the Music," *Musicae Scientiae*, 16 (2012), 19–40.

37. J. K. Vuoskoski, Thompson, E. F. Clarke, and C. Spence, "Crossmodal Interactions in the Perception of Expressivity in Musical Performance," *Attention, Perception, & Psychophysics*, 76 (2014), 591–604.

38. C.-J. Tsay, "Sight over Sound in the Judgment of Music Performance," *Proceedings of the National Academy of Sciences of the United States of America*, 110 (2013), 14580–5.

39. *Ibid.*

40. Tsay, "The Vision Heuristic: Judging Music Ensembles by Sight Alone," *Organizational Behavior and Human Decision Processes*, 124 (2014), 24–33.

41. R. Chaffin and G. Imreh, "'Pulling Teeth and Torture:' Musical Memory and Problem Solving," *Thinking & Reasoning*, 3 (1997), 315–36.

42. Chaffin, T. Lisboa, T. Logan, T., and K. T. Begosh, "Preparing for Memorized Cello Performance: The Role of Performance Cues," *Psychology of Music*, 1 (2010), 3–30.

43. J. Ginsborg, and Chaffin, "Preparation and Spontaneity in Performance: A Singer's Thoughts while Singing Schoenberg," *Psychomusicology: Music, Mind & Brain*, 21 (2011), 137–58.