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Music, Motor Control, and the Brain

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RESearch ON PERCEPTUAL PROCESSES has traditionally dominated the field of music cognition relative to the study of performance. A better balance has grown in recent years, evidenced by a surge of edited volumes on performance. Among these are books edited by Parncutt and McPherson (2002) and Rink (2002), as well as an edition of the new online journal *Advances in Cognitive Psychology* (Thompson, Dalla Bella, & Keller, 2006). In this context, the edited volume reviewed here may appear as just another soldier on the field. Such a conclusion would be unfair, however.

In several respects, *Music, Motor Control, and the Brain* is novel and would be of use to those readers of *Music Perception* who are interested in the study of performance. Much of the book diverges from the strictly cognitivist perspective with which we are familiar. Many articles touch on issues that are often discussed as passing concerns (e.g., differences across instruments, the role of kinematics) but not addressed directly. These newer issues combine with chapters representing cognitive psychology and cognitive neuroscience approaches that will be more familiar to the reader. Although this volume may not provide a full review of any of the topics it includes, the conjoining of fairly disparate approaches invites the reader to consider new and refreshing connections.

For me, the most striking departure of the research discussed here from research familiar to me was the discussion of motion data, which inhabit one section of the book (4 chapters) and also appear in one chapter (by Palmer) in the “Psychology” section. An increasing number of music cognition labs have incorporated movement analysis techniques, facilitated by recent technological advances and the data analysis techniques (e.g., functional data analysis, Ramsay & Silverman, 2002; cf. Vines, Nuzzo, & Levitin, 2005). It is possible that these advances will do for the study of kinematics in performance what MIDI did for the study of performance

in general. The reader interested in gaining a new perspective on movement will find in these chapters a useful—though challenging—introduction. In a similar vein, the book devotes an entire section to performance-related disorders, primarily focal dystonia. Although the research summarized in this section may not relate directly to the interests of many readers it makes for interesting reading and an introduction to applied research in the neurophysiology of music performance. Moreover, the issues that arise in these chapters provide new insights into the mechanisms that underlie fluent performance.

A second refreshing aspect of this book is a frequent focus on instrument-specific physical constraints on performance. Music performance research, for practical reasons, has typically focused on the keyboard, and that focus is present here. Researchers who use the piano as a model system often refer to studies of piano performance as simply “music performance,” implying that the data from such studies are representative of performance in all its forms (I myself have done this). Such rhetorical devices, however, beg the question of whether the piano is representative of music performance in general. In this context, it is pleasing to see that the current volume devotes considerable coverage to the violin, drumming, and singing. Although direct comparisons across these performance contexts are not always presented, the reader nevertheless has access to data sets that can lead to such comparisons.

Finally, because the chapters in it originated from a conference held in Switzerland (in 2002), this book presents research primarily from researchers based on continental Europe, in contrast from the dominant American/Canadian/British majority one usually finds. I am not certain how much these distinctions lead to substantially different programs of research. Nevertheless, in these chapters I became familiar with research that I would not otherwise be—non English language publications that have appeared in journals that may be unfamiliar to most readers.

In reading *Music, Motor Control, and the Brain*, therefore, I found more to learn and think about than I had expected. The book is divided into five sections, though one section comprises only a single chapter (“History”). The second section, entitled “Psychology,” includes research that is most likely to be familiar to readers of *Music Perception*. Section three, “Movement Analysis,” discusses research that uses motion capture, mentioned before. The fourth section, “Representation

in the Brain,” will remind some readers of recent edited volumes on Music and Neuroscience (e.g., Avanzini, Lopez, Koelesh, & Majno, 2005; Peretz & Zatorre, 2001, 2003), though the research summarized is positioned uniquely in the current volume by virtue of the neighboring topics and the exclusive focus on performance. The book closes with a pleasantly surprising twist by discussing the neurological bases of musician-specific disorders in “Apollo’s Curse—Loss of Motor Control in Musicians.”

The first chapter, by Andreas Lehmann, (which also constitutes the first section) considers historical changes in performance practice and in the abilities manifested by musicians and athletes. It tracks the astounding changes in the precision and dexterity exhibited by performers. Musicians from only one hundred years ago were expected to dabble in different instruments, and often performed publicly after minimal practice, resulting in a product that was far from error-free. By contrast, current-day performers are expected to perform perfectly after hours of arduous practice and are expected to perform with virtually perfect accuracy. Lehmann invokes the concept of deliberate practice as a unifying theme: Over time, performers have increasingly practiced in this manner, leading to enhanced specialization but reduced generalization. As such, performers are now distinct from composers, as was not the case historically. Interestingly, the final section on focal dystonia leads the reader to wonder whether such focused practice, which appears to be linked to musician’s cramps, has substantial costs as well as benefits. This is a fascinating and well-written chapter.

Chapter 2, by Lutz Jäncke (one of two chapters he authors), opens the section on “Psychology.” Jäncke presents a general overview of the various psychological constraints and skills that are required for a musician to perform effectively. The general framework of this chapter links music performance skills to general-purpose cognitive abilities, like those observed in chess or grasping. The summary will no doubt be familiar to most readers of *Music Perception*. Nevertheless it is well-written and makes a good general introduction or review.

Chapter 3, by Caroline Palmer, also details research that may be familiar to most readers. The final section of this chapter, however, discusses newer research that links anticipatory planning, as evidenced by serial ordering errors during performances, to anticipatory finger movements. Here the cognitive perspective in section two dovetails with the section on movement data. Although other recent reviews by Palmer document similar research (Palmer, 2005a, 2005b), this chapter provides

substantially more discussion (and presentation of data) to movement analysis than the other articles. The link between motion and planning is compelling, and suggests that subtle gestures—undetected by standard techniques like MIDI recording—may provide substantial information about the cognitive bases of performance. It also brings up the important question of the degree to which serial ordering errors may be linked to kinematic or cognitive sources.

Chapter 4, by Bruno Repp, which closes the “Psychology” section, stands alone in this volume in focusing on how musicians synchronize with external sounds. As with the chapter by Palmer, this chapter considers issues that also appear in recent reviews by Repp (2005, 2006). However, Chapter 4 focuses particularly on music (in contrast to Repp, 2005) and considers links to a broad range of timing models (in contrast to Repp, 2006) that were not originally developed for musical behaviors. Chapter 4 provides a clear, basic introduction to a set of models that can be difficult to understand at first exposure. Much of the research summarized involves tapping rather than performing music, although data that link this simpler task to more complex musical behaviors are also discussed. I was particularly pleased to see the author bring up dance—a ubiquitous musical behavior that has received little attention. The reader interested in this issue may wish to consult recent neuroimaging evidence for entrainment during tango dancing (Brown, Martinez, & Parsons, 2006). Repp also discusses interesting new research on synchronization with a conductor by Gordon Luck.

The section on “Movement Analysis” opens with a chapter by Thomas Jerde and colleagues. This chapter focuses on an issue all too familiar to those of us who have struggled with finger dexterity: The inability to move one finger independently of the others. Jerde and colleagues refer to this aggravating condition as “enslavement.” This chapter reviews how movement analysis has been used to assess the degree of enslavement among the fingers. The authors link enslavement to coarticulation in speech, and through this connection the reader is invited to consider the challenge of finger nonindependence as a communicative constraint that, like coarticulation in speech, may form part of the code that becomes music. Moreover, degree of enslavement may vary depending on how much emphasis the performer places on a note. The data summarized in this chapter is from research on writing, although the author speculates on how similar research from music may play out. Unfortunately, the timing of this chapter did not allow the authors to incorporate highly related research from Loehr & Palmer (2007).

Chapter 6, by Hans-Christian Jabusch, explicitly addresses movement during piano performance. The chapter opens with a valuable and engaging historical introduction to the topic, starting with photographic recordings of movements, on to the advent of MIDI recordings (which disregards all but the contact times), and then back to movements now measured with new techniques. Despite the music cognition flavor of the opening sections, Jabusch's primary interest is in focal dystonia (he also appears as first author on a chapter in the section on music performance disorders), and the chapter closes with a discussion of how movement analysis can be used in diagnosing focal dystonia. Unfortunately, the reported study on dystonia does not benefit from the movement analysis techniques that are described, although other research by the author on scale playing provides measures of finger overlap that may be useful for those interested in the ergonomics of piano fingering (cf., Parncutt, Sloboda, Clarke, Raekallio, & Desain, 1997).

Chapter 7, by Mario Wiesendanger and colleagues, is one of two chapters to consider string playing (on the violin). It begins with a historically based introduction, and then describes the results of a recent experiment. This description is fairly dense and challenging but well worth the effort. Too little focus has been given to mastery of the coordinative demands of bowed string instruments. While reading the methodology incorporated by Wiesendanger and colleagues, one understands why—this is intricate stuff. The figures are informative but take some time to understand. The authors consider finger-bow synchronization, the use of left-hand finger movements to generate pitch by lifting or pressing down one's finger, and the radial movements of the bow used to switch strings. Similar to the chapter by Jerde, Wiesendanger and colleagues interpret anticipatory finger movements during string performance as analogous to coarticulation in speech. Finger-bow synchronizations were in a range analogous to those reported by Repp (Chapter 4) for finger tapping in sensorimotor synchronization. Chapter 7 goes beyond the kinematic analyses provided by all movement analyses to discuss the kinetics of string playing. The buildup of forces that precede note onset converges with evidence from kinematics that also suggests anticipatory movements. Overall this was a chapter rich with data, valuable as a source of information on performance, but demanding.

The final chapter on movement analysis, by Sofia Dahl, concerns drumming. It is a pleasure to read. A reader unfamiliar with movement analysis may wish to start with this chapter given its very accessible style. Dahl begins by considering the constraints common to

percussion instruments along with the diversity of instruments available. Of course, most music performance research technically does focus on a percussion instrument—the piano—but Dahl points out distinct constraints for drumming. The author's main focus is on whether movements converge with pedagogy. In so doing, she focuses closely on individual performances that are representative of different styles. The data nicely converge with intuitions from pedagogy and expectations based on musical style. One may be skeptical of single-subject designs, but it is hard to imagine that data from full samples would diverge greatly from the data reported here. At the same time, there is clearly more to pursue: in particular, the data in Figure 8.3 suggest that bistability may exist in the relationship between performance intentions (here, dynamic level and tempo) and striking velocity.

Chapter 9, by Gottfried Schlaug, opens the section entitled "Representation in the brain." Schlaug avoids summarizing his well-known earlier research (which is cited in many other chapters throughout this volume) and turns to a highly ambitious longitudinal study that has been carried out over the past several years. Cross-sectional data are reported here that suggest significant morphological changes over reasonably brief periods of training. The researchers use both training and musical ability measures (an index of the success of training) as predictor variables for morphometric changes. A primary consideration of this work, whether changes in the brain reflect genetics or training, will await final confirmation from the longitudinal data. However, Schlaug clearly believes that exposure plays a large part in these differences. Data reported later in the chapter support this contention further. As do other chapters, Chapter 9 comments on differences across instruments, pointing to hemispheric asymmetries in the pre-central gyrus that differ between pianists and string players. The chapter closes with suggestions about how changes in inferior frontal regions may reflect the enhancement of a mirror-neuron system that assists music performance. Indeed, a general theme one extracts from this section is that brain regions in the vicinity of "Broca's area" play a substantial role in the cognitive bases of music performance, particularly with respect to sensorimotor interactions.

Chapter 10 is the second chapter by Lutz Jäncke. The title suggests that a comparison between pianists and string players is the primary focus. However, this focus takes center stage only in the first section, which reports a very interesting behavioral experiment (by the author and colleagues) on how musical training (piano versus string) promotes greater parity among the hands when

engaging in speeded tapping. Although all musicians are able to tap faster than non-musicians, with either the dominant or non-dominant hand, keyboard more so than string instrument training also promotes similarly high maximal rates for both hands. The remainder of the chapter, though interesting, does not carry on this comparison and ends up focusing mostly on musical imagery. Thus, although I enjoyed this chapter, it did not end up being the kind of review I had expected.

Chapter 11, by Marc Bangert, addresses how musical training promotes sensori-motor integration. The chapter is characterized as “. . . [describing] in detail an electroencephalography (EEG) study . . .” (p. 173). The study in question appears to be Bangert & Altenmüller (2003, e.g., cf. Figure 11.2-a of Chapter 11 with Figure 4 of Bangert & Altenmüller, 2003), although this is not said explicitly and I could not find the reference in the text (though it appears in the reference section). Either way, I would recommend this chapter. It provides a number of thoughtful insights on the way perception/action reorientations contribute to performance and change with training, and a very clear and helpful review of the relevant literature—including a bullet list of brain areas involved in performance that can serve as a handy “crib sheet” for newcomers. My recommendation to interested readers is to consult this chapter after reading Bangert & Altenmüller (2003)—a paper worth reading in any case.

The third chapter to consider string playing, Chapter 12 by Nirrko and Kristeva, comes next. This chapter presents an ambitious set of studies on string playing that harness both fMRI and EEG techniques. Unfortunately I found the chapter confusing on a number of dimensions. Ultimately, the important issue of bimanual coordination, seemingly the focus of this work, was lost on me, as the reported data (plots for which often focused on individuals whereas the text focused on groups) did not connect clearly with any predictions regarding bimanual coordination. Beyond this, the authors incorporated a control task that, while creative (it involved pulling a drawer with the left hand while reaching for an object in the drawer with the right), seemed oddly disparate from many motoric demands involved in string playing. Some more discussion of how this control task was chosen would have helped a great deal.

Chapter 13, by Ackermann and colleagues, is the first of two chapters to focus on vocal production. The chapter opens with a discussion of comparative research on song behavior in birds and mammals, although this section is not clearly linked to the remainder of the chapter. A primary focus of the chapter ultimately is on

cerebral asymmetries in speaking and singing. The authors make a valiant attempt to make sense out of occasionally conflicting findings. They tentatively conclude that song is less strongly lateralized (though it tends toward the right hemisphere) than is speech production, although they report new data that suggest rather strong right lateralization (insular cortex) for music, with reversed lateralization (right: speech, left: music) in the cerebellum. The authors also incorporate tasks that use musical imagery and non-vocal tongue movements, and find (interestingly) greater similarity with activations for singing during imagery than tongue movements—suggesting a predominantly “cognitive” basis for brain activations during singing.

The next chapter on singing, Chapter 14 by Reyna Leigh Gordon and colleagues, takes a more clinical approach. It begins with a review of research on the role of attention and memory in song, focusing on the issue of how text and melody come together. This discussion leads to a summary of two recent studies that apply this research to the use of melodic intonation therapy (both of which have been published elsewhere, one in *Music Perception*) by having participants learn songs and/or text by imitation. Generally speaking, these new studies support the conclusion (also expressed in some, but not all, articles from this literature) that music and text are supported by independent processes. By this logic, the success of melodic intonation therapy may be, in part, an artifact of tempo.

The section on “Representation in the brain” closes with a dense chapter by Gerloff and Hummel, on the role of inhibition in finger movements. This chapter may offer more detail into the procedure than is warranted, but the implications are significant: Inhibition may not constitute a passive “waiting” state, but may instead constitute an active “withholding” state. One implication of these results is that periodic fluctuations in neural activity continue even when an overt action is not generated. This implication converges with recent theoretical and empirical research suggesting that periodic oscillations of an internal timekeeper persist when expected event onsets are absent (e.g., Large & Jones, 1999; Osman, Albert, Ridderinkhof, Band, & van der Molen, 2007; Snyder & Large, 2005).

The final section, entitled “Apollo’s curse—loss of motor control in musicians” opens with a tremendously engaging chapter by Ekart Altenmüller. The chapter documents Robert Schumann’s difficulties controlling his right middle finger, summarizes existing theories concerning what might have caused this deficit, and then discredits these theories in favor of an account based on focal dystonia. The chapter is written in the

detective-like style of classic case studies (e.g., *Anna O*) and thus amounts to quite a page-turner. During the suspenseful tale, one learns theories about the basis of focal dystonia relevant to general principles of motor control in manual performance. Focal dystonia likely arises from a “blurring of receptive fields” for the finger (p. 262) perhaps due to a failure of lateral inhibition in the hand. Thus, what appears to be a strictly peripheral dysfunction may have central origins.

The next three chapters continue with the theme of focal dystonia. Chapter 17, by Jabusch and Altenmüller, details a treatment study of focal dystonia. In this chapter we learn a good deal about varieties and treatments of dystonia. Unfortunately, two reasonably successful injection treatments (Trihexyphenidyl and Botulinum toxin) are not described in great detail, leading the reader to wonder why exactly these treatments work. It is clear from this study that focal dystonia is a complex, multifaceted disorder worthy of further research.

Chapter 18, by Karin Rosenkranz, addresses the role of inhibition in hand dystonia. This research is motivated by the well-known finding that the organization of cortical regions associated with specific effectors changes with training. Rosenkranz hypothesizes that “. . . these changes develop too far in musician’s dystonia, from being beneficial to being a maladaptation” (p. 286). She goes on to summarize convincing data in humans showing changes of receptive fields for the hand as revealed by transcortical magnetic stimulation (TMS), which is also used to elicit the kind of sensorimotor connections that occur during training. Interestingly, receptive fields of non-musicians begin to look more like those of musicians after a minimal amount of stimulation with TMS (cf. Bangert & Altenmüller, 2003). The result in both groups, unexpected to this reader, is less lateral inhibition among fingers after training. A group with dystonia showed even less inhibition across fingers (in fact, stimulation of one finger through TMS causes activity in other fingers). One important finding discussed here is a distinction between writer’s cramp and musician’s dystonia—the former resulting in less of a tendency for cross-talk among the fingers.

Chapter 19, the third chapter on dystonia, by Byl and Priori, discusses further the idea that focal dystonia constitutes “maladaptive plasticity.” Here we learn more about causes and successful therapies, although the data discussed do not come from musical behaviors (and so, given Rosenkranz’s data, one wonders about generalizability). With respect to cause, the authors cite evidence from comparative research that animals can (but do not always) develop focal dystonia from repetitive manual

tasks, even when effectors show no damage (e.g., nerve inflammation). One therapeutic technique the authors discuss, which involves immobilizing the effected hand, seems untenable, practically speaking, for performing musicians. The other technique is based on forming different sensorimotor connections to the fingers based on various movement types and sources of feedback. This technique on the surface appears more palatable for the musician and more theoretically intriguing, though in the space provided the authors could only discuss general characteristics of the technique.

The research discussed on focal dystonia, clearly a major theme of the conference that led to this book, was intellectually stimulating but clearly describes an area ready for more work. One factor this reviewer was left wondering about, in general, is practice. It seems likely that dystonia is related to practice that is, well, *too* deliberate: patients tend to be anxious and perfectionist, and in the case of Robert Schumann, the increase in skill was quite rapid. Chapters 18 and 19 hint at support for this view, but the experiments reported in this volume do not directly test this hypothesis. Another problem arising from these chapters has to do with varieties of dystonia. Chapters 18 and 19 focus exclusively on dystonia of the hand. However, Chapter 17 makes clear that many wind instrumentalists experience embouchure dystonia. It is not clear how the theories regarding receptive fields could be applied to embouchure dystonia, and the treatments cited as being successful in Chapter 17 for hand dystonia did not work as well for the embouchure. Effector specificity is thus another important issue that needs to be addressed regarding focal dystonia.

The final chapter, by Jürg Kesslering, diverges from the theme of focal dystonia to discuss the problem of performance anxiety. Much of the chapter is devoted to a discussion of the phenomenology of performance anxiety, along with some discussion of treatments. Unfortunately no data are discussed that help the reader understand better how performance anxiety is caused or alleviated, and so we will eagerly await future research on the matter.

Even excellent books have weaknesses, and this book was no exception. Two general weaknesses I found were in fact byproducts of this book’s strength: the diversity of approaches. Both weaknesses are common for volumes of this sort (i.e., collections of papers from a conference) but are worth pointing out, in my opinion. First, there were many possibilities for links across the chapters but this prospect was not realized. The sections could have benefited from introductory chapters, and perhaps a closing chapter, to make these connections

come to life. Second, the diversity of views leads to a rather dizzying array of terms that one must know or learn to fully appreciate the work. Cognitive scientists in the past few years have become increasingly accustomed to reading papers that refer to Brodmann areas and Gyri with no accompanying tutorial. Here we can add terms from kinesiology. Fortunately (for this researcher at least), the Internet provides a handy way to review terms like “proximal interphalangeal joint” and “abductor pollicis brevis” (terms we should no doubt all know), but the inclusion of a glossary and/or diagrams would have been kind.

Overall, I found the book highly useful, thought provoking, often challenging, and occasionally captivating.

It is in some ways a curious book, given the unusual set of topics, and the editors do not attempt to weave them together under a common construction (other than the somewhat catch-all title). Nevertheless, I liked the diversity here. I recommend this book to the reader who already has some familiarity with music cognition research in music performance, who wishes to know more about the basic mechanics of performance, and who enjoys a unique convergence of views.

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