EDITORIAL

Special Issue—Musical Movement and Synchronization

Music and movement are inseparable. Human music making requires the body—and often an instrument that serves as an extension of the body—to move in order to produce sound energy. When listening to music, moreover, most individuals experience the urge to move. Indeed, dance and music are blissfully wed in most cultures. Even if overt movement is inhibited, music perception recruits motor-related brain areas. Thus, some of the core cognitive and motor processes that underlie music performance are involved in the even more common activity of music listening.

From a historical perspective, the synergy of musical sound and bodily movement was the subject of early systematic but highly subjective investigations by Becking (1928) and Truslit (1938). Empirical music research targeted auditory processing in the ensuing decades (eventually well-nourished by the fruition of cognitivism in psychology) until sparks of renewed interest in the 1970s (e.g., Clynes, 1977) led to the emergence of rigorous qualitative and quantitative approaches to musical movement (see Davidson, 2005; Gabrielsson, 1987; Shove & Repp, 1995; Todd, 1999). An undercurrent to these developments is provided by research on sensorimotor synchronization (typically in the guise of finger tapping studies), which yielded sophisticated computational models of sensorimotor timing control by the mid-1990s (see Large, 2000; Pressing, 1999; Repp, 2005; Vorberg & Wing, 1996). Most recently, theoretical and empirical approaches that focus on links between music cognition and action have addressed the impact of motor processes on the perception of musical structure, as well as reciprocal effects of auditory information on motor control in the context of music performance in healthy individuals as well as in clinical settings (e.g., Bangert et al., 2006; Drost, Rieger, & Prinz, 2007; Leman, 2007; Pfordresher, 2008; Phillips-Silver & Trainor, 2008; Repp & Knoblich, 2007; Thaut, 2005).

To further our knowledge about such links, a workshop on 'Musical Movement and Synchronization' was held at the Max Planck Institute for Human Cognitive and Brain Sciences in Leipzig on the 3rd and 4th of May 2008. The main catalyst for this event was a visit to Leipzig by workshop co-organizer Caroline Palmer in October 2007. A specific aim of the workshop was to provide a forum for exchanging ideas on the scientific investigation of body movements that accompany solo and ensemble music performance and dance. Sixteen researchers were invited to present their discoveries about these topics, and this special issue of *Music Perception* comprises a reviewed and edited selection of eight articles based on these presentations. The organization of this collection of articles is tripartite: A quartet of articles on musical timing and kinematics is followed by two duets, one on movement coordination in space and time, and the other on links between movement and social communication.

Music is characterized by the precise temporal relation of sounds both within and between separate instrumental parts. The perceptual and motor processes that enable such precision are addressed in research reported in the first four articles, which examine movement timing and kinematics during musical activity. In the first contribution, Rankin, Large, and Fink focus on mechanisms involved in pulse prediction. To synchronize movements with music, it is necessary to predict the timing of upcoming sounds. Music typically contains both unintentional and intentional fluctuations in local tempo, with the latter being used by performers to communicate structural and expressive information to co-performers and audience members. Rankin, Large, and Fink employed a sensorimotor synchronization task to study adaptation to tempo fluctuations in expressive performances of piano music. Analyses of the relation between tap timing and expressive timing revealed that listeners are sensitive to long-range serial correlation (timing in an early portion of a sequence piece is similar to timing in a later portion) and fractal scaling (timing at fast time scales is proportionally similar to timing at slower time scales) in the expressive timing profiles of the music. Results indicated that listeners use these types of regularities to predict tempo changes.

In the next contribution, Loehr and Palmer describe a study that was designed to tease apart auditory and motor contributions to processes that underlie musical synchronization. In ensemble performance, musicians typically produce different rhythms that mesh to form a coherent Gestalt. Thus, performers routinely synchronize with each other under conditions where the

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temporal intervals produced by one performer are subdivided by those produced by another performer. Loehr and Palmer investigated the effects of such subdivisions on synchronization accuracy by employing a MIDI piano and a motion capture system to analyze the timing and movement characteristics of pianists as they performed melodic sequences in time with a metronome. In separate conditions, melody tones were subdivided by auditory information (heard tones), motor production (produced tones), both, or neither. The presence of subdivisions increased asynchronies in a manner suggesting that pianists were sensitive to the timing of both heard and produced subdivisions. However, kinematic analyses indicated that movement trajectories were influenced only by produced subdivisions.

Ensemble musicians coordinate their actions with one another under conditions of varying auditory and visual feedback, and these conditions can influence the roles that performers assume in the musical interplay. Goebl and Palmer investigated these issues by examining timing and movement characteristics in pianists who were assigned roles as leaders and followers during duet performance. The analysis of pianists' key stroke timing revealed that, under ideal circumstances (i.e., full auditory feedback), pianists adopted a cooperative performance style (with bidirectional adjustments) irrespective of the assigned roles. Analysis of head movements indicated that visual cues from co-performers were of greatest importance to coordination when auditory information was absent.

The articles described thus far illustrate how our understanding of musical timing and kinematics has profited from the study of piano performance. The final contribution in this section is relevant to the question whether results obtained with the piano generalize to other musical instruments. It is known from previous studies of piano performance that timing accuracy is influenced by sensory information associated with the finger's arrival at the piano key: Performances that contain kinematic landmarks indicative of high acceleration—and therefore force—at initial key contact display more accurate timing (Goebl & Palmer, 2008). Of course, finger acceleration also is used to control the intensity (loudness) of tones in piano playing. To investigate the contribution of tactile feedback to temporal accuracy while sidestepping this potential confound, Palmer, Koopmans, Loehr, and Carter examined clarinet playing in the current article. In contrast to the piano, clarinetists' finger movements affect the timing of tones, but not their intensity (which is controlled by airflow). Palmer et al. found a similar relationship between kinematic landmarks and temporal accuracy to that previously observed for piano playing. This buttresses the generality of the claim that tactile feedback plays an important role in timing control during music performance.

The second thematic cluster of the special issue contains two articles on spatial and temporal aspects of movement coordination. Consider the following scene: A man in a black lycra bodysuit sashays across the silent, darkened room, halts, arches his back, then performs a circular jump as another man in a red shirt and a woman in a purple dress swoop toward him. For some, dance as an artform may be a perplexing activity to engage in either as performer or audience member. The contribution by Stevens, Schubert, Wang, Kroos, and Havlovic demonstrates, nevertheless, that dance is not only "an ancient and ubiquitous form of human expression and communication" (Stevens et al., this volume, p. 451) but also an activity ideally suited to study time keeping, synchronization, and memory for movement sequences. Stevens et al. used a motion capture system to record the movements of one dancer from a trio as the group performed the same contemporary work twice; first without and then with accompanying music. It was found that the silent performance was shorter. Time-series analyses designed to distinguish between temporal scaling (uniformly faster or slower timing) and lapsing (omitted or inserted material) suggested that this duration difference was more likely due to memory lapses than a miscalibrated internal time-keeping mechanism.

The second contribution in this section addresses the coordination of movements with a conductor's gestures. Luck and Sloboda investigated the spatio-temporal cues that mediate this visually mediated form of synchronization in a study that required finger tapping in time with dynamic point-light displays of beat gestures produced by an experienced conductor. Analyses of the tapping data examined the effects of factors such as beat clarity and tempo on the kinematic features that participants spontaneously selected as synchronization targets. Points of high absolute acceleration were dominant cues to target time points for synchronization across differing levels of beat clarity and tempi.

The final section of this special issue includes two articles that deal with the relationship between movement and emotional and social aspects of musical behavior. Although movement is an essential ingredient in musical experience, movement per se is not typically the primary motivation for engaging in musical activity. Music is by and large a social phenomenon; a medium for affective communication. Vocal music is particularly interesting in this regard not only because it seems reasonable to assume that the voice is a phylogenetically and ontogenetically early mediator of group music making, but also because vocal sounds effortlessly carry acoustic traces of an individual's real or imagined emotional state. Furthermore, facial expressions when singing convey emotional information in a similar manner to how they function in everyday nonmusical interactions. In a study of emotional communication in singing, Livingstone, Thompson, and Russo employed motion capture and electromyography to monitor the facial expressions of singers as they viewed (and heard) audiovisual recordings of musical phrases that had to be subsequently imitated. These phrases had been recorded by a model singer with the intention to sound happy, sad, or emotionally neutral. Expressive facial activity that differentiated between target emotional states was observed during all stages of the task—perception, planning, production, and post-production—suggesting that cognition, action, and affect are tightly interwoven in emotional singing.

The final article in the special issue offers a broad literature review and theoretical discussion of music making and listening as inherently social activities. Indeed, it is well documented that even individuals who seem relatively disinterested in conventional social interaction, such as people with autism, find a companion in music. Overy and Molnar-Szakacs present a model that posits that the affective power of music derives from the way in which it supports imitation, synchronization, and shared experience. They argue that music does so by activating a network of brain areas—including the so-called 'mirror neuron system'—that play a role in action simulation, action understanding, and intention attribution. As a consequence, music conveys a sense of agency, arousing in the listener the experience of empathically perceiving another's actions and affective states. Overy and Molnar-Szakacs propose that this accounts for the effectiveness of music in emotional communication, and in therapeutic and educational contexts.

The full program of the Musical Movement and Synchronization workshop can be found on the Internet (www.cbs.mpg.de/news/workshops/1). Other publications by workshop participants that are relevant to this special issue address expressive body movements in music performance (Davidson, 2009; Nusseck & Wanderley, 2009), anticipatory movements in drumming and piano performance (Dahl, 2006; Dalla Bella & Palmer, 2006; Palmer, 2006), the effects of the firmness of the tapping surface on timing and kinematics during sensorimotor synchronization (Pfordresher & Palmer, 2008), the use of adaptively timed pacing signals to interrogate temporal error correction processes (Repp & Keller, 2008), and the cognitive/motor skills that underlie musical ensemble performance (Keller, 2008). Together with the articles published in this special issue, these studies exemplify the rich diversity of questions that have been tackled in research on musical movement and synchronization. In short, this vibrant field holds great promise for deepening our understanding of music cognition, action, and human interaction.

The metamorphosis of workshop presentations into journal articles is not a self-organizing process. We conclude by thanking the team of expert reviewers who provided constructive comments to the authors of the articles published in this special issue. Their dedication—together with the support of Editor Lola Cuddy and Managing Editor Christine Koh from *Music Perception*—has made possible the timely delivery of this compilation of fresh discoveries about musical movement and synchronization.

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