Chapter 14

Capturing Motion for Enhancing Performance: An Embodied Cognition Perspective on Sports and the Performing Arts

Vassilis Sevdalis[1], **Clemens Wöllner**[2]
[1]Department of Performance Psychology, Institute of Psychology, German Sport University Cologne, Cologne, Germany; [2]Institute of Systematic Musicology, University of Hamburg, Hamburg, Germany

During learning, a young musician has to find an optimal body posture in relation to his/her instrument to produce sounds effectively and without strain; a dancer needs to develop synchronization skills to match the movements of a partner. During performance, an athlete has to be able to "read" incidental variations of the game and position his/her body appropriately to score a goal. Early stages of learning require boosting the motivation and pleasure of the young trainee; professional performance requires a sustained amount of learning musical materials or sustaining high-pressure situations where each action may result in a win or a loss of the game.

Playing music, dancing, and practicing sports essentially entail some forms of bodily and cognitive engagement. These forms vary throughout learning processes and in performance situations. Ultimately, the goal of engagement with sports and the performing arts (e.g., music, dance) is to achieve an optimal outcome that meets certain standards compatible with one's level of training. This goal is achieved through long-term embodied practices: these practices require complex corporeal activities that combine high motor and cognitive demands. Applied motor performance domains, such as sports and the performing arts (i.e., music and dance), share considerable similarities regarding the engagement of the human body and the cognitive demands (e.g., perception and learning) imposed on the performing individuals. This chapter aims to shed light on the contributions of the body in guiding performance in perceptual and learning tasks, and it outlines how sensorimotor activities enable the long-term development of individual and interpersonal performance competences.

Performance Psychology. http://dx.doi.org/10.1016/B978-0-12-803377-7.00014-4

OVERVIEW OF THEORETICAL APPROACHES

Recent advances in cognitive science have underlined the potential of bodily functions in shaping cognitive processes (Grafton, 2009; Wilson, 2002), a conception that is often referred to as embodied cognition in scientific literature. Although different definitions of what qualifies as "embodied" have been suggested (e.g., Goldman & de Vignemont, 2009; Wilson & Golonka, 2013), most of the embodied cognition approaches converge to the fact that bodily contributions are fundamentally potent in altering cognitive functions (Schubert & Semin, 2009), especially those that concern perception and learning of body movements (Sevdalis & Keller, 2011a). A fundamental premise of the mechanism of embodied cognition is that individuals rely on their own sensorimotor experience when perceiving and learning actions (Herwig, Beisert, & Prinz, 2013; Prinz, 1990). For instance, while observing someone performing an action, observers can recruit some of their own sensorimotor resources as if they were performing the action themselves. This mapping of observed movements onto one's own sensory-motor system is known as action simulation (Jeannerod, 2006; see also Pizzera, Chapter 13 and Kennel & Pizzera, Chapter 15 in this book). The direct consequence of this premise is that alterations in sensorimotor experience that occur incidentally (e.g., by everyday experience) or deliberately (e.g., through training) have the potential to influence the processing that accompanies the observation of actions: this is done by (re-) establishing and updating (internal models of) the relations of the body and the environment in which the actions take place.

Quite some time ago, some of these concepts had already been discussed as "ideomotor theory," postulating strong links between action and perception (Lotze, 1852). Ideomotor learning occurs when people become aware that certain action consequences are caused by their movements. Focusing on action outcomes and exerting control over them may, thus, enhance motor learning (see also Koch, Keller, & Prinz, 2004). Similar ideas were developed by Theodor Lipps (1883, 1903), who stated that human interactions are largely based on inner co-sensations. Perceiving someone else moving may resonate with one's own kinaesthetic representation of these movements, eventually leading to empathic responses between the observer and the performer (for a recent review on empathy in sports and the performing arts, see Sevdalis & Raab, 2014). Interestingly, in addition to the perception of actions as such, even the perception of action outcomes, such as expressive variations in sound patterns, may trigger motor resonance in the observer (for a review, see Sevdalis & Keller, 2014).

Further pioneering work highlighted the importance of the environment and its properties in shaping an organism's behavior, especially with regard to visual perception (Gibson, 1979). Within an ecological framework, the environment specifies affordances to the organism, as possibilities for action, which the organism then perceives and acts upon. The task of the organism is to pick up information from the environment by detecting features that are relevant for dealing with a specific situation. Later approaches extended the approach of Gibson to more interpersonal/social settings: apart from an individual organism's relation with its environments, detecting features of other individuals can shape an organism's interactions with them (Marsh, Richardson, Baron, & Schmidt, 2006; McArthur & Baron, 1983). The presence of others and the interaction with them can also shape an individual's action possibilities. However, only recently theoretical work on joint action has been conducted in ecologically valid environments, such as in music and sports (D'Ausilio, Novembre, Fadiga, & Keller, 2015; Novembre & Keller, 2014; also Bekkering et al., 2009 for some sport examples).

The preceding theoretical approaches underline the benefit of considering the body and the environment as potent candidates in shaping cognitive processes. Features of the body (embodiment) and of the environment (embedding) play an active role in cognitive processing. According to this view, cognition per se is based on interactions between the mind, body, and environment (see Rowlands, 2010). Embodiment can be described as cognitive processes resulting from bodily sensations located in an "inner space," while embedded cognition refers to interactions with an "outer space" beyond one's own body (Leman, 2008). It has already been suggested that cognitive processes may be better understood if certain environments, circumstances, tools, and technologies are considered as parts of an "extended cognitive system": a cognitive system that does not reside exclusively in one's head (extended cognition thesis, Clark, 2008; Clark & Chalmers, 1998). Certain body–environment relations can actually function as vehicles for cognition, by supporting purely cognitive operations (Clark, 2008).

OVERVIEW OF EMPIRICAL RESEARCH

How can these theoretical approaches inform empirical research? Apart from acknowledging the fact that corporeal and environmental contributions can constitute parts of the cognitive system (an extended cognitive system), it is necessary to consider situations where (1) this is (optimally) possible and (2) this is (optimally) trainable. We hold that in order to investigate cognitive processes as they relate to the body and the environment, one has to investigate situations that involve all three components (cognition, body, and environment) where they unfold most prominently. Such situations are most prevalent in sports and the performing arts. Sports and the performing arts are ancient and culturally widespread activities, practiced on a daily basis, and often performed by individuals without much deliberate practice or expertise in them. They appear naturally in development through playful activities and spontaneous interactions. Still, through education and training, they can be cultivated to exceed established limits of the human potential. Practicing sports and performing arts, apart from performance outcomes that are aesthetically pleasurable to experience, brings about health and social-emotional benefits, both acute and long-term ones (MacDonald, Kreutz, & Mitchell, 2012; Williamon, 2004). Still, theoretical and empirical work combining frameworks such as the ones mentioned above is only recently emerging (e.g., D'Ausilio et al., 2015).

The assumption that cognition, body, and environment can be optimally investigated in applied motor performance contexts necessitates a methodological shift in the implementation of experimental designs for uncovering these relationships: research may benefit from moving beyond experimental tasks that stem from a cognitive psychology tradition to tasks that are commonplace to performing individuals (e.g., performing music, dancing, reacting to an opponent's movements, executing movement routines). This methodological shift can pose considerable challenges to the experimenter: learning and performance situations are complex and in continuous flux; they are often unique and difficult to reproduce. Examples of the challenges of studying motor behavior have been documented (Rosenbaum, 2005), and the potential benefits to the study of human behavior by investigating bodily movements have been outlined (de Gelder, 2009).

Innovative technologies that can capture the dynamics of performance at their nascence, such as motion capture, may be of assistance in investigating sports and performing arts contexts. Pioneering work by Johansson (1973) has shown that humans exhibit considerable sensitivity when observing movements, even if actions are depicted by just a few point-lights attached to an individual's body. In fact, human actions provide considerable information about an individual's characteristics (e.g., gender, identity) but also social-communicative signals (e.g., emotions, intentions) (for reviews see Blake & Shiffrar, 2007; Pavlova, 2012). A considerable benefit of capturing human motor performance is that experimental control can be implemented, thus, making the investigation of the dynamics of human (inter-) action possible. In this sense, capturing an individual's motor performance (e.g., by motion capture) and displaying it to observers to judge it (e.g., in point-light displays) is a useful tool to understand cognitive and social processes. Next, we outline some examples from empirical research in the domains of the performing arts (music and dance) and sports.

Research in the Performing Arts

A main stream of research on the relations between perception and action deals with the influence of embodied motor knowledge on perceptual tasks. Because a great deal of actions in the realm of motor performance occurs in social situations (e.g., reacting to an opponent or a dance partner, playing in a musical ensemble), advanced perceptual skills are crucial for successful interactions and interpersonal synchronization. In this regard, a fundamental aspect of acting upon an environment is to be in control of one's actions, understand their properties, and be aware of their consequences to others in interactive situations. In a series of studies, the capacity of individuals to distinguish between self- or other-generated actions and between expressive and inexpressive movement properties were investigated (Sevdalis & Keller, 2009, 2010, 2011b, 2012). In these experiments, the motor performance of individuals was recorded by a motion capture system. The individuals performing in these experiments were instructed to execute certain actions in synchrony with music (i.e., dancing, walking, and clapping). Actions were executed in solo or dyadic conditions. After several months, the same individuals who performed the actions were invited back to the lab, to observe point-light displays of their performances. The movements depicted in these displays were also varying in terms of their properties, with manipulations applied to their spatial-temporal parameters (e.g., duration of the movement, number of point-light markers available). The task for the participants was to identify whether the depicted point-light figure was themselves or another individual, and whether the movements of the depicted individual were expressive or inexpressive. Results indicated that discrimination performance in these tasks was fairly robust (i.e., even under conditions of occlusion), and possible even in non-experts. Self-reported empathy indices were also associated positively with discrimination accuracy. These results suggest that perceiving the actions of oneself and others and their expressive qualities relies on the dynamic properties of actions, especially their spatial and temporal characteristics. More complex movements provide richer information on agency and expression intensity and are, thus, easier to distinguish when observed as point-light displays (cf. Daprati, Wriessnegger, & Lacquaniti, 2007; Loula, Prasad, Harber, & Shiffrar, 2005).

If non-experts may recognize their own spontaneous movements in highly individual and information-rich activities, then experts with deliberately trained motor skills should show comparable performance characteristics even for more constrained movements. Furthermore, because action competencies in a specific domain aid in perception, deliberately trained movements should resonate in the observers' motor system to a higher degree compared to everyday-life movements. For answering these questions, a study investigated highly trained movements of orchestral conductors in comparison with their gait (Wöllner, 2012). Each orchestral conductor was matched with two further conductors according to age, gender, and expertise in a forced-choice self-other paradigm. Conductors were more successful in identifying their own movements when they were presented with point-light displays of skilled conducting gestures as compared to point-light displays of walking. In addition, conductors perceived the quality of their own gestures to be higher than those of others, independently of individual awareness of agency. These results indicate that perceptual response mechanisms resonate more with one's own skilled actions, even if performers are not fully aware of their agency. Individual perception of high-quality actions, thus, matches internal models of movements better in one's domain of expertise.

Characteristics of motor expertise, especially domain-specific action competencies, are mirrored in perceptual accuracy and also in behavioral tasks when reacting to other's movements in social interactions (Wöllner & Cañal-Bruland, 2010). String musicians were able to synchronize more accurately and more consistently with the entry movements of a first violinist shown in several video clips. They benefited from their motor expertise in playing string instruments themselves, as compared to highly trained observers (musicians of other instruments who were visually experienced in watching a first violinist) or individuals without such experiences. Perceptual consistency was, thus, related to motor consistency, which has been described as a key characteristic of expert performance in the domain of music and beyond (cf. Konczak, van der Velden, & Jaeger, 2009; Schoonderwaldt & Altenmüller, 2014).

Further research suggests that motor training may even affect the perception of person-related cues in observers. In common movements such as gait, cues of the walking person's gender are perceivable in point-light displays (e.g., Pollick, Kay, Heim, & Stringer, 2005). In a study by Wöllner and Deconinck (2013), musically trained participants watched point-light displays of male and female orchestral conductors with various degrees of expertise. Multimodal experimental conditions (in which sound and vision was provided alone or in combination) and two further control conditions (walking and static images) were implemented. Observers were able to indicate the conductors' gender in point-light displays of walking, replicating previous research, but not consistently for the skilled movements of conducting; while gestures of novice conductors provided some cues of their gender, experienced conductors' gestures did not afford such cues. Differences between experienced and less-experienced conductors for both males and females were present in their motor behavior as recorded with a motion capture system. Consistency in vertical acceleration patterns—a prominent cue for synchronizing with conducting gestures—was higher in experts. Taken together, these lines of research provide hints for the close relationship between perceptual and motor processes in deliberately trained (conducting) and naturally occurring spontaneous movements (walking). In fact, it remains a challenging task to investigate how facets of motor performance are intertwined: some aspects are explicitly learned and deliberately trained, while others are more implicitly acquired as for many daily movements. These ways of learning have an impact not only on the perception of independent observers, but also on the internal models of the individuals carrying out certain actions, or on the interaction between individuals in tasks with temporal or spatial constraints.

In a recent study, such characteristics were put into experimental test in a learning experiment on musical ensemble coordination (Ragert, Schröder, & Keller, 2013). Expert pianists were instructed to learn musical pieces and perform them in a dyadic situation. Auditory information and body movement were recorded (the latter with a motion capture system) and compared. The results suggest that knowledge about the musical structure of a co-performer's part is important for the interpersonal alignment of ancillary body movements (i.e., head motion and body sway) linked to the music's phrasal and metric structure at long time scales. In other words, interpersonal alignment of body movements may be a natural feature of ensemble performance when co-performers are familiar with each other's parts. This tendency was also shown in previous research where even unintentional congruency between the duet musicians' body sway (Keller & Appel, 2010) or ancillary movements (unrelated to the sound production) such as head nods (Goebl & Palmer, 2009) were shown to contribute to the ensemble's optimal coordination.

Research in Sports

The relationships between perception and performance have been additionally investigated in the domain of sports. Similarly to the domain of performing arts, research commonly focuses on the coupling between perceptual accuracy and performance practices, often in relation to motor expertise. In one study by Hohmann, Troje, Olmos, and Munzert (2011), professional basketball players and novice college students were asked to identify the type of basketball dribbles (e.g., between the legs, behind the back) when observing them as point-light displays. The results showed that experts performed better than novices in terms of identification accuracy and reaction times, but there was no perceptual advantage when observing actions generated by oneself, a teammate, or an unknown expert player. In another experiment (Hohmann et al., 2011), expert basketball players were asked to identify the dribbling actors (e.g., oneself, a teammate). Although identification of one's own actions was slightly better than identification of teammates, this difference did not reach significance. However, actor recognition was better for complex actions, such as dribbling, in comparison to a control condition displaying more stereotypical walking movements. Taken together, these results suggest that both information about an action and previous related training can affect perceptual performance.

Another interesting sport situation where the relations between training and performance become evident is to deliberately intend to deceive an opponent by one's actions. This is a challenging task for both expert and novice players, who need to realize the opponent's true intention and respond appropriately (Aglioti, Cesari, Romani, & Urgesi, 2008; Cañal-Bruland & Schmidt, 2009). Does expertise in performing an action enhance detection of deceptive intentions when observing movements? This question was examined by Sebanz and Shiffrar (2009), who asked experienced and novice basketball players to observe basketball passes and distinguish between fake or true ones. Results indicated that while experts' and novices' perceptual performance was similar when postural cues were displayed (i.e., static movie frames), experts outperformed novices when only kinematic information (i.e., point-light displays) was observed. In another study by Mori and Shimada (2013), anticipation of direction change in a running opponent was investigated in experienced and novice rugby players. Again, experts were better than novices in anticipating deceptive actions, irrespectively of whether actions were depicted as filmed sequences or as point-light displays. These findings highlight the importance of the impact of motor expertise in judging action outcomes.

Apart from cues detected in full body movements, action outcomes can be identified in simpler situations that include, for instance, anticipation of motor information in racket sports. In a series of experiments, prediction accuracy of badminton stroke direction and stroke depth was examined by recruiting expert and non-expert badminton players (Abernethy & Zawi, 2007; Abernethy, Zawi, & Jackson, 2008). The participants observed stroke movements in film and point-light conditions that introduced spatial and temporal occlusions to the kinematic information. The results showed that experts were better than non-experts in perceptual accuracy, especially when kinematic information was only depicted as point-light displays. Interestingly, experts could give accurate predictions by being more sensitive to early kinematic information (before the racquet-shuttle contact) and from kinematics that were functionally unrelated to the stroke (e.g., lower body movements). In contrast, non-expert participants were not attuned to such information and needed more stroke-specific information (e.g., from the racquet and the body movements concurrently).

The use of kinematic information was also investigated in another series of experiments on anticipation accuracy of tennis strokes (ground stroke vs lob stroke) by expert and novice tennis players (Shim, Carlton, & Kwon, 2006; Shim, Chow, Carlton, & Chae, 2005). In these experiments, anticipation accuracy was better than chance for both experts and novices, but non-experts' anticipation accuracy was not degraded by the use of point-light displays. However, with occlusion of the racket and forearm, the players' ability to determine the type of stroke reduced. Taken together, the findings from anticipation accuracy assessment in racket sports suggest that the relations between expertise and the dynamics of kinematic information between body parts and tools (i.e., racquet) are crucial for effective performance.

The deliberate use of critical kinematic information can be of assistance in learning situations, especially during the acquisition phase of a skill, when someone is learning by observation of prototype movements executed by a model. Breslin, Hodges, Williams, Kremer, and Curran (2006) investigated the importance of the relative motions of specific body parts (e.g., intra-limp vs inter-limp) for learning. Participants without previous experience of cricket bowling observed different versions of a point-light cricket bowler model performing an action, and they were asked to reproduce it. Participants were allocated to different learning groups that observed different amounts of kinematic information (e.g., full-body point-light display, intra-limb relative motions of the right bowling arm, inter-limp relative motions of the right and left wrists). The results showed that the groups that observed full-body and intra-limp displays were more accurate in the acquisition of the skill than the inter-limp observing group, suggesting that in early stages of skill acquisition, participants are more perceptually sensitive to the movements of action-specific body parts.

CONCLUSION

In this chapter, we provided an overview of theoretical approaches and empirical studies on how embodied practices situated in performance environments such as sports and the performing arts (i.e., music and dance) can support cognitive processes, especially in perceptual and learning tasks. The emphasis was put on investigations that considered the interactions between cognitive and bodily aspects of performance in ecologically valid settings. Variants of embodied experience became evident in action-specific bodily expertise, self-generated actions, effector-specific training, and bodily extensions by the use of tools. It is remarkable that across diverse performance domains such as sports, music, and dance, similar experimental and methodological paradigms have been implemented. For instance, agency (i.e., experiencing one's self as being in control of one's actions and their effects) has been investigated in performers as distinct as dancers, orchestral conductors, and basketball players. Action intentions have been a topic of inquiry for expressive body movements and for deceptive body movements. Action anticipation has been studied in interactive contexts, including the movements of an opponent rugby player or the movements of a fellow piano player. These studies introduced manipulations that tested the effects of sensorimotor experience both in terms of overt motor behavior (e.g., spatial-temporal occlusions) and long-term deliberate practice (e.g., expert–novice comparisons). These similarities may provide the ground for essential interdisciplinary dialogue in future investigations, especially with regard to the transfer of motor expertise across performance domains (see also Sevdalis & Raab, 2014).

Despite the diversity in domain-specific motor performance requirements and practices, examples such as the previous can be considered as facets of the same fundamental ability of social cognition. Being able to perform tasks such as perceiving agents, intentions, and anticipation tendencies informs individuals about themselves and others. The processing of social signals available in movements and their deliberate use in interactions is serving as a mutual action organization or "orchestration." It requires awareness of oneself and awareness of the effects of one's signals on others; it also relies on the ability to take into account another individual's point of view (Goldman & de Vignemont, 2009; Frith & Frith, 2012). Consequently, being in control of bodily information and responding appropriately to it has obvious benefits for an individual or a team in interactive contexts: it can lead to a more accurate representation of the dynamics of the situation and a better organization of one's actions toward shared or competitive goals. It can promote efficient action execution while playing, individually or in unison, by more accurately perceiving and predicting one's own and others' movements. It can contribute in building rapport and empathy between interacting individuals.

Performance enhancement also poses considerable challenges to the individual. Action execution and perception are error prone and require time to reach certain standards (see also Gray, 2014). For example, a player's intention can be misunderstood; a musician's instrumental sounds may lag behind those of others. As the empirical research overview highlighted, there are often considerable differences between experts and novices in aspects of motor performance such as timing consistency, movement variability, and use of kinematic information.

Implementing motion capture technology-based training programs that target sensorimotor skills can be a promising path for the future. The transition from novice to expert performance can be supported by exploiting embodied motor knowledge for learning purposes. Learning from or about others in performance contexts requires intense engagement of one's sensorimotor skills and guidance from experienced instructors. It is still an open empirical issue to define the degree of influence of embodied experience on cognitive functioning in a long-term perspective and in teaching situations. Therefore, longitudinal studies are necessary that investigate how emerging sensory-motor skills are mutually affecting each other during development. Comparisons between older and younger individuals are also required, which control for expertise and age effects: these characteristics may additionally influence cognitive fluency and command of motor precision because there are critical time points in development when sensorimotor skills begin to fade. More studies that involve interacting individuals can also be beneficial because they will inform about the development of action–perception links in real time. To conclude, sports, music, and dance provide a wealth of possibilities for examining perception–action links and can be at the forefront of scientific inquiries in performance psychology.

REFERENCES

Abernethy, B., & Zawi, K. (2007). Pickup of essential kinematics underpins expert perception of movement patterns. *Journal of Motor Behavior*, *39*, 353–367.

Abernethy, B., Zawi, K., & Jackson, R. C. (2008). Expertise and attunement to kinematic constraints. *Perception*, *37*, 931–948.

Aglioti, S. M., Cesari, P., Romani, M., & Urgesi, C. (2008). Action anticipation and motor resonance in elite basketball players. *Nature Neuroscience*, *11*, 1109–1116.

Bekkering, H., De Bruijn, E., Cuipers, R., Newman-Norlund, R., Van Schie, H., & Muelenbroek, R. (2009). Joint action: neurocognitive mechanisms supporting human interaction. *Topics in Cognitive Science*, *1*, 340–352.

Blake, R., & Shiffrar, M. (2007). Perception of human motion. *Annual Review of Psychology*, *58*, 47–73.

Breslin, G., Hodges, N. J., Williams, A. M., Kremer, J., & Curran, W. (2006). A comparison of intra- and inter-limb relative motion information in modelling a novel motor skill. *Human Movement Science*, *25*, 753–766.

Cañal-Bruland, R., & Schmidt, M. (2009). Response bias in judging deceptive movements. *Acta Psychologica*, *130*, 235–240.

Clark, A. (2008). *Supersizing the mind: Embodiment, action, and cognitive extension*. Oxford and New York: Oxford University Press.

Clark, A., & Chalmers, D. J. (1998). The extended mind. *Analysis*, *58*, 7–19.

Daprati, E., Wriessnegger, S., & Lacquaniti, F. (2007). Kinematic cues and recognition of self-generated actions. *Experimental Brain Research*, *177*, 31–44.

D'Ausilio, A., Novembre, G., Fadiga, L., & Keller, P. E. (2015). What can music tell us about social interaction? *Trends in Cognitive Sciences*, *19*, 111–114.

Frith, C. D., & Frith, U. (2012). Mechanisms of social cognition. *Annual Review of Psychology*, *63*, 287–313.

de Gelder, B. (2009). Why bodies? Twelve reasons for including bodily expressions in affective neuroscience. *Philosophical Transactions of the Royal Society B: Biological Sciences*, *364*, 3475–3484.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston, MA: Houghton Mifflin.

Goebl, W., & Palmer, C. (2009). Synchronization of timing and motion among performing musicians. *Music Perception*, *26*, 427–438.

Goldman, A., & de Vignemont, F. (2009). Is social cognition embodied? *Trends in Cognitive Science*, *13*, 154–159.

Grafton, S. T. (2009). Embodied cognition and the simulation of action to understand others. *Annals of the New York Academy of Sciences*, *1156*, 97–117.

Gray, R. (2014). Embodied perception in sport. *International Review of Sport and Exercise Psychology*, *7*, 72–86.

Herwig, A., Beisert, M., & Prinz, W. (2013). Action science emerging: introduction and leitmotifs. In W. Prinz, M. Beisert, & A. Herwig (Eds.), *Action science: Foundations of an emerging discipline* (pp. 1–33). Cambridge, MA: MIT Press.

Hohmann, T., Troje, N. F., Olmos, A., & Munzert, J. (2011). The influence of motor expertise and motor experience on action and actor recognition. *Journal of Cognitive Psychology*, *23*, 403–415.

Jeannerod, M. (2006). *Motor cognition: What actions tell the self*. New York: Oxford University Press.

Johansson, G. (1973). Visual perception of biological motion and a model for its analysis. *Perception & Psychophysics*, *14*, 201–211.

Keller, P. E., & Appel, M. (2010). Individual differences, auditory imagery, and the coordination of body movements and sounds in musical ensembles. *Music Perception*, *28*, 27–46.

Koch, I., Keller, P. E., & Prinz, W. (2004). The ideomotor approach to action control: implications for skilled performance. *International Journal of Sport and Exercise Psychology*, *2*, 362–375.

Konczak, J., van der Velden, H., & Jaeger, L. (2009). Learning to play the violin: motor control by freezing, not freeing degrees of freedom. *Journal of Motor Behavior*, *41*, 243–252.

Leman, M. (2008). *Embodied music cognition and mediation technology*. Cambridge, MA: MIT Press.

Lipps, T. (1883). *Grundtatsachen des Seelenlebens* [*Foundation principles of the mind*]. Bonn: Max Cohen & Sohn.

Lipps, T. (1903). *Grundlegung der Ästhetik* [*Foundation of aesthetics*]. Hamburg and Leipzig: Leopold Voss.

Lotze, R. H. (1852). *Medizinische Psychologie oder Physiologie der Seele* [*Medical psychology or physiology of the mind*]. Leipzig: Weidmannsche Buchhandlung.

Loula, F., Prasad, S., Harber, K., & Shiffrar, M. (2005). Recognizing people from their movement. *Journal of Experimental Psychology: Human Perception and Performance*, *31*, 210–220.

MacDonald, R., Kreutz, G., & Mitchell, L. (Eds.). (2012). *Music, health and wellbeing*. New York: Oxford University Press.

Marsh, K. L., Richardson, M. J., Baron, R. M., & Schmidt, R. C. (2006). Contrasting approaches to perceiving and acting with others. *Ecological Psychology*, *18*, 1–37.

McArthur, L. Z., & Baron, R. M. (1983). Toward an ecological theory of social perception. *Psychological Review*, *90*, 215–238.

Mori, S., & Shimada, T. (2013). Expert anticipation from deceptive action. *Attention, Perception, and Psychophysics*, *75*, 751–770.

Novembre, G., & Keller, P. E. (2014). A conceptual review on action-perception coupling in the musicians' brain: what is it good for? *Frontiers in Human Neuroscience*, *8*, 603.

Pavlova, M. A. (2012). Biological motion processing as a hallmark of social cognition. *Cerebral Cortex*, *22*, 981–995.

Pollick, F. E., Kay, J., Heim, K., & Stringer, R. (2005). Gender recognition from point-light walkers. *Journal of Experimental Psychology: Human Perception and Performance*, *31*, 1247–1265.

Prinz, W. (1990). A common coding approach to perception and action. In O. Neumann & W. Prinz (Eds.), *Relationships between perception and action: Current approaches* (pp. 167–201). Berlin: Springer.

Ragert, M., Schröder, T., & Keller, P. E. (2013). Knowing too little or too much: the effects of familiarity with a co-performer's part on interpersonal coordination in musical ensembles. *Frontiers in Psychology*, *4*, 368.

Rosenbaum, D. A. (2005). The Cinderella of psychology: the neglect of motor control in the science of mental life and behavior. *American Psychologist*, *60*, 308–317.

Rowlands, M. (2010). *The new science of the mind: From extended mind to embodied phenomenology*. Cambridge, MA: MIT Press.

Schoonderwaldt, E., & Altenmüller, E. (2014). Coordination in fast repetitive violin-bowing patterns. *PLoS One*, *9*(9), e106615.

Schubert, T. W., & Semin, G. R. (2009). Embodiment as a unifying perspective for psychology. *European Journal of Social Psychology*, *39*, 1135–1141.

Sebanz, N., & Shiffrar, M. (2009). Detecting deception in a bluffing body: The role of expertise. *Psychonomic Bulletin & Review*, *16*, 170–175.

Sevdalis, V., & Keller, P. E. (2009). Self-recognition in the perception of actions performed in synchrony with music. *Annals of the New York Academy of Sciences*, *1169*, 499–502.

Sevdalis, V., & Keller, P. E. (2010). Cues for self-recognition in point-light displays of actions performed in synchrony with music. *Consciousness and Cognition*, *19*, 617–626.

Sevdalis, V., & Keller, P. E. (2011a). Captured by motion: dance, action understanding, and social cognition. *Brain and Cognition*, *77*, 231–236.

Sevdalis, V., & Keller, P. E. (2011b). Perceiving performer identity and intended expression intensity in point-light displays of dance. *Psychological Research*, *75*, 423–434.

Sevdalis, V., & Keller, P. E. (2012). Perceiving bodies in motion: expression intensity, empathy, and experience. *Experimental Brain Research*, *222*, 447–453.

Sevdalis, V., & Keller, P. E. (2014). Know thy sound: perceiving self and others in musical contexts. *Acta Psychologica*, *152*, 67–74.

Sevdalis, V., & Raab, M. (2014). Empathy in sports, exercise, and the performing arts. *Psychology of Sport and Exercise*, *15*, 173–179.

Shim, J., Carlton, L. G., & Kwon, Y. H. (2006). Perception of kinematic characteristics of tennis strokes for anticipating stroke type and direction. *Research Quarterly for Exercise and Sport*, *77*, 326–339.

Shim, J., Chow, J. W., Carlton, L. G., & Chae, W. S. (2005). The use of anticipatory visual cues by highly skilled tennis players. *Journal of Motor Behavior*, *37*, 164–175.

Williamon, A. (Ed.). (2004). *Musical excellence: Strategies and techniques to enhance performance*. New York: Oxford University Press.

Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review*, *9*, 625–636.

Wilson, A. D., & Golonka, S. (2013). Embodied cognition is not what you think it is. *Frontiers in Psychology*, *4*, 58.

Wöllner, C. (2012). Self-recognition of highly skilled actions: a study of orchestral conductors. *Consciousness and Cognition*, *21*, 1311–1321.

Wöllner, C., & Cañal-Bruland, R. (2010). Keeping an eye on the violinist: motor experts show superior timing consistency in a visual perception task. *Psychological Research*, *74*, 579–585.

Wöllner, C., & Deconinck, F. J. A. (2013). Gender recognition depends on type of movement and motor skill. Analysing and perceiving biological motion in musical and nonmusical tasks. *Acta Psychologica*, *143*, 79–87.

Chapter 15

Auditory Action Perception

Christian Kennel[1], Alexandra Pizzera[2]

[1]Department of Performance Psychology, German Sport University Cologne, Cologne, Germany;
[2]Institute of Sports and Sports Sciences, Heidelberg University, Heidelberg, Germany

Walking produces sounds through an individual's footsteps. If an individual hears the sound of a foot dragging on the ground, this may cause the individual to lift up the foot a little bit higher during the next step. Furthermore, the individual may use this experience in perceiving footstep sounds for subsequent steps. Consider athletes who, on hearing their own footstep sounds, make adjustments to stride while running over hurdles or sprinting toward the takeoff board for the long jump.

Every action produces sound, which influences every subsequent action, leading to a strong interplay between the senses and motor activity. In this chapter, we elaborate on this action–auditory perception interplay. We begin with a brief description of auditory perception and then discuss how this perception is processed when focusing on action. We then present theoretical advances in this field and how these can explain the bidirectional link between perception and action from an auditory perspective. To round off this chapter, we discuss empirical studies that have explored the effects of natural as well as artificial movement sounds on the perception, learning, and control of bodily movements.

AUDITORY PERCEPTION

Hearing is the ability to perceive sounds by detecting changes in the air pressure (or other medium) which are caused by vibrations. It is one of the remote senses, that is, it is used to collect information from a distance. These vibrations (sound waves), captured by the ear, are transduced into nerve impulses in the cochlea. Afterward, multiple brain areas such as the auditory cortex of the temporal lobe perceive the nerve impulses. Humans are able (with intra- and extra-individual variation) to hear sounds with a frequency between 20 Hz and 16 kHz and sound pressure between 0 and 120 dB (Faller & Schünke, 2012). This ability to detect and translate sound waves is highly sensitive, even to the tiniest changes in the intensity or type of sound wave. However, this is not the only important characteristic of the auditory system. In addition, humans are able to segregate an auditory percept into different streams (Bregman, Liao, & Levitan, 1990). This segregation happens hierarchically to obtain a meaningful

Performance Psychology. http://dx.doi.org/10.1016/B978-0-12-803377-7.00015-6