1 General introduction

1.1 Anticipatory action control

A central issue of sport psychology is to understand how highly skilled performers of, for example, soccer, gymnasts, or track and field are able to seemingly effortless and smoothly perform complex movements (Schmidt & Lee, 2011). The set of processes that enable athletes to move the body in desired ways are subsumed under the term *motor control* (referring to Rosenbaum, 2002, p. 315). Moreover, athletes usually perform particular movements to attain an intended goal, which turns a movement by definition to an *action* (referring to Gallese, 2000). Accordingly, motor control of sport movements also can be termed as *action control.* Within this thesis, the term action control is used to emphasize intentional, goal oriented processes. The term motor control is used for mainly describing physiological regulation and control processes.

Former theories of motor control traditionally can be classified as closed loop (Adams, 1971) and open loop theories (James, 1890). Closed loop theories generally claim that sensory information resulting from movement production is used to control the movement. That is, sensory feedback is used to compare the intended movement stage with the actual movement stage and to correct movement errors (i.e. a discrepancy between intended and actual movement stages) if necessary. Open loop theories, in contrast, claim that sensory information is not necessary for movement production but might serve as trigger stimulus for the next contraction until the movement is completed (response-chaining hypothesis, James, 1890). As a variety of deafferentation studies in animals (e.g. Polit & Bizzi, 1978) and humans (Kelso, 1977; Kelso, Holt, & Flatt, 1980) indicated that no sensory feedback is needed to produce goal oriented movements, a central control of movements has been proposed (Keele, 1968; Lashley, 1917; Schmidt, 1975). More precisely, centrally stored motor programs for a particular class of actions were assumed to carry out movements with nearly no need of sensory feedback (Schmidt, 1975). In order to distinguish centrally stored motor programs from the response chaining hypothesis, motor program theories overemphasized the role of central mechanisms and neglected the importance of sensory effects for movement control (Schack, 2007, 2010).

Recently, sensory action effects have been reconsidered as being crucial for motor control (Hoffmann, Butz, Herbort, Kiesel, & Lenhard, 2007; Kunde, 2006). It is argued that producing an action leads to sensory effects which are automatically linked with the corresponding action. The strength of the relation between an action and its effect increases the more often it is experienced. Moreover, the relation between actions and its effects is bi-directional, that is, anticipating an effect might initiate the action producing the effect. This view on motor control is called *ideo-motor approach.* Without naming it ideo-motor, this principle has already been described in the early 19th century by Herbart (1825). Herbart (1825) points out that the ideo-motor principle might explain voluntary action control. It explains how an intended goal leads to appropriate body movements.

The term ideo-motor originally was coined by the British researcher Carpenter (1852) who claimed that the mere *idea* of an action might trigger the corresponding *motor* activity. Carpenter, in contrast to Herbart (1825), suggested ideo-motor movements as being reflex-like and non-intentional (for a historical overview of the ideo-motor principle see Stock & Stock, 2004). James (1890) considered the ideas about voluntary action control (Herbart, 1825) and adopted Carpenters' suitable term ideo-motor (1852). By publishing this view on voluntary action control in a standard textbook of psychology (James, 1890), James ensured a wide-spread popularity of the ideo-motor principle.
To date, the ideo-motor principle can be regarded as core topic in cognitive psychology and has been adopted to recent theoretical frameworks of action control (i.e. Anticipatory Behavioral Control (ABC), Hoffmann, 2003; Theory of Event Coding (TEC), Hommel, Müsseler, Aschersleben, & Prinz, 2001; Cognitive Action Architecture Approach (CAA-A), Schack, 2010). The core aspect of the early ideo-motor suggestions (Herbart, 1825) still applies today. An action not only produces effects, but anticipating an effect also activates the corresponding action (i.e. *effect anticipation*). Besides, a second anticipatory mechanism recently is associated with the ideo-motor approach. Namely that planned actions might immediately be executed if an anticipatory defined stimulus pattern signals an appropriate action possibility (i.e. *start anticipation* (Kunde, Elsner, & Kiesel, 2007)). Start anticipations have also been termed *situational contextualisation* (Hoffmann et al., 2007; Hoffmann, Butz, et al., 2007) or *action trigger conditions* (Kunde, Kiesel, & Hoffmann, 2003).
As outlined, effect anticipations play a crucial role for the initiation of voluntary actions. Importantly, effect anticipations might also be used to control an ongoing action. That is, anticipated action effects might be compared with perceived action effects, and discrepancies were corrected if necessary. Concerning start anticipations, it seems obvious that only a fast visual recognition of, for example, the intended action of an opponent might enable an athlete to initiate a motor reaction in time. Evidently, action production and action perception are highly interwoven. Therefore, the main purpose of this thesis is to investigate the role of motor expertise influencing perceptual processes necessary for action initiation and action control. Before illuminating the issue of skilled action perception, specific aspects of the ideo-motor principle are outlined in greater detail.

1.1.1 Effect anticipations

There are preliminary two different methodological approaches supporting the idea that the anticipation of an effect activates the action commonly producing the effect. One experimental approach is based on participants' learning of action-effect associations (Greenwald, 1970). In a first acquisition phase, participants learn, for example, that a left key press triggers a low tone, whereas pressing a right key triggers a high tone. In the test phase, participants were asked to respond to the previous effect tones as quickly as possible. Participants assigned to a stimulus response mapping