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The influence of attentional focus on the development of skill representation in a complex action

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ABSTRACT

Objectives: Recent research has indicated that performers' mental representation of a motor skill changes over the course of learning. In the present study, we sought to ascertain whether the type of instructions (instructions that emphasize either an internal or external focus of attention) influences the development of skill representation during motor learning.

Design: Participants without golf experience were recruited to practice a golf putting task over the course of three training days. Participants were randomly assigned to either an internal focus (focus on the swing of the arms; $n = 10$) or external focus (focus on the speed of the ball roll; $n = 10$) learning group. Changes in putting performance and mental representation structure were assessed over the course of learning, as well as during a follow-up retention test two days after practice.

Methods: Mental representation structure was measured employing the structural dimensional analysis of mental representations (SDA-M), which provided psychometric data on the structure of the mental representation in long-term memory. Additionally, the change in putting accuracy and consistency was recorded over the course of learning.

Results: Findings indicated that the external focus group performed with greater accuracy and consistency during training, and revealed a larger degree of development in their mental representation of the putting task.

Conclusions: Overall, our findings suggest that facilitating the link between an action and its effect by means of an external focus is crucial for motor performance as well as the development of skill representation.

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It has been well established that an individual's focus of attention can have important implications for motor performance (e.g., Beilock, Carr, MacMahon, & Starkes, 2002; Gray, 2004; Jackson, Ashford, & Norsworthy, 2006; Wulf, 2007). That is, what an individual focuses on during the execution of a motor task can greatly influence the quality and accuracy of the movement. To this extent, research has demonstrated that an external focus of attention (i.e., focus on the effects of the movement on the environment) can lead to greater performance accuracy (e.g., Wulf, Lauterbach, & Toole, 1999; Wulf & Su, 2007), reduced attentional/working memory demands (e.g., Wulf, McNevin, & Shea, 2001), reduced brain and muscle activity (e.g., Zachry, Wulf, Mercer, & Bezodis, 2004), reduced susceptibility to choking under pressure (e.g., Land & Tenenbaum, 2012), and overall better outcome performance (e.g., McNevin, Shea, & Wulf, 2003) compared to an internal focus (i.e., attention directed to the performer's own body movements) or irrelevant focus (i.e., attention directed to stimuli not pertaining to the task).

Furthermore, one's focus of attention may also play an important role during the learning of a new motor skill. Research has indicated significant differences in motor skill acquisition as a result of how one focuses their attention (e.g., external or internal focus of attention) during learning (see Wulf, 2007). Traditionally, motor learning has been assumed to benefit from attention directed to the step-by-step components of skill execution (Wulf & McNevin, 2003). Instructions and feedback, therefore, are typically given to novices regarding various aspects of their movements. However, recent research suggests that skill acquisition is facilitated when attention is directed externally to the effects of one's

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movement on the environment, and not the movements themselves (Castaneda & Gray, 2007; McNevin et al., 2003; Shea & Wulf, 1999).

One such study that demonstrated the learning advantage of an external focus was conducted by Wulf et al. (1999). In the study, novice participants were required to practice a golf pitch shot under learning instructions that emphasized either an internal focus or an external focus of attention. Specifically, the internal learning group was instructed to focus on the swinging motion of their arms. In contrast, the external learning group was instructed to focus on the swinging of the golf club. Results from the study indicated that learners who adopted an external focus significantly outperformed (i.e., high accuracy scores) those who adopted an internal focus of attention during learning. Furthermore, a subsequent retention test on the following day revealed that the external learning group maintained a performance advantage even when no focus instructions were given. Similar findings were also reported by Wulf and Su (2007).

The comparative learning benefits associated with an external focus compared to an internal focus have been observed across a variety of tasks such as ski simulators (Wulf, Höß, & Prinz, 1998), golf pitch shots (Wulf et al., 1999), soccer throw-ins (Wulf, Chiviacowsky, Schiller, & Ávila, 2010), and tennis backhands (Maddox, Wulf, & Wright, 1999). These learning benefits have been argued to result from promoting movements supported by automatic motor control processes, whereas, an internal focus is suggested to be ineffective and delay learning due to the conscious interferences with normal and automatic motor control processes (i.e., constrained action hypothesis; McNevin et al., 2003; Wulf, McNevin, et al., 2001; Wulf, Shea, & Park, 2001). Additionally, the benefits associated with an external focus have been linked to the coding of motor actions in long term memory. Drawn from the principles of ideomotor theory (James, 1890; Lotze, 1852), Prinz's (1990), common-coding theory postulates that actions are represented in terms of their perceptual effects in the environment. Furthermore, it is suggested that a commonality exists between the representations underlying perception and action such that the anticipation of the perceptual consequences of an action act to prime the intended motor execution (see Hommel, Müsseler, Aschersleben, & Prinz, 2001).

Given that focusing on the effects of one's movements on the environment is thought to prime the associated motor execution, it is also likely that this same kind of focus is beneficial for acquiring the underlying sensorimotor representation linking actions to their effects (Hommel, 2007). That is, an external focus may also facilitate the integration of effector and perceptual processes during motor learning, and play an important role in the development of one's sensorimotor representation (Weigelt, Schack, & Kunde, 2007).

During practice, researchers have suggested that task specific cognitive representations are acquired which act to guide the planning and execution of actions (Ericsson, 2007; Hommel et al., 2001; Schack & Ritter, 2013; Schmidt, 1975, 1976). According to the cognitive action architecture approach (CAA-A, Schack, 2004; Schack & Mechsner, 2006; Schack & Ritter, 2009), motor learning is considered as the modification and adaptation of such representation structures in memory. Specifically, Schack and Mechsner (2006) suggest that the representation of complex actions are organized within hierarchical memory structures comprised of cognitive units, referred to as basic action concepts (BACs). These BACs represent particular body postures (key elements of movements) and correspond to perceptual effects of movement events in order to organize motor coordination. Therefore, they are seen as cognitive tools in realization of action goals. Within the cognitive architecture of action, BACs are stored at a representational level and code the movement structure at a given level of expertise. Consequently, BACs are considered the major building blocks of cognitive representations, with the chunking and hierarchical ordering of the BACs reflecting the degree of expertise associated with a particular motor action. A number of studies have shown, that motor expertise is functionally related to the degree of order formation of BACs in memory (e.g., Bläsing, Tenenbaum, & Schack, 2009; Schack & Hackfort, 2007). Similarly, Elsner and Hommel (2001) propose that actions are controlled via representational units comprised of integrated motor structures along with their perceptual consequences.

In order to investigate the structure of these representations in memory, Schack and Mechsner (2006) employed an experimental approach to examine differences in the structure of mental representations between expert, low-level, and novice tennis players. In their study, the authors investigated the players' mental representation of a tennis serve using the structural dimensional analysis of mental representation (SDA-M; Schack, 2004; 2012). The SDA-M analysis identifies the structural composition of skill representation through revealing the hierarchical and temporal structure of BACs within long-term memory. Findings from the study indicated that experts' representations were more elaborate compared to the non-experts' representations. Specifically, experts' representations were organized in a distinctive tree-like structure comprised of clusters of BACs relating to the biomechanical task demands, whereas the representations of novices and low-level players' were organized less hierarchically and were unrelated to the functional demands of the task. In addition, experts' representations were highly similar across individuals, while lower skilled participants' representations were more varied. These findings highlight the significant differences in skill representation between performers of differing skill levels.

Similar differences in representation structure between experts and novices have been found across a variety of complex motor skills such as windsurfing (Schack & Hackfort, 2007), judo (Weigelt, Ahlmeyer, Lex, & Schack, 2011), and dance (Bläsing et al., 2009), as well as in manual action tasks (e.g., Stöckel, Hughes, & Schack, 2011) and within special populations (e.g., stroke rehabilitation; Braun et al., 2007). The striking differences in representations found between performers of different skill levels support the assumption that motor learning leads to the development of skill representations which play an important role in the control and organization of actions (e.g., Elsner & Hommel, 2001).

As a more direct test of this assertion, Frank, Land, and Schack (2013) recently investigated the development of mental representation structures during the early skill acquisition of a complex motor task. Using a longitudinal design, a group of novices practiced a golf putting task over the course of five training days. The structure of the participants' skill representations were assessed before and after training. Results indicated that along with improved putting proficiency, significant changes emerged within the practice group's mental representation. Specifically, prior to practice, no functional structure was evident within the group's mental representation. However, after considerable task experience, the practice group's representation structure reflected a shift towards a hierarchical organization of action concepts similar to that of more skilled players. In contrast, a control group, who did not practice the golf task, did not reveal any significant changes in skill representation between pre- and post-testing. These findings support the notion that functional adaptations of motor skill representations (i.e., changes in the representation structure which more closely resembles the movement phases of the motor skill) are closely tied to motor learning.

While motor skill acquisition has been shown to be accompanied by the formation of representation structures in long term memory, it is currently unclear how different foci of attention affect

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