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Effects of attentional-focus instructions on movement kinematics

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ABSTRACT

Background: Recent research has shown that internal (body-related) attention-focus instructions disrupt motor learning and performance, whereas paying attention to the environmental effects of movements (external focus) leads to better performance than an internal focus [see, for reviews, Wulf, G. (2007). Attentional focus and motor learning: a review of 10 years of research. *E-Journal Bewegung und Training, 1*, 4–14.; Wulf, G., & Prinz, W. (2001). Directing attention to movement effects enhances learning: a review. *Psychonomic Bulletin & Review, 8*, 648–660.]. However, Beilock's studies [Beilock, S. L., Bertenthal, B. I., McCoy, A. M., & Carr, T. H. (2004). Haste does not always make waste: expertise, direction of attention, and speed versus accuracy in performing sensorimotor skills. *Psychonomic Bulletin & Review, 11*, 373–379.] suggest that an internal focus is detrimental in experts but not in novices. Because detrimental effects of consciously attending to movements have generally been measured by performance scores such as accuracy scores or reaction times, it remains unclear how internal and external attentional-focus instructions influence movement kinematics when learning a new skill. To fill this gap, the present study investigated attentional-focus effects on a biomechanical level.

Methods: A video of an expert juggler demonstrating a two-ball juggling task was presented to juggling novices. Experimental groups were given either body-related (internal group) or ball-related (external group) verbal instructions or no attention-guiding instructions (control group). In the retention phase without attention-guiding instructions, the body-movement and ball-flight aspects of performance focused on in the verbal instruction were subjected to biomechanical analyses.

Results and Conclusions: Juggling performance improved equally in all three groups. However, internally vs. externally instructed acquisition phases had differential effects on the kinematics of the upper body as well as ball trajectories when performing the juggling task. Remarkably, ball trajectories in the control group who received no specific attentional cueing were similar to those in the externally instructed group. This suggests that task-relevant information is picked up independently of instructions, and that external instructions provide redundant information. Internal instructions for object-related tasks, however, may confront novice learners with the need to process additional information. As a result, task difficulty might be unnecessarily enhanced in an observational learning setting.

Instructions are used ubiquitously when teaching motor skills (Magill, 2004). Not only do practitioners commonly present model demonstrations as a visual instruction in order to build up motor representations (Horn & Williams, 2004; Hodges et al., 2003), but they also use verbal instructions to guide the "learners' search for the best motor solution" (Magill, 2004, p. 259). Early research by Solley (1952) found that the initial focus during task execution mediated by a verbal instruction impacted strongly on both performance and learning. Participants were instructed initially to emphasize either speed or accuracy in a striking skill. A transfer test with new instructions revealed that the effects were maintained (especially for speed), indicating that the instructional pattern given to the learner at the beginning of practice had long-term effects on motor behavior.

Wulf et al. have also studied attentional-focus instructions in recent times. Their studies used instructions to guide learners' attentional focus during the execution of a novel skill. They called consciously attending to the movements (i.e., the moving body parts) during skill execution "internal attentional focus," and focusing attention on the effects of the movements in the

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environment (i.e., a moving racquet or a ball) "external attentional focus." In a series of experiments (McNevin, Shea, & Wulf, 2003; Totsika & Wulf, 2003; Wulf, Hoess, & Prinz, 1998; Wulf, Lauterbach, & Toole, 1999; Wulf, McNevin, & Shea, 2001), they showed that an internal focus was detrimental to performance and learning, whereas an external attentional focus was superior—especially for learning. To assess learning, Wulf et al. administered retention tests without attentional guiding. These revealed enduring effects of the attentional-focus instructions given in the acquisition phase.

To explain these attentional-focus effects in motor learning, recent behavioral literature has proposed hypotheses derived from the idea that skills run more automatically in a nonconscious mode and that unfamiliar attentional tasks might interrupt automaticity (Masters, Polman, & Hammond, 1993). For example, Wulf et al. (2001) formulated the constrained-action hypothesis (CAH) to interpret their empirical results. This posits that conscious internal, body-related attention disturbs natural motor-control processes. CAH suggests that external attention is more compatible with the mode in which actions are actually controlled (see, for details, Wulf, 2007; Wulf & Prinz, 2001). The attentional-focus literature has proposed ideomotor approaches to explain these results. Ideomotor approaches state that actions are based on representations that code for anticipated sensory consequences, that is, action effects (Koch, Keller, & Prinz, 2004; Prinz, 1987, 1997). Empirically, it has been shown that external instructions focusing on the *effect* of the movement are superior to external instructions that refer merely to non-movement-related aspects in the environment (Castaneda & Gray, 2007 [but only for highly skilled players]; Wulf, McNevin, Fuchs, Ritter, & Toole, 2000).

Beilock et al. (Beilock et al., 2004; Beilock, Carr, MacMahon, & Starkes, 2002) and Gray (Castaneda & Gray, 2007; Gray, 2004) have adopted a different theoretical and empirical approach. These authors found detrimental effects of an internal focus only in overlearned, automatic tasks. In other words, an internal focus did not cause detrimental effects per se but only in experts. Results were explained with the deautomatization-of-skills hypothesis (DoSH). This assumes that an internal attentional orientation leads to skill deproceduralization through the re-emergence of single task elements in working memory, as suggested by the theory of reinvestment (see, for a review, Masters & Maxwell, 2008). Therefore, an internal focus should have negative effects on expert, but not on novice performance. Interestingly, novices performed better in skill-focused conditions compared with dual-task conditions that distracted participants' attention away from the skill (Beilock et al., 2002, 2004). These results challenge the assumption that attentional-focus effects operate comparably in experts and novices, and seem to suggest specific effects that are more skill-dependent.

At present, the issue of when and how attentional foci affect motor performance is unresolved for numerous reasons. One problem is that the CAH lacks a clear notion of the characteristics of "natural" motor-control processes, and these are rarely investigated in Wulf's studies. DoSH, on the other hand, also needs to specify how deproceduralization impacts on motor-control parameters. Therefore, to overcome the gap between these theories and performance effects, it is necessary to clarify how the specific contents of attentional-focus instructions influence motor control and learning. Analyzing movement kinematics in relation to instructional content might be a vital intermediate step in resolving this issue (see, for a similar suggestion, Wulf, 2007).

The objective of the present study was to use a juggling task to investigate attentional-focus effects on motor control from a biomechanical viewpoint. Wohlschläger and Bekkering (2002) suggested that objects represent the main goal (i.e., the action effects) in an object-related motor task, whereas the effectors (i.e., the limbs) are the means to achieve these goals. In juggling, action effects can be perceived clearly by means of ball trajectories, which is the task-relevant and salient cue in juggling. The external instruction given in this study is clearly related to ball flight (i.e., the action effect as the main goal), whereas the internal instruction relates to the arm movement during juggling by which ball-flight effects are achieved. In this study, we investigated how the specific instructional contents given in the external and internal conditions were implemented in participants' motor behavior. This makes this the first study to examine whether and how the content of a specific, attentional-guiding instruction (Solley, 1952) actually is implemented in motor behavior. Our design also permitted the study of the nonattended instructional aspect, that is, the external instructional aspect in the internal group and vice versa. Finally, biomechanical data were compared with learners receiving no instructions who served as controls.

It was hypothesized that the internal instructional content would be implemented in participants' behavior, that is, that the internal-focus instruction would specifically affect body movements compared with the external group. Likewise, it was hypothesized that ball-flight aspects would be superior in the external compared with the internal group.

Novices pay specific attention to ball characteristics, because these express the essential task goal of juggling (Gentile, 1972; Wohlschläger & Bekkering, 2002). Studies on action observation and action control also suggest that in object-manipulation tasks, gaze is directed implicitly toward the object rather than the moving hand (Flanagan & Johansson, 2003). This is relevant for other object-related sports tasks such as kicking a soccer ball, returning a tennis ball, or serving in volleyball. Therefore, it was hypothesized that ball-flight aspects of the external group would resemble the pattern of the noninstructed control group, because the control group picks up this salient movement effect without explicit verbal instruction. Focusing internally, however, should conflict with this externally oriented learning mode. Accordingly, a decrement in ball-flight aspects should result for learners receiving internal-focus instructions.

Methods

Participants

A total of 61 university students (30 female, 31 male) participated in this experiment. One participant was excluded because she was absent at the retention test. Two further participants were dropped after the pretest for novice status (see below), because they proved to be advanced jugglers. The remaining 58 participants (29 female, 29 male, age $M = 23.7$ years, $SD = 2.54$) had no or very little juggling experience. They were divided into three experimental groups ($n = 23$ external, $n = 23$ internal, $n = 12$ control) on the basis of their pretest performance and sex. Participants were informed that the aim of the study was to examine learning a juggling skill, but were not told about the differential group interventions. Each participant signed informed consent forms and filled out questionnaires with personal data. They were all right-handed (according to the Edinburgh Handedness Inventory, Oldfield, 1971) and had normal or corrected-to-normal vision. Participants volunteered and were not paid for their services. The experiment was conducted in accordance with the Declaration of Helsinki.

To verify that all participants were novices, they were given a pretest of one-hand-one-ball juggling (a so-called column) for both hands. Three independent raters counted and documented the tosses and catches during 10 trials on each side. Performance was generally superior for the right hand because all participants were right-handed. This pretest was used to balance the