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# Cognitive mediation of putting: Use of a think-aloud measure and implications for studies of golf-putting in the laboratory

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ABSTRACT

*Objectives:* Whereas accounts of skilled performance based on automaticity (Beilock & Carr, 2001; Fitts & Posner, 1967) emphasize reduced cognitive involvement in advanced skill, other accounts propose that skilled performance relies on increased cognitive control (Ericsson & Kintsch, 1995). The objective of this study was to test predictions differentiating the automaticity and cognitive control accounts by assessing thinking during golf putting.
*Design:* The cognitive processes of less-skilled and more-skilled golfers were examined during putting using concurrent, think-aloud verbal reports. The design included putting conditions that differed in complexity and thus the need to adapt the putt to the particular conditions.
*Method:* Putting complexity was manipulated via changes to putt length and perceived stress during putting. Putts were executed from two starting locations (i.e., the same starting location as the previous putt or a new starting location).
*Results:* The analysis showed that, during putting: more thoughts were verbalized overall by more-skilled golfers than less-skilled golfers; both groups verbalized more thoughts overall during higher-complexity putts (i.e., longer distance putts, and putts under higher stress when executed from a new starting location) than lower-complexity putts; and the two groups did not differ significantly in the number of thoughts related to motor mechanics.
*Conclusions:* The results of this study provide support for a cognitive control account of skilled performance and suggest that the path to skilled performance involves the acquisition of more refined higher-level cognitive representations mediating planning and analysis.


Many theories of skill acquisition, such as Fitts and Posner's (1967) three-stage model and Dreyfus and Dreyfus's (1986) skill acquisition theory, characterize skill learning as transitions from cognitive control to eventual automatic execution. These theories assert that, early in learning, successful performance requires the execution of a sequence of cognitive steps. With extended practice, components of a skill gradually become encoded together as integrated units in long-term memory (LTM). The skill is then performed by recognition of patterns and direct retrieval of integrated actions from LTM, requiring less attention and eventually becoming automatic, where proficient processing cannot be changed in response to cognitive control (Shiffrin & Schneider, 1977). In contrast to these theories, Ericsson and Kintsch's (1995) long-term working memory (LTWM) theory proposes that, while automaticity-based theories of skill acquisition apply to the performance of many "everyday" tasks, they do not apply to the performance of tasks for which individuals are motivated to attain or maintain expert performance. According to LTWM theory, experts intentionally resist the normal tendency toward automaticity in order to maintain cognitive awareness and control of performance so they can monitor, evaluate and change performance to improve it during practice. In this paper, we will explore these competing accounts of skilled performance, which we refer to as the "automaticity" and "cognitive control" accounts, respectively. In the next section, we will review the evidence supporting the automaticity account in relation to the performance of motor tasks.

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## 1. Skill acquisition accounts based on automaticity

Skill acquisition theories based on automaticity (Dreyfus & Dreyfus, 1986; Fitts & Posner, 1967) offer two key testable predictions. First, these theories propose that expert performance is controlled by integrated actions retrieved directly from LTM that do not require explicit conscious processes for their execution. Consequently, experts' retrieval of the details of cognitive processes mediating their performance is predicted to decrease as a function of skill (Beilock & Carr, 2001). Second, if experts are instructed to try to attend to the individual steps originally involved in executing a task, they are assumed to retrieve the integrated units from LTM into working memory and then have to decompose them into slower and less proficient control structures (Masters, 1992). This additional cognitive activity is predicted to interfere with normal execution and thus degrade performance. Empirical support for these two claims is reviewed below. Space limits constraint our review to a small but representative set of studies. We first examine whether verbal report procedures used in studies of experts' thoughts during performance elicit data that accurately reflect their thoughts, and then whether disruptions to performance caused by instructions to participants to monitor their performance actually provide evidence of the absence of cognitive control.

Beilock and Carr (2001, Experiments 1 & 2) asked novice and expert golfers to provide written responses concerning their episodic memory for the last putt in a putt series. On average, novices reported around two more steps than experts concerning motor mechanics (e.g., hand positions on putter, swing action), which is consistent with the automaticity account that experts have poorer recall than novices of the detailed steps of their performance. However, the episodic recall instructions used by Beilock and Carr (2001, Experiments 1 & 2) differ from the standard procedures for eliciting "think-aloud" verbalizations (Eccles, 2012; Fox, Ericsson, & Best, 2011). Beilock and Carr's (2001) instructions asked participants to: "Pretend that your friend just walked into the room. Describe the last putt you took, in enough detail so that your friend could perform the same putt you just took" (p. 725). Thus, participants were asked to describe and explain what they did rather than merely report on their thoughts. In a review, Fox et al. (2011) found that generating explanations of one's task performance changed the performance and thus did not reflect thoughts generated during a normal task performance. Also, when Beilock and Carr's participants provided their written descriptions, they may have been selective in their recall and made inferences based on their extensive knowledge of golf obtained, for example, by interactions with instructors. Furthermore, written descriptions often differ in accuracy from descriptions given orally (Kellogg, 2007). Finally, Beilock and Carr's participants may have experienced difficulties in recalling details of their last putt, due to the delay between their last putt and when they began their written putt description. In summary, Beilock and Carr's recall method is unlikely to have yielded valid and accurate data reflecting golfers' actual thoughts during a single, specific putt.

Toner and Moran (2011) published a more recent study supporting the automaticity account. In one condition, expert golfers performed 10 putts under normal, silent conditions and then, immediately after the 10th putt, were asked "to state aloud any thoughts relating to the task of which they were consciously aware" (p. 678). Their procedure for eliciting "think-aloud" verbalizations differs from the standard methods (Fox et al., 2011) and they recorded only 39 thoughts in total for all 18 golfers (Toner & Moran, 2011; Table IV, p. 680). The most frequent verbalized thought was "just look at the target" (p. 680). Toner and Moran concluded that their findings support Beilock and Carr's (2001) view that "a lack of 'on-line' attentional control" (p. 681) facilitates expert performance.

In a subsequent study, Beilock, Carr, MacMahon, and Starkes (2002, Experiment 1) required experienced golfers to consciously monitor a component of their stroke while putting and found this activity interfered with their putting performance, supporting the view that attention to individual task steps interferes with normal task execution. Wulf and colleagues (Wulf, 2013; Wulf, McNevin, & Shea, 2001) identified attentional conditions leading to decrements in performance. In the 2013 review, Wulf showed that directing attention to movement effects (i.e., external focus) benefits performance and learning more than directing attention to the movements themselves (i.e., internal focus). According to Wulf et al.'s constrained action hypothesis, adopting an external focus allows individuals to utilize faster reflex loops that operate automatically, whereas an internal focus constrains the motor system and disrupts these automatic processes. These studies imply that imposing the requirement of conscious control degrades performance by disrupting automatic processes that normally regulate movement. Since Wulf et al.'s and Beilock et al.'s (2002) studies, there have been many demonstrations that requiring skilled individuals to attend to particular performance components results in performance decrements (for a review, see Winter, MacPherson, & Collins, 2014).

However, Toner and Moran (2011) found that conscious attention can be deployed to control and foster performance improvements without negatively affecting performance. When the expert golfers in their study made a conscious adjustment to "their technique in a manner that improved or 'fixed' a flawed aspect of their movement" (p. 681), putting performance was unaffected. An important difference between Toner and Moran's study and the studies showing interference (e.g., Beilock et al., 2002) is that Toner and Moran allowed their experts freedom to select which aspect to focus attention on but, in the studies showing interference (e.g., Beilock et al., 2002), the experimenters decided which particular performance component should be monitored. No interference study has collected participants' thought data in the experimental conditions to compare them with their thoughts while putting normally. A first step towards better understanding the effects of conscious control on performance would involve collecting verbal reports of thinking during normal putting performance (Kearney, 2015). In summary, our review of studies supporting the automaticity account shows that the methods in these studies have important shortcomings that cast doubt on the validity of the data in these studies for making inferences about the nature and frequency of experts' thought processes. We now outline the cognitive control account of skilled performance.

## 2. Skill acquisition accounts based on cognitive control and LTWM

The cognitive control account of skilled performance (Ericsson & Kintsch, 1995; Ericsson, 2006a, 2006b) involves a contrast between the acquisition of expert performance in a specific domain and skill acquisition in everyday life. For "everyday" tasks such as tying shoelaces or a daily bicycle ride to work, individuals are motivated to achieve only a satisfactory level of performance, which, once reached, there is no motivation to improve. Thus, decreases in cognitive control that follow extensive engagement in everyday tasks are acceptable and in many cases desirable because they lead to reductions in physical and mental effort required to complete these tasks. In contrast, during the acquisition of expert performance, performers cannot settle for a satisfactory performance and instead continually strive to enhance their performance. To this end, they seek to increase their cognitive control over performance by engaging in deliberate practice activities that change and