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CONSCIOUS AND EFFORTFUL OR EFFORTLESS AND AUTOMATIC: A PRACTICE/PERFORMANCE PARADOX IN MOTOR LEARNING [1,2]

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Summary.—High cognitive effort has been frequently related to better indices of motor learning through the study of many different paradigms. However, automaticity presumably invokes minimal cognitive processing but has often been related to high-level motor performance, which suggests a paradox. The objective of this study was to approach this paradox by examining the viability of the use of different cognitive strategies during practice and performance which promote the benefits of high cognitive effort and automaticity. Members of the university community (14 men and 15 women) divided into 3 groups practiced a discrete precision task. All participants completed four sessions totaling 320 trials and were tested on retention and transfer seven days later. Findings suggest that it is indeed possible to benefit from both effortful and minimal cognitive processing strategies and that they should be used complementarily.

In 1964, Fitts proposed the division of perceptual-motor skill acquisition into phases. According to him those phases were not clearly separated, although certain characteristics distinguished them allowing the division of the learning process into stages (Fitts, 1964). This notion of perceptual-motor learning was further developed with the proposal of the now classic three stages of learning: cognitive, associative, and autonomous (Fitts & Posner, 1967), which were further refined by Anderson (1999).

The cognitive stage was thought to represent the earliest phase of learning in which the learner attempts to formulate a representation of "what to do" by experimenting with different strategies and verbalizing the content of what is practiced. The associative stage also involved some of the same processes seen in the cognitive stage, but in this phase a learner used evaluative methods to compare the desired movement to the actual outcome. This evaluation is carried out to modify and strengthen the representation of the task and make minor adjustments to the strategies used. In this phase there is a focus on "how to do" the task. The autonomous stage is considered to be the final phase of skill acquisition. After establishing what to do and how to

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do the task, adaptations occur leading to more stability and economy of effort. The autonomous stage is characterized by nonconscious, highly automatic processes. The demand for attention is minimized, allowing multitasking, and explicit knowledge about the skill is replaced by implicit, procedural knowledge.

To reach the highest performance of a skill, it appears that there must be an intentional component as part of the learning process. Bryan and Harter (1897, 1899) in an early study with learning telegraphic skill showed that after periods of extensive practice, plateaus of performance could be identified. These same authors demonstrated that with enough incentive, learning could be resumed and performance improved. Keller (1958) challenged the view that learning was accompanied by plateaus by demonstrating that the plateaus could be avoided when using the appropriate learning strategies. It appears the plateaus seen in Bryan and Harter's early work were a reflection of the system "settling for" a good enough solution and therefore shifting to a more stable state in which gains of performance were minimized in a trade-off with greater reliability and less variability. The characteristics of learners during the performance plateaus resemble those of the autonomous stage described earlier. As Ericsson (2002) proposed, a premature shift to the autonomous stage of learning promotes arrested development as the performance stabilizes in a nonmaximal state. Sloboda (2001) argued that the learning curve often flattens out long before any physiological limits. It is evident then that the transition between the learning phases does not always promote maximal performance, and in many cases performance stabilizes before reaching its maximal state. The process of human learning, however, is also subjected to intention and will, so these components might be the key to specialization and high performance.

Recently, a number of studies have focused on the role of cognitive effort in motor learning (Lee, Swinnen, & Serrien, 1994; Kruisselbrink, 2000; Beilock, Wierenga, & Carr, 2003; Sherwood & Lee, 2003). The primary argument is that increased cognitive effort might be the locus of many phenomena observed in motor-learning research. Thus, effects seen in contextual interference, the role of augmented feedback, and observational learning may all be mediated by cognitive effort. It follows that increases in cognitive effort may benefit learning by promoting stronger and more flexible memory representations that allow enhanced retention and transfer of the tasks being practiced.

According to deliberate practice theory (Ericsson, Krampe, & Tesch-Romer, 1993), experts engage in highly effortful practice with the deliberate intent to improve performance. Morgan and Pollock (1977) reported that elite marathon runners constantly monitor their physiological state as well as their running technique, a characteristic of the earlier cognitive and associative stages of learning. Nonelite runners reported deliberately thinking about things that were unrelated to their running to minimize their experience of pain. This shows similar characteristics to those in the autonomous stage. Performance of the nonelite runners was necessarily automatic and nonconscious to enable thoughts not related to running.

Analogies to reading and walking further illustrate what presumably happens during this premature transition to the autonomous stage. When reading for long periods of time, it is common to have the act become so automatic that one reads words, sentences and sometimes even paragraphs or pages without being consciously aware of what was read. The words were read, but they do not appear to reach conscious cognition. In skill learning automaticity may happen in much the same way. Once the process becomes automatic, the learner loses awareness of what is being done and, therefore, is unlikely to make any major corrections to performance. Walking provides a good example of this. Not many people have to think about what to do before initiating a walking pattern. For most, walking has become so highly automatic that the simple intent to initiate walking appears to trigger a reliable and stable walking pattern.

However, this does not imply that we are all elite walkers. Indeed, there is certainly room for improvement by most walkers, but it is simply 'good enough' for our needs. Thus, little or no improvement in our walking patterns over many years, sometimes decades, is apparent, even though walking is likely to be the motor skill that is most practiced by humans. The situation changes, however, when performance based skills such as shooting a free throw for a basketball player or even surgical skills for a medical surgeon are considered. In these cases less than perfect performance is simply never good enough. Here the cost of expending more energy associated with the higher demands of attention is minimal in comparison to the benefits of performance improvements.

Given that the maintenance of high cognitive effort and the extension of the cognitive and associative stages of learning promote higher performances, a question that arises is why elite motor performance is often associated with automaticity (Singer, 2002; Gray, 2004) and effortless execution (Ravizza, 1984). The answer may lie in the distinction of practice and performance. The intent of practice is to improve over the long-term promoting long-term retention and transfer of skill. This is in contrast to demonstrating improved immediate performance at the particular time of practice. Therefore strategies that promote long-term retention and transfer should be used. Exceptional performances in competition, e.g., sports, and in real life situations, e.g., surgery, are the ultimate goal and should reflect the full capacity and potential of the performer.

With this distinction in mind, it seems reasonable to propose that the characteristics of the cognitive and associative stages are beneficial to learning and should be maintained during practice. On the other hand, the characteristics of the autonomous stage are beneficial to performance and should therefore be promoted whenever learners are required to perform to their full potential.

An important means of avoiding automaticity is to verbalize the content of practice. The benefits of the verbalization were detailed by Fitts and Posner (1967) in their description of the personal experience of Alex Williams, an aircraft pilot instructor. By conducting detailed discussions of each maneuver and emphasizing the "intellectualization" of the pilot's task, he was able to reduce the number of hours of assisted flying from 10 to $3^1/_2$ before having pilots fly solo.

Anderson (1992) through his Adaptive Control of Thought theory, postulated that, as learning occurs, a transition from declarative memory to production memory takes place. By this, he means that the set of rules that mediate reaching a response from an initial goal is lost during the process of learning and the memory representation becomes as simple as a direct response to the initial goal. With motor skills, the set of rules would be represented by the conscious knowledge of what to do in the task. In walking for example, starting from the initial intent, one would have to think about flexing the hip and the knee to raise the leg, reaching forward, swinging the leg through, and so forth. After sufficient practice, the memory representation is not composed of the steps to achieve the goal anymore but rather consists of simply having the act of walking as a direct response to the intent to walk. Literal semantic knowledge is substituted for motor codes that are not easily interpreted. It is as if the content would be translated to a new language and the knowledge of the previous language would be lost. This idea of maintaining a "bilingual" mode is appealing, as in theory, it would allow for intentional (semantic-based) corrections and modifications of the representation.

The objective of this study was to test the use of instructions promoting the combined benefits of cognitive effort and automatism. We hypothesized that the engagement in highly effortful cognitive strategies during the practice phase combined with the engagement in automatism during the posttests would promote optimal learning. Planning, monitoring, and anticipating performance as well as verbalization of the content were stressed during the acquisition phase. Automatic, nonconscious performances were emphasized during retention and transfer tests of a discrete precision task.

Method

Participants

The participants were 29 members of the university community (15

women and 14 men; *M* age = 22.8 yr., *SD* = 3.9), who were naïve to the purpose of the experiment.

Task

The task used was novel to all participants and consisted of rolling a pool ball on a v-shaped pool-like table. The ball had to hit each side of the table before returning back to a target as shown in Fig. 1. All participants performed two to four trials without visual occlusion to understand and become familiarized with the task. The acquisition trials were performed with vision of the far end of the table occluded by a curtain. This prevented participants from viewing where the ball contacted the sides of the table. Error was measured as the absolute distance in centimeters from the centre of the ball to the target and provided as feedback to the participants after every trial.

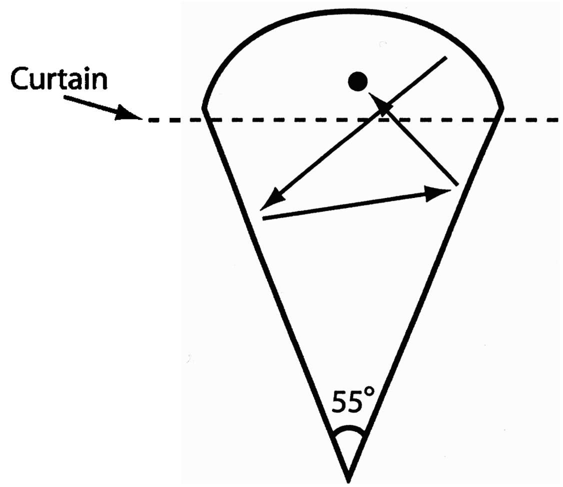

Fig. 1. Top view of v-shaped pool-like table

Experimental Design

Thirty participants[3] were randomly divided into three groups of 10, the Control group, Conscious-conscious group, and Conscious-autonomous group. They then underwent four practice sessions divided into two sessions per week, with one day of rest between, during which they performed eight sets of 10 trials, with a 20-sec. mandatory break between each set. Practice

[3]One participant withdrew from the Conscious-autonomous group

totaled 320 trials. Retention and transfer tests were performed seven days after the last practice session and involved 10 trials of the same task (retention task) and 10 trials of a similar task in which the target was moved to a new place after every trial (transfer task).

Experimental Treatment

Acquisition phase.—The different treatments provided to each group were presented in the form of the instructions given to their participants. Before the first practice session, subjects in both the Conscious-conscious group and the Conscious-autonomous group watched a short video (approximately 3 minutes) explaining the benefits of cognitive effort and the maintenance of conscious cognitive processing for learning, as well as examples of useful implementation strategies. The video consisted of instructions to engage in planning, monitoring performance, and anticipation—strategies typically associated with the cognitive and associative stages of learning. The participants in these two groups were advised to use verbalization as means to elaborate in detail their plan for action. They were also advised to verbalize what they did correctly and incorrectly on the previous trial and what they anticipated the outcome of each action to be. The Control group also watched a video of similar duration, which only explained the task and did not provide any information about cognitive strategies to be used during the learning process.

Retention and transfer tests.—For the retention and transfer tests, the Conscious-autonomous group watched a second video, explaining the benefits of autonomous cognitive processes for performance, as well as how to maintain them. The so-called "zone" said to be experienced by high-level athletes and consisting of a cognitive state represented by a "quiet mind" and highly automatic cognitive processes was used as an example to illustrate the cognitive strategy to be used. Both the Conscious-conscious group and the Control group watched a video explaining the posttests and received no instruction on the type of cognitive strategy they should use. To maximize the effects of motivation to learn and perform, financial rewards were given according to the participant's performance.

Results and Discussion

Two separate single-factor (group) analyses of variance were used to test for differences in retention and transfer performance. The dependent measures used were transfer score (transfer test) and amount of retention (retention test minus last set of practice). Tukey *HSD* test was used for *post hoc* analysis, and a liberal alpha level of .20 was set *a priori* given the exploratory nature of the study. In light of this, the interpretation of the results should consider an elevated probability of a Type I error.

Retention

As expected, the Conscious-autonomous group outperformed the Conscious-conscious group ($Ms = -.67$ and 4.45, respectively, $p = .19$; $d = .87$) on the amount of retention, but neither of the groups were statistically different than the Control group ($M = 2.0$).

TABLE 1
Mean Error Scores and Standard Deviations (cm) by Group

	Conscious-conscious		Conscious-autonomous		Control	
	M	*SD*	*M*	*SD*	*M*	*SD*
Amount of Retention	4.45	5.05	−.67	6.62	2.00	7.05
Transfer	19.45	5.89	26.17	9.42	23.25	5.66

Note.—Amount of retention = last acquisition block – retention test score.

Transfer

In transfer the results were opposite those presented in retention with the Conscious-conscious group outperforming the Conscious-autonomous group ($Ms = 19.45$ and 26.17, respectively, $p = .11$; $d = .87$), neither of the experimental groups' means being statistically different than the Control group's ($M = 23.25$). For a complete breakdown of the results see Tables 1 and 2.

TABLE 2
Pairwise Comparisons Between Groups and Respective *p* Values, Effect Sizes (Cohen's *d*) and Observed Power

	Amount of Retention			Transfer		
	p	Effect Size	Observed Power	*p*	Effect Size	Observed Power
Conscious-conscious × Conscious-autonomous	.19	.87	.71	.11	.87	.72
Conscious-conscious × Control	.66	.40	.36	.46	.65	.56
Control × Conscious-autonomous	.63	.39	.34	.64	.38	.34

Now, the representation of motor skills appears to have a particular characteristic which differentiates it from other types of memory representations, e.g., perceptual or semantic memory. Given its procedural characteristic, motoric memory is established through the same process by which it is retrieved, i.e., the execution of the action. This makes it difficult for a motor skill learner to separate the process of memory acquisition from the process of memory retrieval, both essential components of the learning process that may lead an individual to elite performance. The objective of this study was to separate those two processes, yielding a benefit from the use of the appropriate and, indeed, different cognitive strategies for each one of them. However, a paradoxical relationship may exist between the establishment of memory representations and their retrieval. That is, memory acquisition could benefit from conscious and effortful cognitive strategies, but memory retrieval could benefit from highly automatic and effortless cognitive strategies.

Our results support the notion that a change in the cognitive strategies used from practice to performance may indeed be beneficial as shown by the larger amount of retention presented by the Conscious-autonomous group over the Conscious-conscious group. However, the intentional use of effortless and automatic strategies appears to depress transfer performance, as a higher cognitive component is needed to adapt to changes in parameters. Furthermore, our results suggest that the uninstructed Control group could have employed intermediate strategies: through self-regulation, the participants in this group could have employed in part the strategies suggested to be beneficial to each phase, i.e., practice or performance.

As suggested by anecdotal evidence as well as previous studies (Ravizza, 1984; Singer, 2002; Gray, 2004), maintaining a quiet mind and letting the motor performance become effortless and automatic without much conscious thought seems to favor memory retrieval. It therefore seems one could benefit from the use of such strategies along with the benefits of cognitive effort when memory is being established. This may be one key to solve the mystery of expert motor performance. A great part of practice is preparing to perform by making one more accustomed to the inner states that will be experienced during actual performance, which suggests that practice could be divided into two components, practice to establish strong memory representations of the act and practice to perform (or retrieve memories). Even though there is some independence between the two systems (establishment and retrieval), they are intrinsically linked. Moreover, given these data, there seems to be interference between cognitive effort and memory retrieval. When cognitive effort and conscious thought are instructed, immediate performance was hindered, as if the memory was less effective. A recent study by Gray (2004) supported this proposition. Gray found that skill-focused attention, which is similar to what has been conceptualized as conscious and effortful cognitive strategies in this paper, increases performance variability and is "negatively and roughly monotonically related to the current level of performance." Nevertheless, it is suggested here and elsewhere (Ericsson, 2002, 2003; Beilock, *et al.*, 2003; Gray, 2004) that simply performing a task without cognitive effort and conscious processing may not be sufficient to improve the memory representation of the action. Beilock and Carr (2001) proposed that in situations requiring immediate performance, motor experts present "expertise-induced amnesia." This phenomenon relates to the idea that, when focusing purely on performance of a task, little information is stored in the form of episodic memory. According to Beilock, *et al.* (2003), inability to recall details about performance is linked to the lack of capacity to correct the performance to meet desired goals in following trials. This may not be restricted solely to experts but to anyone using the cognitive strategies associated with autonomous performance. An illustrative situation might be weekend athletes who intend to perform to their full potential every time they go to play and thus become exclusive memory retrievers. By doing this, they presumably avoid the malefic effects of cognitive effort on immediate performance, presenting relatively reliable and stable performances. Thus, and analogous to what is observed with the aforementioned walking pattern, performance will neither improve nor become more flexible over time (or weekends).

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