INTRODUCTION
What are the innermost truths of the golf swing? Watch an instructional video, pick up a golf magazine or listen to a golf analyst, the conclusion is the same: golf success reflects a combination of hard work together with attention to more information and more facts. In other words, the same principles used to land a rocket on the moon translate into success on the golf course [1, 2]. Peter Lightbown’s assertions challenge this dogma. Golf performance is not a matter of more attention to details, but less. By focusing on the goal of the shot rather than the process, the fundamentals of a good swing appear on their own accord. Thus, we have been following false prophets: out with Newton, in with Krishnamurti. In support of Peter’s point of view is the fact that his innermost truths strongly resonate with current understandings of how the golfer’s brain plays golf.

SKILL AND EXPERTISE IN GOLF
The issues addressed by Peter Lightbown concern how the nervous system becomes expert at playing golf. At the crux of the matter is the distinction between skill and expertise [3]. The skill level of a golfer is reflected in the accuracy and uniformity by which the skill is performed on repeated swings.

Expertise is the ability to perform a skill at a high level under a variety of environmental conditions. The distinction between skill and expertise accounts for the observation that a golfer’s handicap for tournament play is typically five or more strokes higher than that for recreational play. Thus expertise is about playing the game of golf whereas skill is about swing mechanics.

THE ROLE OF REPERTITION IN SKILL DEVELOPMENT
The golf swing is a complex voluntary skilled movement that involves a sequence of activities organized in both a temporal and spatial manner to achieve a well-defined goal. At a global level the nervous system works as a feedback controller to improve skill. Given a measurable error; i.e., difference between the desired and actual
outcome, the nervous system gradually self-organizes to produce a plan, or motor program, that reduces the error [4, 5]. This learning process is accompanied by structural changes both at the level of single neurons and in the organization of large neural networks. The important role of repetition in skill development stems from the fact that these structural changes take time to develop and implement. Thus as the complexity of the motor task increases, the longer it takes to perfect the skill.

CHOKING
However, even the most highly skilled golfer can choke, i.e. their skills can rapidly deteriorate under certain conditions [6-8]. Thus expertise is about how different regions of the nervous system involved in movement control are able to interact and cooperate. In other words expertise is about playing the game of golf.

VOLUNTARY CONTROL AND AUTOMATICITY
Behavioral and physiological studies support the concept that as expertise develops, the focus, or attention, of the golfer shifts from the process of producing a golf swing (“where do I put my hands”) to the goal of the shot (“where do I want the ball to go”). This attentional shift is accompanied by a change in the relative roles played by different parts of the nervous system in providing the instructions to the muscles to move the club [6, 9, 10]. Studies of brain activation during the golfer’s preshot routine indicate that expert golfers activate less brain than novice golfers [11, 12]. This suggests that, as expertise develops, more and more of the control of the golf swing must be taken over by parts of the nervous system located for example in the spinal cord that once trained are capable of functioning automatically [6, 9, 10] and economically [10, 13]. Unfortunately Mother Nature overlooked one detail: the little voice in the golfer’s brain that remains capable of introducing voluntary changes to the motor programs even when the golf swing has already been over-learned. Managing the balance between those regions of the nervous system that issue voluntary commands and those that function automatically represents the essence of playing the game of golf. These observations provide a framework within which we can interpret the innermost truths expounded by Peter Lightbown.

THE GOLFER’S MIND IS NOT INSTRUCTIONAL ONCE SKILL HAS BEEN LEARNED
Once the golf swing has been learned, most of the control of the swing involves those regions of the nervous system that function automatically. Thus, by definition, introducing a voluntary last-minute command (“let’s increase my wrist cock”) likely decreases performance. Consequently, optimizing performance of a learned golf swing requires that “the role of the mind is one of perceiving and responding to what is happening rather than instructing the body what to do” (p. 77).

PERFORMANCE IS BEST WHEN ATTENTION IS FOCUSED
Comparisons of brain activation of golfers during their preshot routine show that novice golfers activate more brain regions than does an expert [12]. Behavioral observations indicate that whereas experts are focused on the goal of the shot (“I want the ball to land on that spot 10 feet to the right of the hole”), novices are overly pre-
occupied with irrelevant details (“I hope that I don’t hit the ball into the water again”). In other words the brain of the novice golfer is trying to solve a much more complex task than the expert. As the complexity of the task increases, performance decreases.

**THE MIND OF THE GOLFER CAN ONLY CONTROL WHAT IS POSSIBLE TO CONTROL**

It is important for a golfer to remember that there are aspects of golf that cannot be controlled by their nervous system. Obviously the golfer cannot control what happens to the ball after it leaves the clubface. Moreover the golf downswing occurs so quickly that the nervous system has only very limited abilities to introduce corrections while it is occurring. When golfers try to control the impossible, attention is not focused only on important issues. Performance is best when attention is focused.

It is for this reason that good golf instruction focuses on those aspects of the golf swing that can be controlled: grip, aim, set-up and position at follow through [14]. Obviously if the starting and ending positions of a golf swing are correct, then it is reasonable to expect that what occurred in between is likely to be good as well. Peter Lightbown extends this list by using “awareness as the means by which balance, relaxation and rhythm are introduced into every aspect of the swing” (p. 77). However, it is important to keep in mind that there is a voluntary aspect to these skills and hence the very same conflicts that arise in the development of an expert golf swing can also arise in the development of expert balance and rhythm control. Indeed, the harder people try to control balance, the worse the outcome! A familiar example is the waiter’s trick of not looking at a full bowl of soup carried on a tray to try to avoid spillage.

**CONCLUSION**

The teaching strategies stressed by Lightbown would not be expected to apply to novices. Watching others hit golf balls, feedback-based ‘hands-on’ instruction and, above all, repetition remain the keystones for the development of skill. The crucial question is, at what point does this emphasis on details become detrimental rather than beneficial? In other words, is the rate-limiting step for learning to play golf the time it takes to develop a good golf swing or the time it takes to learn to muzzle that inner voice? The important implication of Lightbown’s observation is that transition in coaching strategy should be implemented at much earlier stages of the coaching process than is currently realized. Who knows, but maybe by doing so our students might actually have fun playing golf and perhaps settle a few on-course bets in their favor!

**REFERENCES**


EDITOR’S NOTE

John Milton, MD, PhD, ABPN, FRCP(C), FAPS is a physician-scientist with an avid interest in golf. Over the last decade, his research has focused on how the human nervous system develops expertise in the performance of complex motor skills with a particular emphasis on balancing tasks. While at the University of Chicago, he led a team of neuroscientists in a study that documented the differences in brain activation between novice and tour-level golfers during their pre-shot routine. This study was conducted in collaboration with the Ladies Professional Golf Association (LPGA) and took place in conjunction with the 2000 U.S. Women’s Open at Merit Club, Libertyville, IL. He is presently the William R. Kenan, Jr. Chair in Computational Neuroscience at the Claremont Colleges in California.