

# Effects of focus of attention depend on golfers' skill

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In this study, we examined the influence of internal and external attention instructions on the performance of a pitch shot by golfers who were either highly skilled (mean handicap = 4) or low skilled (mean handicap = 26). Ten golfers in each skill group used a 9-iron to pitch a ball as close as possible to an orange pylon, which was located at distances of 10, 15, 20 or 25 m from the golfer. Focus of attention was manipulated within participants (counterbalanced across golfers). Under internal focus of attention instructions, the participants were told to concentrate on the form of the golf swing and to adjust the force of their swing depending on the distance of the shot. For the external focus of attention conditions, the participants were told to concentrate on hitting the ball as close to the target pylon as possible. The most intriguing finding was an interaction of skill with focus of attention instructions for variability in performance. Similar to the findings of Wulf and colleagues, the highly skilled golfers performed better with external attention instructions than with internal focus instructions. In contrast, the low-skill golfers performed better with the internal than with the external focus of attention instructions. These findings are discussed relative to theoretical issues in motor learning and practical issues for golf instruction.

*Keywords:* focus of attention, golf, motor performance, skill.

## Introduction

The mechanics, biomechanics, motor control and physiology involved in playing golf have received considerable attention in the sport science literature recently (e.g. Craig *et al.*, 2000; Lindsay *et al.*, 2000; Dorado *et al.*, 2002). However, evidence about the mental aspects of golf performance has generally been limited to anecdotal testimonies. This appears to be changing. New empirical evidence has emerged on the mental training of the golf swing (Christina and Alpenfels, 2002; Guadagnoli *et al.*, 2002), the electroencephalographic patterns of the pre-putt routine (Crews and Landers, 1993), the responses of golfers to pressure (Beilock and Carr, 2001) and the study of the 'yips' in putting (Smith *et al.*, 2000). Another issue, which is the focus of this paper, is the role of *attentional focus*, defined as the influence of instructions to consciously attend to specific information during the production of action.

For many years, attentional focus received considerable attention in both learning theory and the game of golf, but only recently has it become the subject of empirical investigation. Discussion of the

role of attentional focus in golf was restricted to opinions offered in golf instruction books by professional golfers and golf instructors. Not surprisingly, there is wide variation in opinion on the topic. For example, some emphasize that the golfer's attention should be focused on what the limbs are doing during the swing, with suggestions such as: 'consciously make sure your hands are firm at the finish of each swing' (Toski *et al.*, 1978, p. 19), and, in putting, 'concentrate on keeping your hand and wrist position steady through impact' (Kern, 2001, p. 22). Others, however, suggest that attention should be directed away from what the hands or other body parts are doing. For example, Jack Nicklaus suggests that 'it's all too easy to become so immersed in "swing mechanics" that you forget the object of the exercise ... stay focused on swinging the club head freely through the ball' (Nicklaus and Bowden, 2000). In lagging putts, David Leadbetter suggests you 'imagine that you're sweeping the putter-blade just as you would a broom ... The brush point – where the bristles would make contact – should be right at the ball' (Leadbetter and Smith, 2001).

Researchers have also commented on the role of attentional focus (James, 1890; Bernstein, 1996), but it was not until recently that Wulf and her colleagues provided some empirical evidence. Using different

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sports and laboratory tasks, Wulf and others (recently reviewed in Wulf and Prinz, 2001) examined the impact of attentional focus, often by comparing the effects of instructions that direct a participant's attention to the production of body movement (*internal* focus of attention) or to the effect in the environment that is produced as the result of body movement (*external* focus of attention). Their results revealed that performance under external focus of attention instructions was better than performance under internal focus of attention instructions for both the performance and learning of motor skills. These findings have been replicated and extended by others (Hodges and Franks, 2000), implying that the focus of attention finding is a rather robust and potentially important component of the 'mental' aspect of sport performance.

For golf performance, the results of several studies have suggested that performance improves when attention is directed away from the production of movement. Masters (1992) and Hardy *et al.* (1996) conducted golf putting studies in which participants who learned to putt while simultaneously doing a secondary task performed better under pressure than participants who tried to learn the task with attention to the explicit procedures involved in putting. In a study by Beilock *et al.* (2002), relatively high-skill golfers (handicap < 8) also benefitted from secondary task performance. In this study, participants either monitored their swing (verbally indicating when the follow-through was completed) or did not monitor their swing by performing an attention-distracting task (listening to a tape and responding verbally when a specific tone was detected). Performance in the tone-monitoring condition was better than in the swing-monitoring condition, lending support to the idea that internally focused attention disrupts putting performance. In another study by Wulf *et al.* (1999), groups of inexperienced individuals learned a golf chipping task under differing conditions of attentional focus. The participants who were asked to focus on the club during the swing (an external focus) performed better in practice and retention than the participants who were asked to focus attention on the arms during the swing (an internal focus). Thus, there is some evidence to support the contention that an external focus of attention is better than an internal focus of attention for golf performance (and learning).

Although focusing one's attention on the movement of the limbs during a golf shot appears to be detrimental to performance (compared with an external focus), this may depend on the skill of the golfer. On a theoretical level, Bernstein (1996) suggested that an external focus of attention might be more beneficial for skilled athletes than less skilled athletes because the level of automatizations are different. Bernstein argued that motor skills (or the subcomponents of motor skills) are more highly

automatized in expert athletes than in non-experts. An internal focus of attention would essentially revert the athlete to a mode of control associated with less skill, consequently disrupting the current mode of control. A similar theoretical idea (dechunking of proceduralized skills) was suggested by Beilock and her colleagues for the breakdown in performance associated with attentional monitoring of the putting stroke (Beilock and Carr, 2001; Beilock *et al.*, 2002).

There is also some empirical evidence which suggests that attentional demands have different effects on automatized and non-automatized skills. A second study in Beilock *et al.* (2002) compared the dribbling performance of skilled and novice football players who used either their dominant or non-dominant foot. In the attention demanding task (listening to words and speaking a target word out loud when detected), the high-skill soccer players' performance far exceeded that of the novices in both the dominant and non-dominant foot conditions. However, when attention was directed to movement (the foot), the performance of the experienced players was far better than that of the novices for the non-dominant foot, but only moderately better when using the dominant foot. These findings suggest that the internal focus of attention conditions disrupted performance of the high-skill players only when they performed with the foot that, presumably, had achieved more automated performance control. Also, there was a slight trend in the findings of Beilock *et al.* (2002) for the novices to perform better in the internally focused conditions than in the attentionally demanding condition when using both the dominant and non-dominant foot.

The findings of Beilock *et al.* (2002), together with other theoretical predictions, suggest that the detrimental effects of internal focus of attention instructions might be greater for high-skill golfers than for low-skill golfers. Also, because their mode of control would probably be far less 'automated' than that of high-skill golfers, it might be expected that the performance of low-skill golfers under an internal focus of attention would be less detrimental or, perhaps, even better than with an external focus of attention. These experimental predictions were examined in the present study using a golf pitch shot.

## Methods

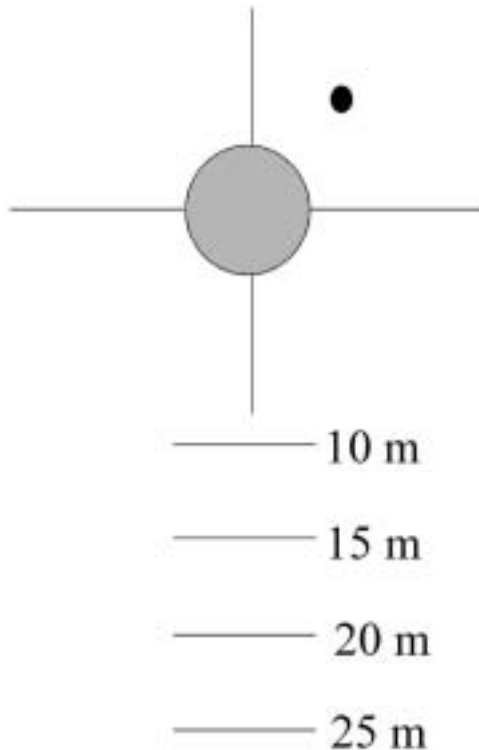
### *Participants*

Ten high-skill male golfers and 10 low-skill golfers (8 males, 2 females) volunteered to participate in the study. The high-skill golfers had a mean Royal Canadian Golf Association (RCGA) handicap of 4; all had handicaps between 0 and 8. The mean handicap of

the low-skill golfers was 26; all had handicaps between 20 and 36. None of the low-skill golfers had ever received formal golf training and all had played recreationally for a minimum of 2 years. All individuals signed informed consent, were naive to the purpose of this study and were paid \$20 (Cdn) at the end of the study.

### Apparatus and task

Pitch shots were performed on a flat grass field. The participants chose to use either their own 9-iron or one that was provided by the experimenter. Although the 9-iron may not be the club preferred by all golfers for pitch shots of varying distances, we believed that, for low-skill golfers, it is a club that is more commonly used and easier to control for pitch shots than wedges. Solid core white golf balls were used by every participant throughout. The participants pitched at a target from four hitting locations of 10, 15, 20 and 25 m. The target was a standard fluorescent orange pylon. A '+' was created from the centre of the pylon with yellow nylon rope to divide the target area into four quadrants (see Fig. 1). Initial ball contact position (the location where the ball first landed on the grass) was used to measure performance. To determine this position, all golf balls



**Fig. 1.** The experimental set-up. The small dark circle represents a spot where a ball landed, the larger shaded circle represents the target pylon, and the four distances from the pylons represent the hitting locations (not drawn to scale).

were coated with white chalk. This chalking resulted in a white mark where the ball first contacted the grass surface. This method allowed for a quick and accurate measure of the initial contact position of the golf ball in terms of its distance and angle relative to the pylon. Two experimenters determined the ball's location: one calculated the distance with a measuring tape radiating from the centre point, while the other measured the angle with a protractor. From the distance and angle information, x- and y-coordinates were determined through basic trigonometric calculations. These coordinates were necessary to calculate two-dimensional error scores.

The participants were not informed of the results of their performance after each trial so as to reduce the effects of knowledge of results on the performance of subsequent shots. To further reduce information feedback about the just-performed shot, occlusion goggles were worn to prevent direct vision of the outcome of the shot. The goggles permitted full vision during set up, preparation to hit the ball and during the swing until the point at which the club made contact with the ball. At this point, a third experimenter manually controlled a switch that resulted in the goggles immediately becoming opaque. Vision remained occluded until after all measurements had been taken, the resting golf ball had been removed from the field and the golfer had been guided to the next starting position. Although not very 'natural', it was our belief that the effectiveness and consistency of the experimental manipulations would be stronger if information about the outcome of the shot was eliminated, since post-action feedback is generally acknowledged to be a leading contributor to trial-to-trial changes in motor behaviour.

The participants' task was to perform golf pitch shots as accurately as possible by attempting to land the ball as close as possible to the target pylon (on the fly) while performing according to the instructions of a particular focus of attention condition. We chose to use the ball's landing point as the task goal simply because the 'smoothness' of the grass landing area where the experiment was conducted was much less consistent than would be expected, for example, when pitching the ball onto a green and rolling the ball towards the hole – true bounces and rolls were much less consistent in our test area than would be expected on a green. Thus, the landing point was considered to be a more reliable estimate of the golfer's shot than the final resting point.

### Procedure

The participants performed five practice trials from a distance other than the four used in the study. This allowed each participant to become familiar with the hitting turf and the occlusion goggles. A 5 min rest

period was allowed after these practice trials and participants were instructed about their objective: to hit a target pylon with the golf ball using a 9-iron pitch shot. The participants were assigned to one of the two attention exposure orders, whereby they completed 40 pitch shots in one focus of attention condition, followed by 40 pitch shots in the other focus of attention condition. Order of focus of attention exposure was counterbalanced across participants within each group. Shots occurred in a predetermined, quasi-random order at each of the four shot locations. In total, the golfers performed 10 shots at each of the four target distances under each of the two attentional focus conditions.

The participants received verbal focus of attention instructions at the start of the study and were reminded of these instructions before every fourth shot. For the *internal* focus of attention instructions, the participants were told to concentrate on the form of the golf swing and to adjust the force of their swing depending on the distance of the shot. For the *external* focus of attention conditions, the participants were told to concentrate on hitting the ball as close to the target pylon as possible. To encourage the participants to adopt the given attentional focus instructions, they were asked to make an estimate of their perceived performance after each shot. After shots in the internal focus of attention condition, the participants were asked to estimate the appropriateness of the force that they had used for the just-completed shot based on a 5-point Likert scale ('far too little force', 'too little force', 'just the right amount of force', 'too much force' or 'far too much force'). Our rationale was that asking golfers to estimate the force produced on the just-completed shot would help to encourage an attentional focus on the force requirements needed for the next shot. After each external focus of attention trial, the participants were asked to estimate where the ball had landed relative to the pylon (well before the target, just before the target, on target, just past the target or well past the target). Here, our rationale was that asking the golfers to estimate the outcome of the shot relative to the location of the pylon would encourage attentional focus on the pylon for the upcoming shot.

Two-dimensional average and variable error scores were calculated, using the formulae suggested by Hancock *et al.* (1995). The average error score represented the mean two-dimensional distance of the landing point of the shot relative to the target. The variable error score represented the within-person, within-condition variability of the individual trials about the mean average centroid. The average error score and the variable error score were computed using the following formulae:

$$\text{average error} = (Xc^2 + Yc^2)^{1/2}$$

$$\text{variable error} = \{(1/k) E[(Xi - Xc)^2 + (Yi - Yc)^2]\}^{1/2}$$

where  $Xc$  is the mean distance from the pylon in the direction of the shot,  $Yc$  is the mean distance from the pylon perpendicular to the direction of the shot,  $Xi$  is the distance from the pylon in the direction of the shot for the  $i$ th trial and  $Yi$  is the distance from the pylon perpendicular to the direction of the shot for the  $i$ th trial.

An initial analysis of the data revealed that the assumptions for analysis of variance (ANOVA) regarding homogeneity of variance had not been met, especially for the variable error data. Therefore, before analysis of variance, the average and variable error data were subjected to a log transformation. Subsequently, transformed data for each measure were submitted to a four-factor ANOVA (two between-person and two within-person factors) as an initial analysis. The between-person factors were skill (low *vs* high) and attention order (external-internal *vs* internal-external). The within-person factors were attentional focus (internal *vs* external) and target distance (10, 15, 20 and 25 m). This analysis was conducted to assess the potential influence of order of attentional focus instructions. Subsequent to this analysis, only the data for the first 40 trials were used. That is, within each skill group, we analysed only the first attentional exposure condition. Therefore, the second set of analyses involved a three-factor ANOVA, using skill group and attention condition (internal *vs* external) as between-person factors and distance as the within-person factor. Tukey's HSD tests were used to assess between-mean differences for significant ANOVA effects. Note that although the inferential statistics (ANOVA and *post-hoc* tests) reflect the analysis of transformed data, the means that are reported in the text, tables and figures reflect observed (not transformed) values.

## Results

### Average error

Average error performance by all groups in all conditions is summarized in Table 1. The initial, four-factor ANOVA revealed only main effects for skill ( $F_{1,16} = 16.1$ ,  $P < 0.001$ ) and distance ( $F_{3,48} = 15.9$ ,  $P < 0.001$ ). The low-skill group had significantly higher error scores (mean = 463 cm) than the high-skill group (mean = 205 cm). For the distance main effect, average error increased with target distance (means = 207, 277, 382 and 471 cm for the 10, 15, 20 and 25 m distances, respectively). *Post-hoc* analyses revealed significant

**Table 1.** Mean average error scores (standard deviations in parentheses; all values in cm) for the four groups of golfers as a function of the two orders of instructions and the four shot distances

	Internal focus				External focus			
	10 m	15 m	20 m	25 m	10 m	15 m	20 m	25 m
Low skill (int/ext)	226 (147)	270 (166)	402 (156)	446 (207)	273 (119)	333 (127)	475 (89)	522 (192)
Low skill (ext/int)	300 (278)	487 (290)	546 (344)	749 (437)	369 (213)	469 (151)	581 (310)	963 (646)
High skill (int/ext)	104 (93)	137 (74)	288 (117)	307 (157)	139 (129)	194 (171)	271 (229)	186 (71)
High skill (ext/int)	107 (49)	139 (77)	266 (82)	327 (155)	141 (72)	188 (50)	223 (110)	265 (187)

Note: Int/ext = the internal focus instruction trials given first and the external focus instruction trials given second. Ext/int = the external focus instruction trials given first and the internal focus instruction trials given second.

**Table 2.** Mean variable error scores (standard deviations in parentheses; all values in cm) for four groups of golfers as a function of the two orders of instructions and the four shot distances

	Internal focus				External focus			
	10 m	15 m	20 m	25 m	10 m	15 m	20 m	25 m
Low skill (int/ext)	892 (158)	1341 (292)	1786 (549)	2117 (326)	1274 (354)	1619 (578)	1413 (195)	2135 (578)
Low skill (ext/int)	1403 (307)	2198 (553)	2515 (620)	2560 (908)	1285 (248)	2132 (725)	2982 (1033)	4477 (3413)
High skill (int/ext)	719 (189)	1014 (314)	1576 (537)	1419 (377)	827 (235)	1078 (412)	1318 (410)	1681 (278)
High skill (ext/int)	666 (226)	969 (179)	847 (284)	1214 (251)	524 (262)	624 (158)	820 (213)	1178 (311)

Note: Int/ext = the internal focus instruction trials given first and the external focus instruction trials given second. Ext/int = the external focus instruction trials given first and the internal focus instruction trials given second.

differences between all means with the exception of the difference between the 10 and 15 m targets.

No significant interactions were found in this analysis, raising the concern that the order of attentional focus conditions somehow moderated the results. That is, perhaps once an individual received a given focus of attention instruction, there was a carryover effect that influenced subsequent performance in the other attentional focus condition. Another consideration was that participants' performance may have been affected by fatigue. However, the findings of the second ANOVA,

in which only the data from the first attentional focus condition were analysed (i.e. the first 40 trials), also revealed only the same main effects as the initial analysis. Both skill ( $F_{1,16} = 14.6$ ,  $P < 0.01$ ) and distance ( $F_{3,48} = 7.69$ ,  $P < 0.001$ ) were the only significant effects.

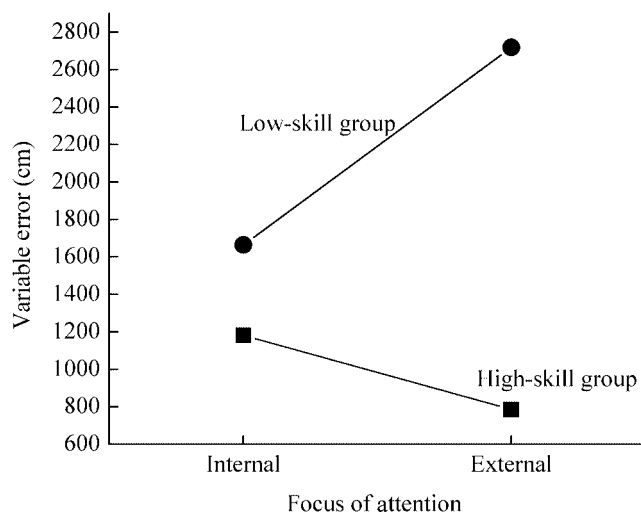
#### Variable error

Variable error performance by all groups in all conditions is summarized in Table 2. The initial, four-factor

ANOVA revealed a significant main effect for skill ( $F_{1,16} = 41.2$ ,  $P < 0.001$ ), with the high-skill group (mean = 1029 cm) performing with significantly less variability than the low-skill group (mean = 2008 cm). A significant main effect was also found for distance ( $F_{3,48} = 44.5$ ,  $P < 0.001$ ), which revealed increased variability with increased pitching distance (means = 949, 1372, 1657 and 2098 cm for target distances of 10, 15, 20 and 25 m, respectively).

We also found a significant two-way interaction between skill and attention exposure order ( $F_{1,16} = 13.0$ ,  $P < 0.01$ ). *Post-hoc* analyses revealed that the low-skill group when performing the internal focus of attention condition first produced less overall variable performance (mean = 1572 cm) than in the reverse order (mean = 2444 cm). The opposite was true, however, for the high-skill group. For these more skilled golfers, performing with external instructions first resulted in overall lower variability (mean = 855 cm) than with internal instructions first (mean = 1204 cm).

The subsequent ANOVA, which used only the data from the first attentional exposure condition, also revealed main effects for skill ( $F_{1,16} = 29.5$ ,  $P < 0.001$ ) and distance ( $F_{3,48} = 46.3$ ,  $P < 0.001$ ), replicating previously described effects. Of importance, however, was the finding of a significant skill by attentional focus interaction ( $F_{1,16} = 11.1$ ,  $P < 0.01$ ). As illustrated in Fig. 2, *post-hoc* analyses revealed that the low-skill golfers performed with significantly more variability when given external focus of attention instructions (mean = 2719) than when given internal focus of attention instructions (mean = 1665 cm). In contrast, the high-skill golfers showed the opposite effect, performing with significantly less variability in the



**Fig. 2.** Variable error performance for the high-skill and low-skill golfers under internal and external focus of attention instructions.

external focus of attention condition (mean = 786 cm) than in the internal focus of attention condition (mean = 1182 cm). Viewing the interaction from a different perspective, the results revealed that the high-skill golfers performed better than the low-skill golfers with the external focus of attention instructions only; the two skill groups were not significantly different under internal focus of attention instructions.

## Discussion

Several findings from the present study provide support for the position that focus of attention effects in golf pitching depend on the skill of the individual. First, we found that the order in which instructions were given affected the low-skill and high-skill golfers differently. For the low-skill golfers, being provided with the internal focus of attention instructions first resulted in more consistent performance *overall* than when provided with the external focus of attention instructions first. If the attention instructions had a carryover effect from the first to the second set of trials (Poulton and Freeman, 1966), then it might be expected that the cause for this effect was the better carryover effect produced by first having performed the internal focus of attention condition. For the high-skill golfers, being presented with the external focus of attention instructions first resulted in better performance overall than being provided with the internal focus of attention instructions first. Thus, if the impact of the first instructional set produced a carryover effect to the second, these findings suggest that the external attentional focus instructions were more beneficial for the more skilled golfers than the internal attentional focus instructions.

Another finding that supports the above interpretation was noted when the data from only the first set of trials were analysed, thereby eliminating the potential carryover influences of order. For these data, the results showed that performance under internal focus of attention instructions was better than under external focus of attention instructions for the low-skill group. Conversely, the external focus of attention instructions resulted in better performance than the internal focus of attention instructions for the high-skill golfers.

We interpret these findings as supporting the view that, in the execution of a golf pitch shot, once the fundamentals of the swing have been learned well, performance will benefit more by concentrating on where to hit the shot than by attending to the action of the golf stroke that will produce the shot. Indeed, the results from the second analysis revealed that the performance of the high-skill golfers was no better than that of the low-skill golfers when both were performing

with internal focus of attention instructions. In contrast, the performance of the low-skill golfers, who may not have learned the fundamentals of the pitch shot to the extent where monitoring of the swing is no longer necessary, appeared to benefit more by concentrating on the action and the force to be produced than by concentrating on the target. These differing roles of attentional focus as a function of skill support both the theoretical predictions of Bernstein (1996) and the empirical findings of Beilock *et al.* (2002).

It is interesting to note that the dependent variable of greatest importance in the present study was variable error, not average error. This finding might reflect what golfers of all levels of skill find to be the most frustrating aspect of the game of golf – the ability to perform consistently from shot to shot. That attentional focus would have such an impact on performance variability supports the widely held contention that the game of golf is strongly influenced by the mental aspects of the game.

It is becoming increasingly apparent that the effectiveness of motor learning practice variables reflects a rather complex relationship that depends on many factors, just one of which is the skill of the individual (e.g. Guadagnoli *et al.*, 1996, 1999). The present findings add to the growing complexity of this general observation – our results should be viewed as preliminary evidence for the differential effectiveness of focus of attention instructions as a function of skill in golfers. Obviously, there are many sources of information that could be used as focal points upon which ‘internal’ and ‘external’ instructions could have been based. For example, as a source for an internal focus, instructions to have the golfer attend to the V-shape produced by the angles of the two wrists, the amount of backswing of the limbs during takeaway or many other swing keys, could very well have produced a set of results that were either stronger or weaker in terms of their influence on performance by golfers of differing skill. Similarly, several other sources of information could have been used as the object of an external focus of attention. Hitting a ball through an imaginary ‘window’, making crisp contact at the ball–ground contact point and other environmental cues to which the golfer could have been directed to attend might also have produced stronger or weaker ‘external’ attention effects. The notion of golf skill might also be a critical variable. For example, there is no assurance that participants with absolutely no prior experience with golf would perform better under either focus of attention condition. Therefore, the present findings should be regarded with cautious optimism that an effect that is entirely ‘mental’ has a profound impact on the performance of golfers depending on their playing skill. The implications of these findings for instructing golfers of differing skill warrants further research on the topic.

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## References

- Beilock, S.L. and Carr, T.H. (2001). On the fragility of skilled performance: what governs choking under pressure? *Journal of Experimental Psychology: General*, **130**, 701–725.
- Beilock, S.L., Carr, T.H., MacMahon, C. and Starkes, J.L. (2002). When paying attention becomes counterproductive: impact of divided versus skill-focused attention on novice and experienced performance of sensorimotor skills. *Journal of Experimental Psychology: Applied*, **8**, 6–16.
- Bernstein, N.A. (1996). Dexterity and its development. In *On Dexterity and its Development* (edited and translated by M.L. Latash and M.T. Turvey), pp. 171–204. Mahwah, NJ: Lawrence Erlbaum.
- Christina, R.W. and Alpenfels, E. (2002). Why does traditional training fail to optimize playing performance? In *Science and Golf IV: Proceedings of the World Scientific Congress of Golf* (edited by E. Thain), pp. 231–245. New York: Routledge.
- Craig, C.M., Delay, D., Grealy, M.A. and Lee, D.N. (2000). Guiding the swing in golf putting. *Nature*, **405**, 295–296.
- Crews, D.J. and Landers, D.M. (1993). Electroencephalographic measures of attentional patterns prior to the golf putt. *Medicine and Science in Sports and Exercise*, **25**, 116–126.
- Dorado, C., Sanchis Moysi, J., Vicente, G., Serrano, J.A., Rodriguez, L.P. and Calbet, J.A.L. (2002). Bone mass, bone mineral density and muscle mass in professional golfers. *Journal of Sports Sciences*, **20**, 591–598.
- Guadagnoli, M.A., Dornier, L.A. and Tandy, R. (1996). Optimal summary knowledge of results: the influence of task related experience and complexity. *Research Quarterly for Exercise and Sport*, **67**, 239–248.
- Guadagnoli, M.A., Holcomb, W.R. and Weber, T. (1999). The relationship between contextual interference effects and performer expertise on the learning of a putting task. *Journal of Human Movement Studies*, **37**, 19–36.
- Guadagnoli, M., Holcomb, W. and Davis, M. (2002). The efficacy of video feedback for learning the golf swing. *Journal of Sports Sciences*, **20**, 615–622.
- Hancock, G.R., Butler, M.S. and Fischman, M.G. (1995). On the problem of two-dimensional error scores: measures and analyses of accuracy, bias, and consistency. *Journal of Motor Behavior*, **27**, 241–250.
- Hardy, L., Mullen, R. and Jones, G. (1996). Knowledge and conscious control of motor actions under stress. *British Journal of Psychology*, **87**, 621–636.

- Hodges, N.J. and Franks, I.M. (2000). Attention focusing instructions and coordination bias: implications for learning a novel bimanual task. *Human Movement Studies*, **19**, 843–869.
- James, W. (1890). *The Principles of Psychology*, Vol. 1. New York: Holt.
- Kern, B. (2001). Make more putts. *Score Golf Magazine*, **21**, April, pp. 20–23.
- Leadbetter, D. and Smith, S. (2001). Roll your long putts close. *Golf Digest* ([www.golfdigest.com/instruction/index.ssf?instruction/200107leadbetter.html](http://www.golfdigest.com/instruction/index.ssf?instruction/200107leadbetter.html)).
- Lindsay, D.M., Horton, J.F. and Vandervoort, A.A. (2000). A review of injury characteristics, aging factors and prevention programmes for the older adult. *Sport Medicine*, **30**, 89–103.
- Masters, R.S.W. (1992). Knowledge, knerves, and know-how: the role of explicit versus implicit knowledge in the breakdown of a complex motor skill under pressure. *British Journal of Psychology*, **83**, 343–358.
- Nicklaus, J. and Bowden, K. (2000). Hit with the club-head. *Sports Illustrated* (<http://sportsillustrated.cnn.com/golffonline/instruction/nicklaus/nov00nick.html>).
- Poulton, E.C. and Freeman, P.R. (1966). Unwanted asymmetrical transfer effects with balanced experimental designs. *Psychological Bulletin*, **66**, 1–8.
- Smith, A.M., Malo, S.A., Laskowski, E.R., Sabick, M., Cooney, W.P., Finnie, S.B., Crews, D.J., Eischen, J.J., Hay, I.D., Detling, N.J. and Kaufman, K. (2000). A multidisciplinary study of the ‘yips’ phenomenon in golf: an exploratory analysis. *Sports Medicine*, **30**, 423–437.
- Toski, B., Flick, J., Merrins, E., Ransom, H. and Runyan, P. (1978). *Instant Golf Lessons*. New York: Simon & Schuster.
- Wulf, G. and Prinz, W. (2001). Directing attention to movement effects enhances learning: a review. *Psychonomic Bulletin and Review*, **8**, 648–660.
- Wulf, G., Lauterbach, B. and Toole, T. (1999). Learning advantages of an external focus of attention in golf. *Research Quarterly for Exercise and Sport*, **70**, 120–126.