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Cardiac and Respiratory Activity and Golf Putting Performance under Attentional Focus

Instructions

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Abstract

Objectives: The purpose of this study was to examine measures of cardiac and respiratory activity when participants at different levels of skill development performed a golf putting task under different attentional focus instructions. Putting performance and self-reports of attentional focus were also examined.

Methods: Novice ($n = 18$), experienced ($n = 16$), and elite golfers ($n = 16$) attempted 2.4 m straight putts under a baseline (no instruction) condition and when instructed to focus attention on a process goal, a performance goal, an outcome goal, or to trust the body to perform the skill.

Results: Compared to novice golfers, the experienced and elite golfers showed better performance and reduced heart rate (HR), greater heart rate variability (HRV), pronounced HR deceleration prior to the putt, and a greater tendency to exhale prior to the putt. The attentional focus instructions also influenced HR and putting performance.

Conclusions: The results show that athletes at different skill levels differ in their performance and focus of attention while performing a motor task.

Keywords: heart rate; respiration; attention; goal setting; golf putting

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Instructions

An athlete's attentional focus can play a vital role during sport performance (Wulf, 2007). Skill acquisition theories highlight changes in attentional processes when an individual progresses from being a novice to an experienced or elite athlete (e.g., Fitts & Posner, 1967; Shiffrin & Schneider, 1977). The role of attentional factors in the development of expertise has been examined using novel tasks, dual tasks, instructions to induce a specific attentional focus, and inducing pressure to perform (Beilock & Carr, 2001; Beilock, Carr, MacMahon, & Starkes, 2002; Castaneda & Gray, 2007; see Abernethy, Maxwell, Masters, van der Kamp, & Jackson, 2007 for a review). Another approach is to employ psychophysiological methods (Collins, 2002). This approach aims to infer psychological states by the measurement of physiological responses. Physiological responses can be measured relatively unobtrusively, are objective, and do not make any additional task demands on the athlete during measurement. Short-term phasic and long-term tonic measures of the cardiovascular system can be particularly insightful, enabling the direction of attentional focus immediately prior to critical events and the level of attentional demands across an entire session to be inferred. Such an approach is particularly useful when the sport of golf is considered because it is a self-paced sport that involves many discrete and repetitive events (shots) over an extended period of time.

The short-term phasic pattern in cardiac activity during golf is typically examined in the few seconds that immediately precede the shot. The intake-rejection hypothesis described by Lacey and Lacey (1974, 1980) suggests that there should be a deceleration in heart rate (HR) immediately prior to task execution if athletes engage their attention externally on the effects of the movements, such as the path of the ball towards the hole (see also Obrist, 1968). In contrast, HR will accelerate if athletes focus attention internally, such as on the movements of their arms during the putting stroke. These patterns were observed in a study of dart throwing

(Radlo, Steinberg, Singer, Barba, & Melnikov, 2002). Golfers also seem to show HR deceleration prior to the putt (Hassmén & Koivula, 2001; Neumann & Thomas, 2009), suggesting an external focusing of attention. Importantly for theories of skill acquisition, the deceleration is greater in elite and experienced golfers than in novice golfers (Neumann & Thomas, 2009). Such findings provide convergent validity to skill acquisition theories that claim a performance advantage with an external attentional focus for either highly skilled athletes (Castaneda & Gray, 2007) or for both novice and skilled athletes (Wulf, 2007).

Long-term tonic patterns in cardiovascular activity can index the athlete's regulation of attentional demands across a series of putts. Moreover, this can be done without imposing a secondary task (e.g., Beilock et al., 2002; Castaneda & Gray, 2007) or relying on self-reports. A lower mean HR, greater heart rate variability (HRV), and reduced respiratory frequency should indicate lower attention demands based on experimental studies showing the relationship between these measures and mental workload (e.g., Neumann, 2002; Veltman & Gaillard, 1998). Heart rate variability, in particular, has received little examination in sport (Abernethy et al., 2007). Spectral power analysis can decompose HRV into three different frequency components (see Grossman, 1992). The very low frequency (VLF) component (0.03 to 0.05 Hz) reflects temperature regulation, the low frequency (LF) component (0.05 to 0.15 Hz) reflects blood pressure regulation, and the high frequency (HF) component (0.15 to 0.4 Hz) indicates respiratory influences on HR (respiratory sinus arrhythmia). Increases in attentional demands can reduce power in all three frequency components (Neumann, 2002), but this is not always found (Veltman & Gaillard, 1998). Increased task demands tend to have a more reliable effect on the LF component than on other components (Aasman, Mulder, & Mulder, 1987; Veltman & Gaillard, 1998).

Mullen, Hardy, and Tattersall (2005) examined HRV in the LF and HF bands while experienced golfers putted under single or dual-task conditions. Although no effects were

found for the LF band, the HF component was higher during the dual-task conditions than during the single-task (putting only) condition. This result is somewhat surprising given prior reports of increased attentional demands producing a reduction in HRV across the LF and HF bands (Neumann, 2002). Mullen et al. (2005) suggested that participants may have adapted to the increased demands of the dual task by adopting a breathing-based relaxation strategy and that this increased the HRV of the HF component via respiratory sinus arrhythmia. Further research was needed to explore the effects of attentional demands on HRV in not only the HF component, but also the LF component. Moreover, as the study by Mullen et al. (2005) included only one group of participants, it did not investigate the relationship between skill level and HRV during putting.

Neumann and Thomas (2009) examined patterns of cardiac and respiratory activity in novice, experienced and elite golfers in a single putting task that formed part of a larger study comprising dual-task conditions. They found no group differences in mean HR, or the VLF or HF components of HRV. The VLF HRV component is unreliable and cannot be interpreted when measured from short-term recordings (Task Force, 1996), such as the 5-min sessions used in their experiment. However, the LF component of HRV was significantly lower in novices than in experienced golfers. There were also significant differences between groups in heart rate change. Elite and experienced golfers showed more fluctuation in HR and significant deceleration prior to the putter contacting the ball, but novices showed less variation in HR and their deceleration peaked after ball contact. Whereas elite golfers generally exhaled and novices generally inhaled prior to the putt, there was no dominant pattern in the experienced golfers. Together these patterns were consistent with an external focus of attention being associated with the superior putting performance of elite and experienced golfers.

Skilled golfers have been found to perform pitch shots better with an external focus of attention, whereas novice golfers performed better with an internal focus (Perkins-Cecceto,

Passmore, & Lee, 2003). However, this finding contrasts with research showing that novice golfers have greater accuracy in making pitch shots when adopting an external focus on the swing of the club than an internal focus on the swing of their arms (Wulf, Lauterbach, & Toole, 1999). Moreover, the benefits of an external focus persisted during a retention test completed one day later. A subsequent study added a control condition in which participants were given no specific attentional focus instructions (Wulf & Su, 2007). Both novice and expert golfers performed better with instructions to adopt an external focus, relative to control and internal focus conditions. More research is needed on how performers' level of expertise interacts with their focus of attention (Wulf, 2007).

Many sport psychology consultants use goal setting strategically to encourage athletes to focus attention on certain aspects of the task (Gould, 2006; Locke & Latham, 1990). Three main types of goals are set (Kingston & Hardy, 1997). Process goals encourage a focus on the actions performed in the execution of a skill (e.g., putt with a smooth action). Performance goals focus an athlete's attention on standards to be achieved (e.g., make 90% of short putts). Outcome goals focus attention on the final result (e.g., win tournament). An alternative strategy is to encourage athletes to focus on one relevant external cue, ignore movement and other contextual information, and trust their body to perform the skill automatically (Singer, Lidor, & Cauraugh, 1993). The automaticity characterizing this strategy is the goal in any skill mastery situation (Logan, 1988). Moore and Stevenson (1991) emphasized this need for trust in skilled performance - letting go of conscious control and allowing automatic processes to execute the motor skill.

In comparison to setting no goals or "do your best" goals, research suggests that setting specific goals enhances athletes' performance (Burton & Naylor, 2002). A meta-analytic review showed goal setting improves performance by 0.34 of a standard deviation (Kyllo & Landers, 1995). Performance improvements have been reported when athletes are specifically

asked to adopt process goals (e.g., Kingston & Hardy, 1997) and performance goals (e.g., Burton, 1989). Athletes were initially advised to set performance goals (Gould, 1986), and later advised to set process and performance goals rather than outcome goals (Gould, 1998). However, meta-analysis indicated that outcome goals may be associated with greater improvements than performance goals (Kyllo & Landers, 1995), and Olympic athletes reported giving higher priority to outcome goals in competition (see Burton, Naylor, & Holiday, 2001). Athletes are now encouraged to set all three types of goals given the effectiveness of multiple-goal strategies (e.g., Filby, Maynard, & Graydon, 1999; see Burton & Weiss, 2008; Gould, 2006; Kingston & Wilson, 2009 for reviews). Adopting a strategy based on trust is not typically seen in goal setting programs, but research has illustrated the benefits of automatic processing in expert performance (Abernethy et al., 2007; Singer, 2000, 2002; Wulf, 2007).

Although research has examined the effects of different goal setting strategies on performance, the attentional processes by which they exert their effect are less well-known. More research is needed on the specific mechanisms through which the different goal types influence task performance (Kingston & Wilson, 2009), and that research should examine potential interactions between goal type and attentional processes (Mullen & Hardy, 2010). The measurement of cardiac responses may indicate which strategies induce a greater level of attentional demands and whether they induce an internal or external focus on task-relevant cues. The present experiment examined the relationship between skill level and patterns in HR, HRV, HR deceleration, and respiratory activity when golfers putted under attentional focus instructions. Participants initially attempted putts under no attentional focus instructions as a baseline condition. They next attempted putts under instructions to adopt process, performance, and outcome goals or a strategy based on trust. Novice golfers were hypothesized to show less HR deceleration and less HRV, reflective of an internal focusing of attention and greater overall attentional demands, compared to the experienced and elite golfers for whom golf

putting is a well practiced skill. Performance and outcome goals were expected to be associated with HR deceleration because these goals are more likely to lead to an external focus of attention on the movements effects (i.e., holing the putt). Heart rate variability was expected to reflect overall attentional demands and to be lower when setting process, performance, and outcome goals than in a trust condition, because the latter strategy encourages athletes to clear the mind and trust the body to execute the skill thus leading to reduced attentional demands.

Method

Participants

Participants were recruited from state and national representative squads, local clubs, and the university and had a mean age of 23.38 years ($SD = 5.81$). Novice golfers (12 male, 6 female) had no prior experience in playing golf or minigolf. Experienced golfers (11 male, 5 female) had competed for at least 3 years at no higher than club or regional level. Elite golfers (10 male, 6 female) were professionals or amateurs who had competed at state or national representative events. The groups did not differ in the ratio of males to females, $\chi^2(2) = .15, p > .05$, or in mean age, $F(2, 47) = 3.09, p > .05$. The experienced group had a significantly higher handicap ($M = 8.00, SD = 7.04$) than the elite group ($M = 0.44, SD = 1.71$), $t(30) = 4.17, p < .001$, but they did not differ in playing experience (experienced: $M = 11.94$ years, $SD = 7.10$; elite: $M = 10.81$ years, $SD = 4.49$) or playing frequency per month (experienced: $M = 7.88, SD = 7.01$; elite: $M = 11.94, SD = 7.51$), both $t_s < 1.58, p > .05$. Experienced and elite golfers were reimbursed \$15 and novices received course credit for participation. Participants gave informed consent to a protocol approved by the institution's Research Ethics Committee.

Apparatus

The participants were tested outdoors on a level synthetic grass surface. A dot was placed 2.4 m away from a standard 108 mm cup to mark the position from which each putt was attempted. Participants struck Optima TS golf balls either with their own putter or with a left or

right-handed Odyssey #2 centre-shafted putter as appropriate. Psychophysiological responses were acquired via a PowerLab (ADInstruments, Sydney) Model 4/20 data acquisition system using a sampling rate of 400 Hz and stored on a Dell Latitude D800 computer for later analysis. The electrocardiogram (ECG) was recorded via disposable ADInstruments MLA1010B Ag/AgCl electrodes applied over the manubrium, xiphoid process, and 6th rib (ground). Respiratory effort was recorded via an ADInstruments MLT1132 Piezo Respiratory Belt Transducer applied around the lower chest. The experimenter depressed a push button switch to mark the time the putter contacted the ball. An evaluation of this method showed that it was reliable with a mean error of 40.05 ms ($SD = 30.40$, min = 0.50, max = 170.00) in the time between depressing the switch and contact between putter and ball.

Measures

The dependent measures were derived from the performance, self-report, and psychophysiological data. Putting performance was measured as the distance that the ball finished from the hole as calculated from photographic records using a method with established reliability (Neumann & Thomas, 2008). The self-reports were examined to determine the type of attentional focus adopted by participants. The psychophysiological measures were scored to obtain HR, HRV in the LF and HF bands, HR change before and after putt onset, and respiratory frequency.

Experimental conditions

The participants completed the putting task under five experimental conditions. In the baseline condition, the participant received no specific instructions on how to prepare and attempt each shot other than that their task was to “make each putt, leaving the ball as close as possible to the hole if it misses.” In the process, performance, outcome, and trust conditions, the participant received the same instructions in addition to further instructions specific to each condition. The process goal condition also asked participants to “focus your attention on the

pressure of your grip on the putter. Notice how the putter feels in your hands. Focus all your attention on the pressure of your grip during the putting stroke.” The performance goal condition noted that the “goal is to improve on your initial (baseline) performance by at least 20%.” The outcome goal condition instructed that the “goal is to beat the best total score recorded by your group.” The best score determined through pilot testing was 12, 17, and 18 for the novice, experienced, and elite groups, respectively. In each case participants were told the score to beat for the first 6 putts, the next 6 putts, and finally all 20 putts. In the trust condition, participants were asked to “plan your putt, and then focus your attention solely on the ball, ignore anything else, and trust your body to perform the putting skill. Focus all of your attention on the ball and just allow your body to perform the skill automatically.”

Procedure

Participants first attempted 10 practice shots at the hole. Next, they completed 20 putts in the baseline putting condition. The baseline condition was completed first to compare across groups independent of any influence from the subsequent instructions. Participants next attempted 20 putts in the process, performance, outcome, and trust conditions in a counterbalanced order. The instructions relevant to each condition were given immediately prior to that condition. All participants were urged to adopt the focus that was instructed, even if it was not part of their usual routine or if it negatively impacted on performance. After each baseline and instruction condition, participants provided a written self-report on what they had focused on during that set of putts.

Response quantification

Self-report data. The self-report data were examined in two ways. The statements given in the baseline condition were examined to determine the attentional focus reported by each participant. The classification scheme, adapted from Thomas, Neumann, and Hooper (2008), contained six categories, each with various themes. The categories were *External* (aim,

target/hole, line/path, break, length, speed/pace, ball), *Internal* (posture/stance, alignment, head, hands/grip, technique, force, rhythm, tempo/speed, stroke, swing path, follow through, state/anxiety, breathing), *Performance* (hole putt, finish close, missed putts, score, standard, improvement), *Outcome* (beat best score, beat others, winning, set the record), *Trust* (ball, trust the body, just do it), and *Other* (putting, routine, adjustment, other). Three coders independently classified each participant statement, using more than one theme where appropriate. The inter-rater agreement as measured by Cohen's kappa were, for raters 1 and 2 $\kappa = .71, p < .001$, raters 1 and 3 $\kappa = .63, p < .001$, and raters 2 and 3 $\kappa = .59, p < .001$, and they indicated moderate to substantial agreement. Only those themes in which two or more coders had classified a statement were counted. The counts within each theme were then summed across participants in each group to allow for between-group comparisons.

Self-reports obtained during the instructed conditions were classified as belonging to the process, performance, outcome, or trust categories. The coding was done blind to the actual condition and participant group identity. Initially, two coders agreed on 77% of the 212 coding decisions and reached full agreement after discussion. A third coder next independently coded the statements and there was 87% agreement with the categorizations agreed upon by the first two coders. Full agreement was reached after discussion. The primary source of disagreement was in categorizing statements in the performance and outcome conditions. Statements that referred to "beating" or "winning" were classified in the outcome condition even when it was not clear the score to beat was the best for the group (e.g., "what score I had to beat" and "beating the number of putts"). Statements that referred to holing the putts were classified in the performance condition regardless of whether individuals referred to their prior score (e.g., "holing every putt" and "getting as many balls in the hole"). Finally, some reports containing multiple themes were not classified due to the uncertainty of the correct category (e.g., "holing the putts. Shadow inside right. Light grip" and "Everything: hole, aiming, ball, pressure, grip,

relaxed swing, and knees”). To evaluate the extent to which participants’ reports were consistent with the instructions given, the percentage agreement between the coded classification and the actual condition was calculated for each group.

Psychophysiological data. The ECG recordings were used to derive three measures of cardiac activity. The measures were calculated on the intervals between successive R-peaks as identified through an absolute value threshold (adjusted for each participant). Potential artifacts when the peak-to-peak interval fell outside of a 400-1000 ms range were manually corrected. The first measure of cardiac activity was mean HR recorded across the block of 20 putts in each condition. The second measure was HRV across the 20 putts in each condition. Both these measures were scored with the Chart software package and HRV analysis extension (ADInstruments, Sydney). Beats were identified when the R-peak exceeded an individually determined threshold. Ectopic beats (5 and 600 ms and 1000 and 2000 ms between successive peaks) and artifacts (< 5 m and > 2000 ms between successive peaks) were automatically identified and corrected manually if required. For the analysis of HRV, the R-R intervals were first extracted from the ECG signal and the linear trend was removed. The fast-Fourier transform (size = 1024, window = cosine, overlap = 0.5) was next applied and spectral power was calculated for two bands to represent the LF (0.04 to 0.15 Hz) and HF (0.15 to 0.4 Hz) components. The third measure was the phasic change in $HR \pm 6$ s around contact between ball and putter. The HR was calculated from the R-R intervals using time-based methods (Graham, 1978) to derive a value for each 0.5 s bin. Final HR change was calculated by subtracting the HR at 6 s prior to ball contact from the HR in each 0.5 s bin such that a negative change reflects HR deceleration.

Respiration was not recorded for one elite golfer due to equipment error. Respiration frequency across the entire set of putts in each putting condition was scored using the cyclic measurements function of the Chart software package (ADInstruments, Sydney) with a 0.9

standard deviation threshold for detecting the minimum peak height. Respiration pattern was also examined in the 12 s that spanned ball contact, and the respiratory state for each individual immediately preceding ball contact was classified as inhale, hold, or exhale (Boutcher & Zinsser, 1990). Two raters blind to group membership classified the respiratory patterns. The raters initially showed 94% agreement and were in 100% agreement following discussion.

Statistical analyses

The statistical analyses for the quantitative variables were based on a mixed factorial design that included Group (novice, experienced, elite) and Putting condition (baseline, process, performance, outcome, trust). Epoch was an additional within-subjects factor for HR change. Univariate ANOVAs used a Greenhouse-Geisser adjustment when the sphericity assumption was violated (the epsilon is reported). Each HRV measure was log transformed due to positive skewness. Post hoc analyses to examine significant effects from the ANOVAs used *t* tests that applied the MSE to estimate pooled variance and were adjusted for the accumulation of Type I error by using Šidák's multiplicative inequality. A chi-square analysis was conducted to examine the classification of respiratory patterns (inhale, hold, and exhale) as a function of group membership (novice, experienced, and elite). Post hoc analyses were conducted using the adjusted standardized residuals in each cell to determine whether the percentage of participants classified in a given respiratory pattern was greater or less than chance (33.3%). Statistical significance was assessed against an $\alpha_{\text{two-tailed}}$ level of .05.

Results

Self-report

The self-reports during the baseline putting condition are shown in Table 1. The experienced and elite groups made more statements classified as an external attentional focus than the novice group. Most statements in this category referred to the line/path (novice: 1, experienced: 8, elite: 8), target/hole (novice: 2, experienced: 2, elite: 4), and ball (novice: 2,

experienced: 1, elite: 4). The elite group also made relatively fewer statements classified as an internal attentional focus than the novice and experienced groups. Most statements in this category for the experienced and elite groups referred to tempo/speed (novice: 1, experienced: 6, elite: 3) and stroke (novice: 0, experienced: 5, elite: 4), whereas most statements in the novice group referred to force (novice: 8, experienced: 1, elite: 0). The most common statement in the performance category was hole putt (novice: 4, experienced: 4, elite: 4). No statement was classified in the outcome category, and the only statement classified in the trust category was focusing on the ball. Finally, the novice group made more statements classified as other than the other groups. The novice group statements were related to the environment (e.g., “the wind blowing around”, “block out external noises”) or incidental to the task, such as referring to the experimenter or placing the ball on the spot that marked the origin of each putt.

The self-reports for the attentional focus conditions confirmed that participants carried out the instructions as requested. In the process focus and performance focus conditions, 100% of the self-report statements were classified in the intended category. In the trust condition, 100% of the novice and elite group statements were classified in this category, as were 92% experienced golfers’ statements. The self-statements in the outcome focus condition were less likely to be classified in this category – 87%, 64%, and 60% for participants in the novice, experienced, and elite groups, respectively. The lower match in the outcome condition reflected difficulty in classifying some decontextualized statements as a performance or outcome focus (e.g., “trying to get the score”).

 Insert Table 1 and Figure 1 about here

Putting task performance

The mean distance that the ball finished from the hole is shown in Figure 1. A 3 x 5 (Group x Putting condition) ANOVA revealed a main effect for Group, $F(2, 47) = 10.24, p <$

.001, $\eta_p^2 = .22$. Performance was poorer in the novice group than in the experienced and elite groups, both $ts > 3.73$, $p < .001$, $d > 1.15$, whereas the two latter groups did not differ, $t = 0.29$, $p = .77$, $d = 0.16$. Performance also differed across putting conditions, as reflected in a main effect for Putting condition, $F(4, 188) = 7.25$, $\epsilon = .80$, $p < .001$, $\eta_p^2 = .13$, and a Group x Putting condition interaction, $F(8, 188) = 3.04$, $\epsilon = .80$, $p = .006$, $\eta_p^2 = .12$. Follow-up analyses compared between putting conditions separately for each group. In the novice group, baseline performance was better than in the trust condition, $t = 3.68$, $p < .001$, $d = 0.68$. A performance or outcome focus was also better than a process focus, both $ts > 3.96$, $p < .001$, $d > 0.63$, or a trust focus, both $ts > 4.86$, $p < .001$, $d > 0.99$. There were no differences across putting conditions for the experienced or elite groups after correction for inflated Type I error, all $ts < 2.06$, $p > .04$, $d < 0.62$.

Psychophysiological measures

Mean heart rate and heart rate variability. A 3 x 5 (Group x Putting condition) ANOVA was conducted for each measure of mean HR, and HRV power for the LF and HF bands. As indicated in Table 2, HR yielded a main effect for Group, $F(2, 47) = 5.12$, $p = .01$, $\eta_p^2 = .18$, a main effect for Putting condition, $F(4, 188) = 5.46$, $\epsilon = .80$, $p = .001$, $\eta_p^2 = .10$, but no significant Group x Putting condition interaction, $F(8, 188) = 1.17$, $p = .33$, $\eta_p^2 = .05$. The Group main effect showed that HR was higher in the novice group than in both the experienced and elite groups, both $ts > 2.61$, $p < .01$, $d > 0.91$, whereas the latter two did not differ, $t = 0.26$, $p = .80$, $d = 0.08$. The Putting condition main effect showed that HR was lower in the baseline condition than in the performance and outcome conditions, both $ts > 3.79$, $p < .001$, $d > 0.42$, and all other comparisons were not significant after correction for inflated Type I error, all $ts < 2.30$, $p > .02$, $d < 0.42$.

Insert Table 2 about here

The LF component yielded a main effect for Group, $F(2, 47) = 14.43, p < .001, \eta_p^2 = .38$, although no other main effects and interactions reached significance, all $F_s < 1.70, p > .05$. The main effect was due to lower power in the novice group ($M = 2.88 \log \text{ms}^2, SD = 0.31$) than in the experienced ($M = 3.49 \log \text{ms}^2, SD = 0.46$) and elite ($M = 3.50 \log \text{ms}^2, SD = 0.39$) groups, both $t_s > 4.49, p < .001, d > 1.56$, and the experienced and elite groups did not differ. The HF component also yielded a main effect for Group, $F(2, 47) = 7.43, p = .002, \eta_p^2 = .24$, and no other main effects or interactions, all $F_s < 1.50, p > .05$. Power in the HF component was lower in the novice group ($M = 2.15 \log \text{ms}^2, SD = 0.32$) than in the experienced ($M = 2.65 \log \text{ms}^2, SD = 0.50$) and elite ($M = 2.60 \log \text{ms}^2, SD = 0.43$) groups, both $t_s > 3.05, p < .001, d > 1.19$, which themselves did not differ.

 Insert Figure 2 about here

Phasic heart rate change. The HR change was examined with a $3 \times 5 \times 12$ (Group x Putting condition x Epoch) ANOVA. The groups differed in the pattern of HR as shown by a main effect for Group, $F(2, 47) = 4.47, p = .02, \eta_p^2 = .16$, a main effect for Epoch, $F(23, 1081) = 43.36, \epsilon = .10, p < .001, \eta_p^2 = .48$, and a Group x Epoch interaction, $F(46, 1081) = 4.21, \epsilon = .10, p = .002, \eta_p^2 = .15$. As shown in Figure 2, the HR in each group was not constant, but varied prior to and following contact with the ball. Inspection of the 95% confidence intervals was used to determine whether the HR change was significantly different from baseline (acceleration or deceleration was deemed to be significant if zero was outside of the confidence interval). The elite and experienced participants showed a significant deceleration that began 5.5 s (elite) and 3.5 s (experienced) prior to ball contact and continued until 3.5 s (elite) and 3 s (experienced) following ball contact. The novice participants appeared to show a small initial acceleration between 4.5 s and 2.5 s prior to ball contact, but this was not a statistically significant effect. The novice participants showed a deceleration in HR that was

not statistically significant until ball contact and continued until 3 s following ball contact. Post hoc comparisons between the groups at each epoch showed that HR deceleration was significantly different in the elite and novice groups between 3 s prior and 2 s following ball contact, all $t_s > 3.79$, $p < .001$, $d > 0.95$. Similarly, HR deceleration differed in the experienced and novice groups between 2.5 s prior and 1 s following ball contact, all $t_s > 3.45$, $p < .001$, $d > 0.95$. The elite and experienced participants did not differ at any epoch, all $t_s < 1.25$, $p > .21$, $d > 0.48$. The Putting condition x Epoch interaction just failed to reach statistical significance, $F(92, 4324) = 1.72$, $\varepsilon = .09$, $p = .08$, $\eta_p^2 = .04$. Similarly, the Group x Putting condition x Epoch, $F(182, 4324) = 0.96$, $\varepsilon = .09$, $p = .50$, $\eta_p^2 = .04$, and all other effects were not significant.

Respiratory activity. A 3 x 5 (Group x Putting condition) ANOVA was used to examine the respiratory frequency calculated across the 20 putts in each putting condition. The mean respiratory frequency averaged across all experimental conditions was 0.32 ($SD = 0.08$) for the novice group, 0.36 ($SD = 0.05$) for the experienced group, and 0.36 ($SD = 0.06$) for the elite group. The differences between groups were not significant, $F(2, 46) = 2.77$, $p = .07$, $\eta_p^2 = .11$. Similarly, respiratory frequency did not differ between the putting conditions as shown by all main effects and interactions involving the Putting condition factor failing to reach significance, all $F_s < 0.63$, $p > .05$, $\eta_p^2 < .08$. The mean of 0.35 ($SD = 0.06$) across all groups and putting conditions indicated that participants completed one respiratory cycle approximately every 3 s.

The classification of the respiratory pattern in the baseline condition (Novice: Inhale = 50%, Hold = 22.2%, Exhale = 27.8%; Experienced: Inhale = 18.8%, Hold = 43.8%, Exhale = 37.5%; Elite: Inhale = 0%, Hold = 26.7%, Exhale = 73.3%) differed across groups, $\chi^2(4) = 14.15$, $p = .007$. More novice golfers (50%) inhaled, $z_{adj} = 3.17$, $p = .002$, immediately prior to the putt than expected by chance. In contrast, more elite golfers (73%) exhaled immediately prior to the putt than expected by chance, $z_{adj} = 2.68$, $p = .007$. Experienced golfers tended to

hold their breath (44%), but the residuals indicated no dominant pattern, all $ps > .05$.

Discussion

Skill level and the goal setting instructions had significant effects on the performance and cardiovascular measures in this study. Independent of explicit instructions, the patterns in HR, HRV, and HR deceleration were similar in elite and experienced golfers, and both these groups differed from the novice golfers. The differences across groups in cardiac activity thus parallel those found in putting performance. Attentional focus instructions had an effect on HR, suggesting that instructions had an effect on tonic cardiac activity across the series of putts and not on phasic cardiac changes prior to the putt. The difference between the tonic and phasic measures suggests that the instructions did not greatly affect the participants' preshot routine or attentional focus during the putting stroke. However, they did appear to influence more global aspects of the task, including cognitive or affective processes in between the putts.

When tonic HR measures were compared between groups, the overall HR was higher and HRV lower in the LF and HF bands in the novice golfers than in the experienced and elite golfers. The results are similar to those reported by Neumann and Thomas (2009), although they reported significant differences in LF and HF HRV only between novice and experienced participants. The present differences between groups cannot be accounted for by differences in breathing frequency. Based on prior research indicating that increased attentional demands are associated with higher HR and reduced HRV in the LF band (Neumann, 2002; Veltman & Gaillard, 1998), the results suggest that the attentional demands of the putting task were greatest in the novice golfers. This interpretation is consistent with the notion that sustained practice and the attainment of proficiency in sport is associated with the automatization of certain components of the skill and a corresponding reduction in attentional demands (Abernethy et al., 2007; Wulf, 2007).

Group differences in phasic HR change prior to the putt were also observed. Consistent

with prior research (Hassmén & Koivula, 2001; Neumann & Thomas, 2009), a deceleration in HR was observed in experienced and elite golfers. Moreover, the deceleration was greater in these groups than in novice golfers, suggesting a difference in the focus of attention between the groups. According to Lacey and Lacey's (1974, 1980) intake-rejection hypothesis, the HR patterns of the elite and experienced golfers reflect a greater external focus of attention than the novice golfers. In contrast, the initial increase in HR suggests the novice golfers' attention was focused internally, but the subsequent deceleration in HR is indicative of an external focus. It is noteworthy that the HR deceleration peaked at the time the ball was struck for the elite and experienced golfers, whereas it peaked 1 s following ball contact in novice golfers. The later deceleration in novice golfers may have been more closely associated with watching the ball travel to the hole than with a preshot attentional focus associated with the putting stroke.

It is worthwhile to consider whether the group differences in the phasic HR change reflect non-attentional factors. Although Obrist (1968) also argued that HR deceleration reflects an external focusing of attention, the underlying mechanism was thought to be reduced muscle and metabolic activity. However, this is unlikely to account for the results because participants engaged in practice strokes and the putt itself, thus increasing muscle activity. A second explanation could be that the HR deceleration reflects respiratory influences. There is an established relationship between breathing and HR such that HR deceleration occurs during expiration (termed respiratory sinus arrhythmia). This explanation may account for the HR patterns in elite and novice golfers because the former showed a predominant pattern to exhale prior to the putt and the latter showed a predominant pattern to inhale. However, experienced golfers did not show any dominant respiratory pattern, yet this group showed a deceleration in HR. It is thus not parsimonious to suggest that the HR pattern reflected respiratory influences in the elite and novice golfers, but not in the experienced golfers.

Tonic HR across the series of putts was lower in the baseline condition than in the

performance and outcome conditions. The difference across conditions suggests that attentional demands were greater during an outcome and performance focus than when instructions did not require participants to focus on a specific goal. The self-report data indicated that few participants reported using performance or outcome goals during the baseline condition. This suggests that the performance and outcome goals added to the attentional demands that were otherwise present in the baseline condition. However, interpretations regarding the outcome condition in the present experiment are somewhat problematic because it is less certain what the participant focused on during this condition. In a component of the study that was designed to check whether the participants followed the instructions, the raters blindly classified the self-reports given following each putting condition. Self-reports for the outcome condition did not always match this category. It is not known whether the lower percentage of matching classifications reflects the greater heterogeneity of focus strategies during the outcome condition, an inability for the participants to accurately report what they focused on in that condition, or other factors.

Strengths, limitations, and future directions

The present research had strengths in its multidisciplinary approach of combining performance, self-report, and psychophysiological measures and the inclusion of groups at different levels of skill development. However, the methods used also raise some limitations as to the interpretation of the results. In order to measure the effects of goal setting on attentional processes and performance at different levels of skill development, we instructed participants to set specific types of goals for each experimental condition. This was done to investigate the specific mechanisms through which different types of goals influence task performance. However, recent attempts to synthesize the findings of goal setting research have emphasized that goals should be incorporated into a hierarchical strategy to optimize their effects (Burton & Weiss, 2008; Kingston & Wilson, 2009). For example, it is recommended that process goals

be the primary focus in competitive situations, but used within a hierarchy of goals that includes performance and outcome goals. One limitation of the design, therefore, was that it did not permit participants to derive potential benefit from multiple-goal strategies (Filby et al., 1999).

The extent to which attentional processes were manipulated by the use of the goal setting instructions deserves consideration. It might be argued that only the process goal instructions were useful in focusing participants' attention during task execution. Process goals contain information that is likely to enhance attentional focus (Kingston & Hardy, 1997; Kingston & Wilson, 2009; Mullen & Hardy, 2010). However, we believe the performance and outcome goal instructions also influenced participants' attentional focus, just as attending to scorecard or leaderboard information is likely to guide immediate task execution for a shot during a round. Moreover, professional tour statistics are readily available for specific aspects of performance such as drives on fairways, greens in regulation, sand saves, and number of putts per round. Corresponding statistics are also available for amateur golfers (Pelz, Pelz, Evans, & Bracey, 2008), and these four shot-making skills have been shown to account for 80 to 90% of a player's overall performance (Callan & Thomas, 2004). Players at all skill levels are encouraged to record these performance statistics during a round and use such information when setting goals and monitoring progress (Gullo, 2009). Coaches are also urged to provide such performance feedback, enabling players to prioritise their goals and focus attention on those that are most important (Gould, 2006).

Participants attended to performance indicators in the experimental conditions, as evidenced by their self-report data. However, a limitation of the present research is that we only collected information about what the golfers focused attention on across the series of 20 putts in each condition. Future research could obtain feedback at regular intervals during the

series of putts to examine how the participant's task execution and attentional focus may change according to whether or not the performance or outcome goals are being met.

The instructions used for the process goal condition also warrant further consideration. The process condition instructed participants to focus on the pressure of their grip on the putter. Whether this induced an internal focus on the pressure felt in the hands, an external focus on the putter, or a combination of both is crucial to the interpretation of the results. Wulf (2007) argued that the internal focus instructions used by Perkins-Ceccato et al. (2003) "to concentrate on the form of the golf swing and to adjust the force of their swing depending on the distance of the shot" (p. 596) may have lead to a focus on external cues, thus confounding their experimental conditions. After consulting golf coaches, we instructed participants to focus on the pressure of their grip on the putter. This was intended to promote an internal focus of attention, but it might be argued that our participants focused externally if their attention was drawn to the effects of their grip on the putter. Clearly this was not the intention of our instructions and was not evident in the self-report data. Although the vast majority of participants' statements confirmed they had focused attention as instructed, some also reported focusing attention on other cues. In no case was it considered necessary to exclude a participant from the analyses, but this potential confound should be noted as it may have limited the putting condition effects.

The task of making a straight flat putt 2.4 m from a hole was reasonably simple as reflected in the relatively good performance of all groups. The novice participants, in particular, showed a high level of performance relative to their experience with the task, in averaging a distance error of approximately 26 cm from the hole. Golfers on the PGA Tour make about half of their putts from 6 ft, but would hole approximately 90% of these putts on perfect and known surfaces (Pelz, 2002). In contrast, golfers with handicaps from 15 to 25 hole about 25% of putts from 6 ft. These findings informed the decision to set the putting distance at

8 ft (2.4 m) in this study. However, it is likely that taking putts from the same location enhanced performance in this study. Practice effects of this kind could be reduced by taking putts from different positions. Alternatively, greater differences between groups could be observed if the putts were made more difficult. For example, putts could be taken from a longer distance, at varying distances, or on a green with contours (i.e., breaking putts).

The timing of the putt poses a potential methodological limitation. Similar to Boutcher and Zinsser (1990), we recorded the time of contact between putter and ball. This time was judged by an experimenter, introducing the possibility of human error. Although this technique was found to be accurate with a mean error of only 40.05 ms, there was a 9 to 1 bias towards marking ball contact before rather than after it actually occurred. This potential bias should be kept in mind when examining the data. The patterns in Figure 2 may have slightly underestimated the time at which HR began to decelerate and the time at which peak deceleration occurred. It is recommended that future research use a more objective technique to measure the timing of the putt. Such techniques could include the use of a switch (e.g., reed switch), and accelerometer attached to the putter, or analysis from video recordings. The latter technique, while potentially more complex, may be advantageous in that it would allow for the measurement of the timing of various aspects of the putting stroke (e.g., onset of the backlift, duration of the stroke, time of contact with the ball). Cottyn, de Clercq, Crombez, and Lenoir (2008) recently used video recordings to synchronize heart rate change with gymnasts' performance on a balance beam, thus showing that this technique can be successfully applied in sport psychology research.

The results of the present experiment suggest future potential avenues for research. The finding that several cardiac and respiratory functions are related to skill level requires further validation as being determined by the development of expertise. For instance, this validation could use a longitudinal approach in which cardiac activity is examined while novices undergo

training. An improvement in performance should coincide with greater HR deceleration prior to the putt and an overall increase in HRV. Programs that teach golfers how to focus attention when putting can also make use of cardiac measures to assess training outcomes. In this respect, there are several questions that remain unanswered. For instance, unlike performance and outcome goals, adopting a trust strategy or a process goal did not seem to increase attentional demands over and above that present when participants putted without a specific goal focus as shown by tonic HR. However, because the trust strategy included the two components of focusing on an externally relevant cue (ball) and trusting the body, it is unclear which one of these features is most conducive to facilitating automaticity of skill execution. In addition, and as noted above, the internal versus external distinction is important in the context of attentional focus during task execution. Future research should use more specific attentional manipulations to separate multiple influences of the direction of attentional focus (internal vs. external) when participants are asked to set goals.

There is also the potential to use cardiac measures as part of a biofeedback training program. The relationship between goal setting and cardiac activity observed in the present experiment suggests that any such biofeedback program would be best served by teaching the attentional processes that lead to the appropriate cardiac responses, rather than teaching the athlete to modify their cardiac response *per se*. One way to use cardiac feedback would be for the golfer to observe the phasic change in HR after the putt is attempted and retrospectively relate it to their attentional focus. However, biofeedback is more traditionally conceptualized as receiving feedback while concurrently performing a task. In this application, there is greater potential for a conflict between the different ways attention can be directed when putting. The potential for conflict would be greatest if the golfer is asked to adopt an external attentional focus when putting (e.g., focus on the ball). In this case, the golfer would need to divide attention between an external focus on the putting task and an internal focus related to HR

feedback. While attending to the cardiac feedback is a type of internal focus (albeit the feedback *per se* would be an external stimulus like a tone), it does not relate to a body movement or muscle activity that is directly involved in putting. As such, the interference between an external and internal focus of attention during putting skill might be minimized.

Conclusions

The present research has confirmed recent evidence that participants at various skill levels differ in patterns of cardiac and respiratory activity during golf putting (Neumann & Thomas, 2009). It extends previous work by showing that an explicit attentional focus instruction influences cardiac activity, but does so differently for individuals at different skill levels. The present results encourage the use of cardiovascular measures during a training program in golf. For instance, it would be expected that across practice sessions, the cardiac patterns in novices will shift towards that seen in experienced and elite golfers. Moreover, phasic HR deceleration prior to the putt could be promoted by focusing attention on external cues. The present results also showed that participants at a lower skill level are especially influenced by attentional focus instructions. They demonstrate how goal setting can be used effectively in training programs, particularly with athletes at lower levels of skill development.

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Table 1. Number of self-report statements classified in each category during the baseline putting condition for the novice, experienced, and elite groups.

Category	Group		
	Novice	Experienced	Elite
External	6	10	15
Internal	15	19	11
Performance	6	7	4
Outcome	0	0	0
Trust	2	0	1
Other	14	4	3

Note. Numbers show the frequency of responses - not participants - classified in each category.

Table 2. Mean heart rate (in beats per minute) in the baseline and goal setting conditions for the novice, experienced, and elite groups. Standard deviations are in parentheses.

Condition	Group		
	Novice	Experienced	Elite
Baseline	101.08 (9.70)	91.23 (10.19)	91.12 (11.61)
Process	103.04 (10.58)	92.09 (13.70)	91.50 (13.29)
Performance	104.56 (9.61)	93.61 (13.69)	92.76 (13.11)
Outcome	104.35 (13.07)	95.00 (15.02)	91.32 (12.46)
Trust	103.32 (10.08)	91.62 (12.94)	91.59 (12.24)

Figure Captions

Figure 1. Mean distance from the hole (mm) in the baseline and attentional focus conditions for the novice, experienced, and elite groups. Error bars depict the standard error of the mean.

Figure 2. Mean heart rate (HR) change in the 6 s prior to ball contact and 6 s following ball contact in the novice, experienced, and elite groups averaged across all experimental conditions. The value for each epoch reflects the lowest value of the interval and is negative for epochs that occurred prior to the putt (e.g., -1 s reflects HR between 1 to 0.5 s prior to ball contact). Error bars depict the standard error of the mean.