

# The Influence of Social Evaluative Threat on the Putting Stroke in Golf

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The goal of this study was to examine the multi-level associations between state anxiety and various indicators of golf putting performance. Participants were 35 amateur golfers who completed golf putting tasks under a neutral condition followed by a social-evaluative condition. Participants were equipped with a high-speed infrared camera to measure various putting stroke parameters. Results of multilevel analyses indicated that the social-evaluative condition was associated with less putter rotation and quicker forward stroke times. A cross-level interaction indicated that golfers with low levels of somatic anxiety holed significantly more putts under pressure compared with baseline, whereas those with high levels of somatic anxiety did not. As well, a significant cross-level interaction indicated that high levels of cognitive anxiety were associated with slower back strokes under pressure. Results are discussed in terms of the complex interaction between psychological variables (i.e., state anxiety) and kinematic performance indicators.

**Keywords:** social evaluative threat, golf putting, state anxiety

Individuals participating in sport related tasks encounter stressors that activate psychological and physiological stress responses. An abundant program of qualitative research in the sport domain has delineated a host of personal and situational characteristics associated with a phenomenological experience of being stressed (e.g., James & Collins, 1997; Hill, Hanton, Matthews, & Fleming 2010a; Mellalieu, Neil, Hanton, & Fletcher, 2009; Neil, Mellalieu, & Hanton, 2009). These characteristics—labeled as stressors or sources of stress—offer a roadmap to detect key features of the sport context that are likely to make some sport participants more vulnerable to the pressure associated with learning or performing sport related tasks. Situational stressors, whether naturally experienced by sport participants or experimentally induced by researchers in laboratory settings, have been presumed

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to impair one's capacity to learn and to achieve a desired level of performance on sport related tasks. Less attention has been allocated to specific vulnerability factors that could exacerbate the debilitating effects of stressors on sport performance. In this study, a *stress-diathesis framework* is proposed to examine how one specific stressor, namely social evaluative threat, can influence the kinematic patterns and the outcome of a putting stroke differentially for sport participants with distinct levels of vulnerability toward sport anxiety.

## Situational Stressors and Sport Performance

Several sources of stress have been identified by sport participants in qualitative studies (James & Collins, 1997; Mellalieu et al., 2009). For the most part, however, the relationship between these sources of stress and sport performance remains largely unknown insofar as they have yet to be studied experimentally. Past research nonetheless offers a good understanding of key situational features likely to activate the type of psychophysiological responses capable of altering one's capacity to optimally learn and perform sport-related tasks. Several situational characteristics are capable of eliciting activated cortisol responses (e.g., Denson, Spanovic, & Miller, 2009), one of the hormones associated with increased stress in humans. According to a meta-analysis conducted by Dickerson and Kemeny (2004), situations increasing the likelihood that core features of the self (e.g., one's traits or skills) could be negatively judged by others engender significantly stronger stress responses ( $d = 0.67$  vs.  $d = 0.15$ ) compared with situations that do not elicit such *social evaluative threat*.

Capturing performance on a permanent record (e.g., videotape), performing in front of an evaluative audience, and the presence of negative social comparison are certainly prototypical of situational features of social evaluative threat. For example, an audience consisting of one person posing as a professional golfer (i.e., an evaluative figure) has been sufficient enough to increase levels of anxiety in research participants (e.g., Kingsbury et al., 2011; Lewis & Linder, 1997). Nevertheless, combining at least two of these situational features can result in a greater stress response than presenting one of these features alone ( $d = 0.86$  vs.  $d = 0.23$ ; Dickerson & Kemeny, 2004). Sport related tasks can inherently be conceived as *motivated performance tasks* because they entail performance related demands in which the person is actively engaged in trying to attain optimal levels of learning or achievement. However, situations that combine social evaluative threat and motivated performance issues elicit stronger stress responses than situations that only include motivated performance issues ( $d = 0.35$  vs.  $d = -0.07$ ; Dickerson & Kemeny, 2004). Thus, it seems as though situations that entail social evaluative threat can be seen as potentially detrimental sources of stress that could inhibit the optimal learning and performance of sport related tasks.

The breaking down of performance under pressure, often described as "choking", has been studied for several decades in sport psychology research (e.g., Beilock & Gray, 2007; Hill, Hanton, Matthews, & Fleming, 2010b). Golf putting is routinely used in the choking literature because of its gradual learning curve and the potential susceptibility of breaking down under pressure (e.g., Beilock & Carr, 2001; Cooke, Kavussanu, McIntyre, & Ring, 2010; Cooke, Kavussanu, McIntyre, Boardley, & Ring, 2011; Lewis & Linder, 1997; Masters, 1992; Maxwell, Masters, & Eves, 2003). Although significant changes in both kinematic and objective

measures of putting performance under stress have been observed, the pattern of results is quite variable and often depend on certain experimental conditions. For example, when novices were trained to putt without learning explicit rules associated with putting, putting performance seemed to be buffered from decrements under pressure (e.g., Masters, 1992; Mullen, Hardy, and Oldham, 2007). Furthermore, golfers who underwent a lengthy goal-setting intervention actually *improved* their putting performance under pressure (Kingston & Hardy, 1997).

In subsequent studies, researchers have attempted to examine the extent to which exposition to a stressor is associated with distinct kinematic changes in the putting stroke itself but, so far, the results have remained equivocal. For example, Mullen and Hardy (2000) conducted a kinematic analysis on recreational golfers (i.e., handicap between 12 and 18). Under evaluative stress, golfers who putted under dual-task conditions (i.e., random-letter generation) demonstrated delayed time to peak acceleration in their strokes. Putting under evaluative conditions has also been associated with increased impact velocity for expert golfers (Cooke et al., 2011), decreases in the distance the putter head traveled for both experts and novices (Tanaka & Sekiya, 2010), and increased X-axis acceleration in novices (Cooke et al., 2010). More recently, Land and Tenenbaum (2012) failed to find any differences in a range of measured kinematic parameters in an expert sample when compared between low and high evaluative conditions. Putting under evaluative conditions has also been linked to changes in psychophysiological measures, such as increased heart rate and heart rate variability, increased muscle tension, and increased variability in motor movements (Cooke et al., 2010; 2011; Moore, Vine, Wilson, & Freeman, 2012; Tanaka & Sekiya, 2010; 2011).

## **Anxiety and Performance**

Frequently mentioned in the sports performance literature is the notion that state anxiety tends to result when an athlete is under pressure. In their multidimensional anxiety theory, Martens, Vealey, & Burton (1990) theorized that state anxiety can be broken down into two components: cognitive anxiety (i.e., anxious thoughts) and somatic anxiety (i.e., the physiological/affective aspect). In their theory, cognitive anxiety is likened to worry, while somatic anxiety is represented as the *interpretation* of one's own somatic symptoms. While meta-analytic research seems to indicate that the *overall* relation between both cognitive/somatic anxiety and performance is not significant when a range of sports and athletes are considered, a number of moderating variables must be taken into consideration including the type of sport one plays, the level at which an athlete competes and the latency between measuring one's anxiety and the actual performance itself (Craft, Magyar, Becker, & Feltz, 2003). While both cognitive and somatic anxiety appear to be facilitative in *elite* athletes, a negative relationship between somatic anxiety and recreational athletes was found. Intuitively speaking, increases in muscle tension, and physiological activation would naturally seem to be detrimental to putting performance in general.

## **A Multilevel and Stress-Diathesis Perspective**

Putts performed across successive trials in a laboratory session or across holes in a game of golf are not totally independent actions insofar as they are performed

by the same individual who is also capable of adapting his or her motor actions according to the outcome of previous trials. Traditional statistical analyses force researchers to aggregate putts across all trials, resulting in models that do not incorporate the natural within-person fluctuations of kinematic patterns and putting outcomes. This limitation was addressed in the current study by considering the transient or momentary nature of putting outcomes in a multilevel model in which putts are conceived as nonindependent instances nested within a person. Putting is also influenced by overall golfing skills or what golfers refer to as the golf handicap (e.g., Beilock, Bertenthal, McCoy, & Carr, 2004; Tanaka & Sekiya, 2010). Multilevel models can readily incorporate between-person variables, such as golf handicap (e.g., Gaudreau, Nicholls, & Levy, 2010), to control for their influence in explaining why certain golfers, overall, obtain better putting outcomes than others.

Several lines of research in both sport and clinical psychology indicate that stressors are not inherently debilitating in and out of themselves (Blascovich, 2008; Jones, Meijen, McCarthy, & Sheffield, 2009; Seery, 2011; Skinner & Brewer, 2004). The relationship between stressors and consequential life outcomes have often been conceived within the confines of transactional models in which dialectic person  $\times$  situation interactions are presumed to explain why some individuals adapt themselves more efficiently than others to a stressful situation (e.g., Lazarus & Folkman, 1984). Clinical psychologists have long identified individual and social characteristics that render certain individuals more vulnerable to the debilitating effects of stressful situations. Some vulnerability factors (e.g., growing in a disadvantaged neighborhood) can create a *generalized* diathesis that makes certain individuals vulnerable to *all* types of stressful situations (Belsky & Pluess, 2009). However, vulnerability factors can take a more specialized form that render the individuals vulnerable to specific stressors that are closely matched or associated with their vulnerability (Hewitt & Flett, 1993). In a sporting context for example, an athlete may be relatively well-adjusted in many domains in their life without a specific generalized propensity to develop an anxious response. However, this same athlete could be prone to high levels of state anxiety while competing (e.g., during the playoffs, a final putt to win, etc.). In this study, we proposed a stress-diathesis model that posits that the relationship between social evaluative threat and performance on a sport related task is moderated by elevated competitive state anxiety—that is, how anxious a person feels in the moment just before competition in an evaluative environment.

An abundant stream of research has indeed indicated that state anxiety can relate to performance and achievement in the sport context. Meta-analytical evidence indicates that perceived stress or state anxiety predicts between-person differences in sport achievement (Woodman & Hardy, 2003), particularly in settings that are inherently more competitive. State anxiety has been demonstrated to be elevated in a number of studies on golf putting. For example, cognitive anxiety has been found to have a negative linear relation with the putting performance of recreational golfers (Chamberlain & Hale, 2007). As mentioned previously, simple exposure to an evaluative condition has been associated with kinematic changes regardless of individual characteristics. Cooke et al. (2010) found that golfers holed fewer putts under stress and demonstrated kinematic changes between conditions. Furthermore, cognitive anxiety increased in the golfers between low and high conditions of evaluative stress. That being said, appraising a stressful situation as either being a *challenge* or a *threat* has also been implicated in differential putting outcomes in

golfers. Individuals with no formal golfing experience who viewed a putting task as a *challenge* demonstrated differential cardiac profiles, better putting performance (both kinematic and objective outcomes), less intense cognitive anxiety, and lower levels of overall cognitive anxiety as compared with those viewing the same task as a *threat* (Moore et al., 2012).

Sport anxiety can also act as an aggravating factor to exacerbate the effect of social evaluative threat on the psychophysiological stress response and performance outcomes. Athletes with elevated sport anxiety tend to use coping actions in which they try to disengage themselves from the process of volitionally pursuing personal goals (e.g., Dias, Cruz, & Fonseca, 2012; Ntoumanis & Biddle, 2000). The effortless nature of their coping efforts might make them more vulnerable to the exacerbating effect of a stressor such as social evaluative threat. According to *processing efficiency theory* (Eysenck & Calvo, 1992), athletes can maintain their performance effectiveness under a stressful situation if they engage in compensatory effort to increase the amount of attention allocated to the task. Past research in the coping literature indicates that athletes with elevated sport anxiety are more likely to disengage their effort from the task at hand, which is a coping tendency generally associated with suboptimal performance outcomes (e.g., Gaudreau, Nicholls, & Levy, 2010; Nicolas, Gaudreau, & Franche, 2011). Accordingly, it can be expected that athletes with high levels of anxiety are less likely than athletes with low levels of anxiety to maintain a good level of learning and performance during episodes of social evaluative threat. In the parlance of a stress-diathesis framework, elevated sport anxiety could act as a vulnerability factor to inhibit optimal learning and performance during a stressful situation.

## The Current Study

In this study, we examined the kinematic parameters of a putting stroke and the objective outcome (i.e., not holed vs. holed) of each of the putts performed across a neutral condition and a condition designed to elicit social evaluative threat. Kinematic indicators of putting performance include: face angle at address/impact ( $^{\circ}$ ), path of putter at impact, amount of face rotation during the stroke, putter head velocity (inches/sec), stroke time (sec), and stroke tempo (ratio of backswing and forwardswing times). To the best of our knowledge this was the first study to examine the influence of social evaluative threat and the kinematic putting performance indicators. We expected that the kinematic parameters of the putting strokes should significantly differ across the neutral and the social evaluative trials of this study. Given that the neutral trials systematically preceded the social evaluative trials in all participants (i.e., AB design), we expected that a learning effect would characterize the longitudinal trajectory of achievement in this study. Therefore, we did not expect that achievement would break down or significantly diminish in the social evaluative trials compared with the neutral trials. According to our stress-diathesis hypothesis, however, we expected that state anxiety would moderate the relationship between conditions (i.e., neutral vs. social evaluative trials) and the likelihood of not making or making the putts. As somatic anxiety is associated with increased physiological activation (e.g., muscle tension), it was expected that stroke times, stroke tempos, and putter head velocity would be positively associated with the more physical manifestations of anxiety reported. More precisely, it was hypothesized that golfers

with low somatic anxiety would have a higher likelihood of making putts during social evaluative trials compared with the neutral trials whereas the likelihood of making putts of the golfers with high somatic anxiety would not significantly differ between the trials. As such, high levels of state anxiety might inhibit the natural learning effect generally observed across successive trials of a putting task. Lastly, an examination of the relation between specific putting parameters and the likelihood of holing putts will be explored as a secondary contribution to the kinematic literature. As roughly 80% of the direction of the golf ball is determined by the alignment of the putter's face at impact (Pelz, 2000), a positive relation between this parameter and successfully holing a putt is expected.

## Method

### Participants

Participants in this study were 35 amateur golfers (4 females, 31 males) who were members of a private indoor golf practice facility in (*Ottawa, Ontario, Canada*) ( $M_{age} = 53.97$  years,  $SD = 14.67$ , range: 18–67). All golfers possessed a valid *Royal Canadian Golf Association* (RCGA) Handicap ( $M = 13.62$ ,  $SD = 7.20$ , ranging from 0 to 30), which was used as a standard measure of golfing ability. For ease of interpretation, a lower handicap represents golfers with higher level of expertise.

### Measures

**Performance.** Each participant's putter was outfitted with a putting analysis tool called the TOMI (The Optional Motion Instructor; Pure Motion, Inc., Southlake, TX). The TOMI consists of an infrared camera placed directly in front of the golfer, which picks up four sensors outfitted on the putter. The TOMI was first designed to serve as a golf-teaching tool to analyze eight different parameters that relate to the putting stroke: alignment at address and impact, putter path, face rotation, loft, impact, speed, and tempo. Mackenzie and Evans (2010) demonstrated that the TOMI is a valid and reliable measure to use in scientific research, with measurement errors falling within acceptable ranges of computerized 3D-mapping techniques.

**State Anxiety.** Participants completed the *Competitive State Anxiety Inventory 2-Revised* (CSAI-2R; Cox, Martens, & Russell, 2003). The CSAI-2R is a widely used measure that assesses two dimensions of state anxiety in an athlete—cognitive anxiety (e.g., “I am concerned about losing”), and somatic anxiety (e.g., “My heart is racing”)—as well as a measure of self-confidence. For the purposes of this study, only the somatic (7 items;  $M = 15.20$ ,  $SD = 4.22$ ,  $\alpha = .78$ ) and cognitive (5 items;  $M = 17.66$ ,  $SD = 6.18$ ,  $\alpha = .82$ ) subscales were used.

### Procedure

For the first set of putts (*neutral trials*), golfers stroked 5 putts, each to a hole from 5 feet away with a straight path to the hole. The artificial putting surface was roughly 30' x 40', with various undulations designed to mimic a real putting green. The putting green itself ran at a speed consistent with real greens (i.e., 10.0 on the stimp-meter), and each participant putted to a standard size golf hole on a flat

portion of the green with no left or right break. During these 5 putts, golfers were told by the experimenter that the machine was being “calibrated to their stroke”, and therefore asked to putt as they normally would while trying their best to hole each putt. Before the start of the second set of putts (*social evaluative trials*), golfers were then instructed that we were interested in seeing how many putts they could hole to compare the performance across participants in the study, with the best three performers being awarded one-dozen premium golf balls. In addition, following previous protocols to increase stress during golf (e.g., Kingsbury et al., 2011; Lewis & Linder, 1997), a confederate posing as a golf professional arrived after the neutral trials to observe and videotape each golfer’s putting stroke. The confederate was a person well-versed in the game of golf and was dressed in golf clothing to increase validity of the cover story. Participants were informed that the confederate was there to record their putting stroke later to be analyzed. Just before the social evaluative trials golfers were administered the CSAI-2R before performing the 5 putts under the eye of the confederate. At the end of the study, participants were informed that no comparisons were to be made, no video footage was actually saved, and that all participants were entered into a draw to win the golf balls regardless of their performance. The study received full approval from the institutional research ethics board.

## Results

### Preliminary Analyses

Results from preliminary analyses indicated that handicap scores were significantly related to somatic anxiety ( $r = .389, p = .034$ ) and to one of the kinematic parameters: mean absolute face rotation ( $r = .408, p = .025$ ). As a result, handicap was entered into each regression equation as a control variable. Table 1 highlights the descriptive statistics of each of the putting parameters.

### Plan of Analyses

Logistic multilevel modeling (MLM) was conducted using HLM Version 7 (Raudenbush, Bryk, & Congdon, 2010) to examine the effects of condition (0 = neutral trials; 1 = social evaluative trials), handicap, state anxiety, and kinematic parameters on the likelihood of not holing (coded as 0) and holing (coded as 1) each of the putts. Furthermore, regular MLM was also used to examine the same effects on each of the kinematic parameters. In all analyses, the condition variable was treated as a Level 1 predictor whereas handicap and state anxiety were treated as Level 2 predictors (for a more complete description of HLM analysis, see Cornelius, Brewer, & Van Raalte, 2007). Intraclass correlations (ICC) indicated that substantial variance in all putting variables could be attributed to between-person variability, indicating the appropriateness of the use of MLM: alignment at address ( $\sigma^2 = 2.997, \tau = 0.864, ICC = .224$ ), alignment at impact ( $\sigma^2 = 0.521, \tau = 0.871, ICC = .626$ ), putter face rotation ( $\sigma^2 = 4.926, \tau = 28.304, ICC = .852$ ), back stroke time ( $\sigma^2 = 0.003, \tau = 0.018, ICC = .845$ ), forward stroke time ( $\sigma^2 = 0.001, \tau = 0.004, ICC = .846$ ), loft at impact ( $\sigma^2 = 0.997, \tau = 6.822, ICC = .873$ ), stroke path ( $\sigma^2 = 3.088, \tau = 13.167, ICC = .810$ ), and putter speed ( $\sigma^2 = 24.758, \tau = 13.204, ICC = .347$ ).

**Table 1 Descriptive Statistics for Kinematic Parameters**

Putting Parameter	Neutral Trials		Social-Evaluative Trials	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Alignment at Address (°) <sup>1</sup>	0.032	3.141	0.045	2.577
Alignment at Impact (°)	1.309	1.486	1.385	1.527
Putter Path (°)	-2.225	4.082	-2.111	3.905
Total Face Rotation (°) <sup>2</sup>	14.097	5.735	13.434	5.663
Loft at Impact (°)	1.019	2.726	1.066	2.811
Speed (inches/sec)	43.954	6.498	43.811	5.764
Back Swing Time (sec)	0.663	0.140	0.6495	0.147
Follow Through Time (sec)	0.348	0.692	0.338	0.071
Total Time (sec)	1.011	0.202	0.987	0.210

*Note.* <sup>1</sup> A negative number for the ° values indicates being closed for the alignment variables, having a putter path coming from the inside, and adding loft at impact

<sup>2</sup> Face Rotation was computed by creating absolute values for the amount of face rotation (i.e., degrees open/closed) on the back swing and the follow through, then added together to create a variable to represent the overall amount of movement during the stroke.

## Logistic Multilevel Regression Analyses

The first portion of our analyses consisted of examining the relation between condition (Level 1), kinematics (Level 1), handicap (Level 2) state anxiety (Level 2), and whether each putt was holed or not. To transform the results from a logistic multilevel model into an interpretable number, an exponential transformation was applied to convert the output into a percentage of putts holed. Applying the exponential transformation to the grand mean estimate ( $\beta_{00}$ ) from the null model (Hox, 2010, p. 123;  $e^{\beta_{00}} / 1 + e^{\beta_{00}}$ ) revealed that approximately 44% of the putts were holed across the 10 putts performed by the 35 participants (see Table 2, model 1).

**Putting Performance, State Anxiety, and Social Evaluation.** The following equations were used to test the effect of the social evaluative condition on the binary likelihood of whether a putt was holed or not (coded as 1 and 0 respectively) with handicap again entered at Level 2 as a control variable:

$$\begin{aligned} \text{Logit}\left\{\Pr\left(\text{HOLING}_{ij}\right)\right\} &= \pi_{0j} + \pi_{1j}\left(\text{CDT}_{ij}\right) + e_{ij} \\ \pi_{0j} &= \beta_{00} + \beta_{01}\left(\text{HDCP}_j\right) + \mu_{0j}, \\ \pi_{1j} &= \beta_{10} + \mu_{1j}. \end{aligned} \quad (1)$$

Putting condition (CDT) was coded as either 0 (neutral) or 1 (social evaluation). The main effect of condition was positive (see Table 2, model 2), meaning that the number of putts holed significantly increased from the baseline (37% putts holed) to the social evaluative condition (51% putts holed), even while controlling for individual differences in handicap. Next, the following equations were used to test the cross-level moderation of cognitive anxiety (model 3a; see equation 2) and

**Table 2 Multilevel Logistic Regression of Likelihood of Hoing Putts (0 = not holed; 1 = holed)**

	Model 1 Estimate (SE) OR	Model 2 Estimate (SE) OR	Model 3a Estimate (SE) OR	Model 3b Estimate (SE) OR
<i>Fixed effect</i>				
<b>Level 1</b>				
$\beta_{00}$ = Intercept	-.255 (.157)	1.290 <sup>a</sup>	1.724 <sup>a</sup>	1.730 <sup>a</sup>
$\beta_{10}$ = Condition		-.524 <sup>**</sup> (.181)	-.544 <sup>**</sup> (.173)	-.548 <sup>**</sup> (.169)
		.558 <sup>*</sup> (.227)	.580 <sup>*</sup> (.223)	.582 <sup>**</sup> (.203)
<b>Level 2</b>				
$\beta_{01}$ = Handicap		1.012	1.020 <sup>a</sup>	1.016 <sup>a</sup>
$\beta_{02}$ = Anxiety <sup>3</sup>		-.011 (.013)	-.021 (.014)	-.016 (.013)
$\beta_{11}$ = Condition X Anxiety			.077 <sup>**</sup> (.027)	.120 <sup>**</sup> (.043)
			-.045 (.037)	-.151 <sup>**</sup> (.048)
<i>Random effect</i>	Variance	Variance	Variance	Variance
$\mu_0$	.459 <sup>*</sup>	.454 <sup>*</sup>	.284	.337
$\mu_1$		.337	.322	.109

Note. <sup>a</sup>Reciprocal of the Odds Ratio to facilitate interpretation of effect size. <sup>\*</sup> $p < .05$ . <sup>\*\*</sup> $p < .01$ .

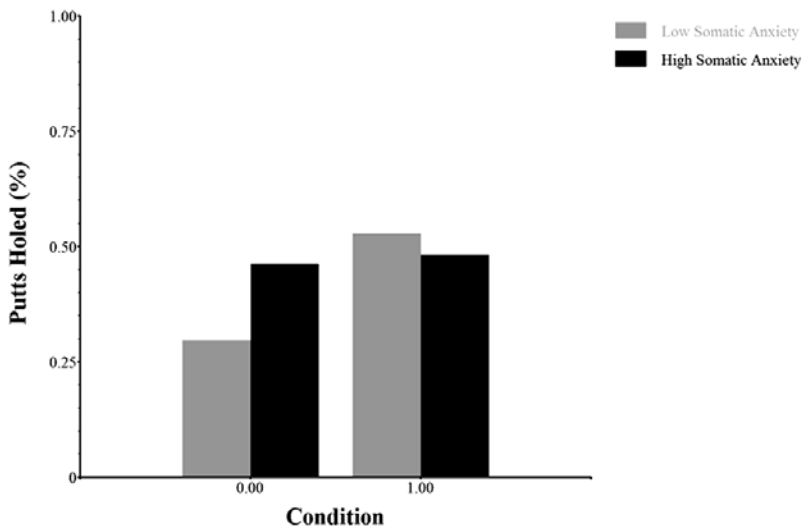
<sup>3</sup> Cognitive anxiety is entered in model 3a; somatic anxiety is entered in model 3b

somatic anxiety (model 3b; see equation 3) in the association between condition and performance<sup>1</sup>:

$$\begin{aligned} \text{Logit}\left\{\Pr\left(\text{HOLING}_{ij}\right)\right\} &= \pi_{0j} + \pi_{1j}\left(\text{CDT}_{ij}\right) + e_{ij} \\ \pi_{0j} &= \beta_{00} + \beta_{01}\left(\text{HDPC}_j\right) + \beta_{02}\left(\text{COG}_j\right) + \mu_{0j}, \\ \pi_{1j} &= \beta_{10} + \beta_{11}\left(\text{COG}_j\right) + \mu_{1j}. \end{aligned} \quad (2)$$

$$\begin{aligned} \text{Logit}\left\{\Pr\left(\text{HOLING}_{ij}\right)\right\} &= \pi_{0j} + \pi_{1j}\left(\text{CDT}_{ij}\right) + e_{ij} \\ \pi_{0j} &= \beta_{00} + \beta_{01}\left(\text{HDPC}_j\right) + \beta_{02}\left(\text{SOM}_j\right) + \mu_{0j}, \\ \pi_{1j} &= \beta_{10} + \beta_{11}\left(\text{SOM}_j\right) + \mu_{1j}. \end{aligned} \quad (3)$$

A cross-level interaction was found between somatic anxiety and condition when predicting the likelihood of holing putts (model 3b). Simple slopes analyses revealed that the relationship between condition (0 = neutral, 1 = social evaluation) and the likelihood of holing putts was significant for golfers with low somatic anxiety ( $\beta_{00} = -1.044$ ,  $\beta_{10} = 1.207$ ,  $p < .001$ ) but not significant for golfers with high somatic anxiety ( $\beta_{00} = -0.053$ ,  $\beta_{10} = -0.030$ ,  $p = .903$ ). In other words, golfers with low somatic anxiety had a higher likelihood of making putts under stress compared with the neutral condition whereas the likelihood of making putts for the golfers with high somatic anxiety did not differ between the stressful and the neutral condition (see Figure 1). It can be concluded that golfers with low levels of somatic anxiety managed to improve their performance across trials (learning effect) whereas those with high level of somatic anxiety experienced a flattened learning effect.



**Figure 1** — Cross-level interaction between condition and somatic anxiety predicting likelihood of holing putts.

**Kinematic Parameters and Putting Performance.** Our final logistic multilevel analysis in this section examined whether any of the kinematic parameters were associated with holing more putts using the following equation:

$$\begin{aligned}\text{Logit}\left\{\Pr\left(\text{HOLING}_{ij}\right)\right\} &= \pi_{0j} + \pi_{1j}\left(\text{PARA}_{ij}\right) + e_{ij} \\ \pi_{0j} &= \beta_{00} + \beta_{01}\left(\text{HDCCP}_j\right) + \mu_{0j}, \\ \pi_{1j} &= \beta_{10} + \mu_{1j}.\end{aligned}\quad (4)$$

Despite our hypotheses, no kinematic parameter was significantly associated with holing putts.

### Multilevel Regression Analyses of Kinematic Parameters

For the next portion of our analyses, the relationships between anxiety (Level 2), handicap (Level 2), and condition (Level 1) with each of the kinematic parameters were examined using multilevel regression. First, to assess the influence of condition on its own, the following equations were used with handicap entered as a control variable:

$$\begin{aligned}\text{PARA}_{ij} &= \pi_{0j} + \pi_{1j}\left(\text{CDT}_{ij}\right) + e_{ij} \\ \pi_{0j} &= \beta_{00} + \beta_{01}\left(\text{HDCCP}_j\right) + \mu_{0j}, \\ \pi_{1j} &= \beta_{10} + \mu_{1j}.\end{aligned}\quad (5)$$

PARA, the dependent variable, represents the individual kinematic parameters measured by the TOMI, CDT represents the putting condition (i.e., 0 = neutral, 1 = social-evaluation), and HDCCP denotes golfers' individual handicap indexes. The social-evaluative condition was significantly associated with decreased putter-face rotation ( $\beta_{10} = -0.663, p = .045$ ), quicker forward stroke times ( $\beta_{10} = -0.011, p = .004$ ), and marginally associated with poorer alignment at impact (i.e., further away from zero degrees at impact;  $\beta_{10} = 0.134, p = .098$ ).

Then, the separate effects of cognitive anxiety (COG; see equation 6), and somatic anxiety (SOM; see equation 7) as well as the cross-level interaction anxiety X condition were assessed using the following equations with handicap being entered to account for individual differences in skill level:

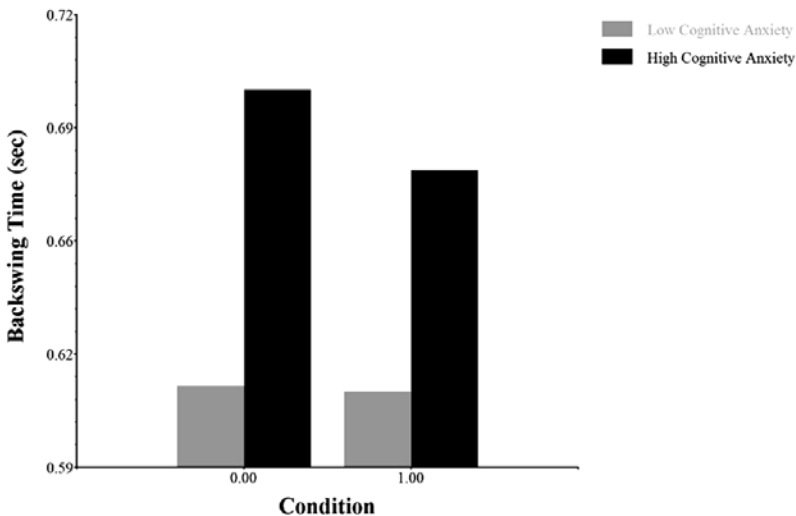
$$\begin{aligned}\text{PARA}_{ij} &= \pi_{0j} + \pi_{1j}\left(\text{CDT}_{ij}\right) + e_{ij} \\ \pi_{0j} &= \beta_{00} + \beta_{01}\left(\text{HDCCP}_j\right) + \beta_{02}\left(\text{COG}_j\right) + \mu_{0j}, \\ \pi_{1j} &= \beta_{10} + \beta_{11}\left(\text{COG}_j\right) + \mu_{1j}.\end{aligned}\quad (6)$$

$$\begin{aligned}\text{PARA}_{ij} &= \pi_{0j} + \pi_{1j}\left(\text{CDT}_{ij}\right) \\ \pi_{0j} &= \beta_{00} + \beta_{01}\left(\text{HDCCP}_j\right) + \beta_{02}\left(\text{SOM}_j\right) + \mu_{0j}, \\ \pi_{1j} &= \beta_{10} + \beta_{11}\left(\text{SOM}_j\right) + \mu_{1j}.\end{aligned}\quad (7)$$

Cognitive state anxiety was associated with longer back stroke times ( $\beta_{02} = 0.010$ ,  $p = .015$ ), forward stroke times ( $\beta_{02} = 0.011$ ,  $p = .013$ ), and marginally associated with better alignment at impact (i.e., closer to zero degrees at impact;  $\beta_{02} = -0.056$ ,  $p = .083$ ). Only one cross-level interaction was found between cognitive anxiety and condition when predicting back stroke times ( $\beta_{11} = -0.002$ ,  $p = .033$ ). Simple slopes analysis indicated that the relationship between condition and back stroke times was not significant for golfers with low cognitive anxiety ( $\beta_{00} = 0.606$ ,  $\beta_{10} = 0.001$ ,  $p = .953$ ) but was significant and negative for golfers with high cognitive anxiety ( $\beta_{00} = 0.713$ ,  $\beta_{10} = -0.026$ ,  $p = .023$ ). In other words, golfers with high cognitive anxiety had quicker back stroke times under stress compared with the neutral condition whereas the back stroke time of golfers with low cognitive anxiety did not differ between the stressful and the neutral condition (see Figure 2). Somatic anxiety was not significantly associated with any kinematic parameter, and no significant cross-level interactions between somatic anxiety and condition were found.

## Discussion

The goal of this study was to examine the multilevel associations between state anxiety and various indicators of golf putting performance. We proposed a multilevel model in which the transient or momentary nature of putting outcomes was taken into consideration by analyzing each putt as a nonindependent instance of performance nested within a person. As such, each putt was considered as a performance episode (Beal, Weiss, Barros, & MacDermid, 2005) likely to be influenced by time-invariant personal factors (i.e., golf handicap, anxiety) and



**Figure 2** — Cross-level interaction between condition and cognitive anxiety predicting backswing times (in seconds).

time varying features of the social environment (i.e., neutral versus social evaluative threat). This model allowed us to move beyond traditional statistical analyses (i.e., aggregate performance outcomes across all trials) to more deeply examine the natural within-person fluctuations of putting outcomes. In our analyses, state anxiety was treated as a time-invariant predictor because it was measured at only one time point (i.e., after the stress instructions were given). From a practical standpoint, it seemed unrealistic to administer a measure, such as the CSAI-2R, within the interval of a few minutes, immediately before and after the social evaluative threat manipulation. As no manipulation check was conducted, it is unclear whether the social evaluative manipulations were indeed effective. However, the significant within-person fluctuations between the two conditions suggests that participants indeed reacted to the external social pressure in the second putting task. That being said, whether their anxiety *changed* as a result of the social pressure was not answered. As a result, the following findings need to be interpreted with this point in mind.

All participants of this study performed a putting task under a neutral condition followed by a social evaluative threat condition. On average, whereas 37% of the putts were holed during the neutral trials, 51% of the putts were holed during the social evaluative threat trials. Participants significantly improved their putting performance, which is consistent with a typical learning effect that occurs when persons repetitively perform the same task over time (Wulf, 2007). However, consistent with our expectations, this effect was significantly moderated by participants' levels of somatic anxiety (see Figure 1). Participants with low levels of somatic anxiety holed significantly more putts (26% versus 54%) in the social evaluative stress trials than in the neutral trials. However, among participants with high somatic anxiety, there was no significant improvement in the subsequent social evaluative stress trials. Thus, despite the stressful nature of the latter part of the experiment, participants with *low* somatic anxiety managed to keep on significantly improving their performance. While one can reasonably conclude that the performance of these individuals were protected and perhaps even facilitated by the pressuring nature of the social evaluative threat conditions, it is also possible that low somatic anxiety could serve as a performance *inhibitor* under low motivation conditions.

Of greater importance, our results indicated that high somatic anxiety can be a vulnerability factor when individuals are facing social evaluative threat. Contrary to those with low somatic anxiety, the participants with *high* somatic anxiety did not hole significantly more putts (51% versus 51%) in the social evaluate stress trials than in the neutral trials. It is important to outline that individuals with high somatic anxiety did not choke under pressure insofar as they were able to maintain a performance comparable to their baseline level in the neutral trials. The effect of the social evaluative threat on the individuals with high somatic anxiety was nevertheless substantive, because it essentially "eliminated" a learning effect that typically occurs across trials of a repetitive putting task. The performance advantages conferred to individuals with high somatic anxiety (compared with low somatic anxiety) were limited to trials during which they performed under a neutral condition (see Figure 1). More notably, individuals with low somatic anxiety improved their performance during social evaluative threat—a condition that was created to mimic an evaluative sport environment in which performance indeed matters.

## Kinematic Parameters

Putting has often been described as an artful skill that requires precision and finesse. Comparably excellent putters can use different techniques, thus making it difficult to compare golfers to one another (i.e., between-person analyses). In this study, we adopted a multilevel perspective to examine within-person fluctuations of the putting stroke while controlling for the fact that each individual has their own kinematic tendencies. Individuals indeed have their tendencies (ICC of kinematic parameters ranging from .224 to .873), but their kinematic parameters did fluctuate to a nonnegligible extent across trials. Furthermore, the within-person fluctuations of four kinematic parameters were significantly associated with the conditions under which participants were putting. During episodes of social evaluative threat, participants had less putter-face rotation, quicker forward strokes, and marginally significant poorer alignment at impact. Results of a cross-level interaction also revealed that the back stroke became quicker during social evaluative threat but only for individuals with high level of cognitive anxiety. Similar to other studies with golfers (e.g., Cooke et al., 2010), these subtle but noticeable within-person changes are meaningful because they indicate that the movement becomes stiffer, jerkier, faster, and less precise during social evaluative threat.

Although social evaluation and anxiety played a role in explaining some of the within-person fluctuations in kinematic parameters, none of these characteristics of the putting movement were related to actually holing putts. From a practical standpoint, these results might suggest that there is more than one way to “get the ball into the hole”. As such, focusing on any different putting parameters (outside of face angle at impact) to improve one’s technique may not necessarily lead to improved performance. Despite such possibilities, Karlsen, Smith, and Nilsson (2008) found that 80% of the variability in the path a golf ball is influenced by the angle of the putter face at impact, followed by putter path (17%) and impact point (3%). As such, the subtle variations in kinematic parameters observed in this study might not be enough to reduce the likelihood of holing a five-foot putt with no curvature under the unchanging condition of an artificial putting green. Future research is needed to examine whether subtle changes in kinematic parameters—in and out of themselves as well as in interaction with time-varying and time invariant psychological predictors—can make more drastic changes in the putting outcome when the putts are longer, more complex, and never twice the same as in a regular golf game.

## Limitations and Future Directions

Some important limitations need to be addressed to frame the results appropriately as well to influence future research directions. It is prudent to highlight that the manipulations used in this study (and most others in the sport-stress literature) do not truly simulate the pressure that one would face in a real sport competition. In fact, the social evaluative threat condition should be depicted as a mild stressor in comparison with the demanding challenges of putting a golf ball in front of a crowd on the 72nd hole of a prestigious golf tournament. Nevertheless, our results indicate that even a mild stressor in the confines of a laboratory is sufficient to yield non-negligible within-person fluctuations in kinematic parameters of a putting stroke. As such, our results are consistent with studies in which *changes* in performance

have been demonstrated under conditions of social evaluative threat. It has been suggested that variability in movement is, in fact, related to more *consistent* performance. However, the sequential arrangement of where the variability occurs in the task appears to be important. In a recent study of a range of skilled golfers, Land and Tenenbaum (2012) found that although expert performers demonstrated increased variability upon the initiation of a golf putting stroke, movement variability decreased toward the moment of impact. Novice performers, in contrast, demonstrated consistent levels of variability throughout the entire stroke. Taking all strokes into account, however, expert golfers were considerably less variable overall. Future studies could examine the sequential order of the stroke to determine if social evaluative threat is associated with an increase in movement variability and, more importantly, when during the stroke these changes in movement variability occur.

As mentioned previously, no manipulation check was used to test the efficacy of the social evaluative manipulation. As a result, whether a participants' anxiety levels changed as a function of the task could not be answered. It is also possible that the cover story itself was not believed by all participants' and therefore may have failed to induce a stress-response. That being said, given that our analyses did not exclude nonreactive participants', it is likely that the results of this study are underestimating the effect that social evaluative threat has on putting performance. Nevertheless, future studies would benefit from unobtrusive pre/post methods of assessing changes in perceived stress, and a poststudy manipulation questionnaire to assess the believability of the cover story.

In this study, we relied on a single dichotomous measure of task performance, namely whether a putt was holed or not. This measure, albeit ecologically valid, does not take into account the fact that several good putts are often missed by less than an inch. As a result, most putting research has collected mean radial error (MRE) as an additional measure of performance. If a putt is not holed, the distance that the ball finishes from the hole is of the utmost importance to ensure the likelihood of the next putt being holed. Future research using this paradigm could implement additional indicators of putting performance such as MRE or directional biases in where a putt is missed (i.e., short/long, left/right). Neumann and Thomas (2008) outline a camera-based scoring system that adds richness to putting performance data that was not present in this study (i.e., distance short or long from the hole, length error, angle of error, target line deviation, and total distance from hole). Furthermore, it is also a possibility that linear relations do not capture the complexity of the relationship between social evaluative threat, anxiety, and performance. While our sample size was large enough to permit *linear* multilevel analyses, examining both quadratic and cubic trends in the data were not possible. Future studies could collect more putts per participant to allow for more sophisticated multilevel analysis.

Participants were recruited through convenience sampling (i.e., members of the golf practice facility). The sample contained a majority of males with high heterogeneity in skill level. Although our analyses controlled for golf handicap, future research should either collect homogenous samples in regards to skill level (e.g., professionals/elite amateurs, recreational, complete beginners) or a larger heterogeneous sample to try to replicate the results of this study. Of particular importance, future studies should examine whether skill level moderates the effect of social evaluative threat on putting performance. That being said, MLM analysis

uses each person as their own control, which inevitably takes into account these individual differences in skill level. Finally, all participants performed the putting task under a neutral condition followed by a stressful condition. Albeit methodologically desirable, counterbalancing might be an undesirable option insofar as performing the task under a stressful condition could have a carryover effect on the subsequent performance under neutral conditions. Future research could adopt an ABA design to determine whether the performance of participants stagnate or improve once the stressor has been removed. Randomizing participants in neutral versus social stress conditions after the baseline trials would offer another option to disentangle the effect of learning and the effect of the stressor on the likelihood of holing putts.

## Conclusion

This study contributes to the sport-stress literature by demonstrating a complex interplay between state anxiety, social evaluative threat, and kinematic putting parameters using a within-person design that allows a person's performance to be compared with their own average, while accounting for individual differences in skill level. Consistent with a stress/diathesis framework, state anxiety moderated the relationship of social evaluative threat with putting performance and one kinematic parameter. More specifically, high somatic anxiety attenuated the improvement of the putting outcome that typically occurs when participants are performing the same task over time. In contrast, participants with low somatic anxiety improved their putting performance despite being confronted with a social evaluative stressor in the latter part of the experiment. Overall, these results indicate that state anxiety can act as a vulnerability factor that exacerbates the effect of social evaluative threat.

## Note

1. Because of the coding of the condition (0 = neutral; 1 = social evaluative threat), this equation estimates the effect of anxiety when all predictors are zero in the equation; hence, the effect of anxiety during the neutral trials.

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