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The Effects of High Pressure on the Point of No Return in Simulated Penalty Kicks

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We investigated the effects of high pressure on the point of no return or the minimum time required for a kicker to respond to the goalkeeper's dive in a simulated penalty kick task. The goalkeeper moved to one side with different times available for the participants to direct the ball to the opposite side in low-pressure (acoustically isolated laboratory) and high-pressure situations (with a participative audience). One group of participants showed a significant lengthening of the point of no return under high pressure. With less time available, performance was at chance level. Unexpectedly, in a second group of participants, high pressure caused a qualitative change in which for short times available participants were inclined to aim in the direction of the goalkeeper's move. The distinct effects of high pressure are discussed within attentional control theory to reflect a decreasing efficiency of the goal-driven attentional system, slowing down performance, and a decreasing effectiveness in inhibiting stimulus-driven behavior.

Keywords: penalty kicking, attentional control theory, point of no return, choking, anti-pointing

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The penalty kick has become a regular and decisive event in professional association football; in one out of five matches during the elimination stage in international tournaments such as the World Cup, the South American Copa Libertadores and the European Champions League, the winner is determined with a series of penalty kicks or penalty shootout (Armatas, Yiannakos, Papadopoulou, & Galazoulas, 2007; Jordet, Hartman, Visscher, & Lemmink, 2007). Because of its decisive nature, the penalty kick is an example par excellence of a high-pressure situation in sports. Michael Owen, former English national team player recounts the Euro 2004 match between England and Portugal: “So we staggered on to penalties, and here I will make a declaration: there is nothing so nerve racking as a penalty shootout, except maybe stepping into a boxing ring, which I did twice as a boy. Fighting for your life, one on one, or taking a penalty in a big game—in both instances your body simply doesn’t belong to you” (Owen, 2004, p. 98). Hence, notwithstanding the blatant advantage for the penalty taker, a surprising 20–35% of penalty kicks are not converted (Morya, Bigatão, Lees, & Ranvaud, 2003).

Often this high failure rate is attributed to situational high pressure. Thus, Jordet et al. (2007) examined match statistics to estimate the relative importance of psychological factors (e.g., coping with stress), perceptual-motor skill (e.g., kicking skill) and physiological factors (e.g., level of fatigue) for success in penalty kicking. They found that the importance of the kick (i.e., the significance of the match and tournament, and the time within the match the kick is taken) is negatively related to the outcome of penalty kicks (see also McGarry & Franks, 2000). They concluded that psychological factors, such as coping with stress, are more important than physiological factors and perceptual motor skills for success in penalty kicking (see also Jordet, 2009; Jordet, Elferink-Gemser, Lemmink, & Visscher, 2007; Jordet & Hartman, 2008).

These studies did not clarify how high-pressure situations lead to suboptimal penalty kick performance. Recently, however, Wilson, Wood and Vine (2009; see also Wood & Wilson, 2010a) have examined participants taking penalty kicks in a laboratory situation to uncover the adverse effects of high pressure. To ensure high levels of pressure a monetary prize was awarded and a leader board with the scores was circulated among the participants. Eye-tracking recordings revealed that under high pressure, penalty kickers gazed significantly longer toward the goalkeeper, which resulted in more centralized shots within goalkeeper’s reach (see also Bakker, Oudejans, Binsch, & van der Kamp, 2006). In line with attentional control theory (Eysenck, Derakshan, Santos, & Calvo, 2007), Wilson et al. (2009) argued that in high-pressure situations attention is more stimulus driven rather than goal driven, and hence, kickers are more likely to focus on the threat-inducing goalkeeper (see below).

An additional factor that may be adversely affected in high-pressure penalty situations is the time needed to respond to goalkeeper motion to select which side to kick the ball. In low-pressure situations, Van der Kamp (2006; see also Van der Kamp, 2011) showed that if goalkeepers make their move within approximately 400 ms before football contact, kickers are less likely to succeed in placing the ball to the opposite side and/or their accuracy is decreased. In other words, penalty kickers require a minimum amount of time to be able to determine the side to which to direct the ball and accurately perform the kicking action. This finding is consistent with earlier observations by Morya, Ranvaud and Pinheiro (2003).

These authors developed a computer-based simulated penalty kick task in which they examined the so-called point of no return (PNR)—the moment beyond which alterations to motor decisions cannot be made, at least not reliably. Knowledge of the PNR is pertinent not only for the kicker, but also for the goalkeeper to decide when to dive. The simulated penalty task involved a computer monitor that displayed a goalmouth with three dots that represented the goalkeeper, ball and kicker. The “kicker” moved toward the stationary “ball,” while the “goalkeeper,” which was located in the middle of the goalmouth, moved randomly to the right or left at different times (≤ 450 ms) before the “kicker” contacted the “ball.” In some trials, the “goalkeeper” did not move. Participants were instructed to tilt a lever to the left or right, exactly at the moment the “kicker” contacted the “ball,” and in the direction opposite to the side the goalkeeper moved. The PNR for this simulated penalty task (the time for which the probability to direct the ball to the opposite side of the goalkeeper is half way through the transition between random response, i.e., 50% correct and perfect response, i.e., 100% correct)¹ was found to be approximately 250 ms. Although the absolute values of PNR were different, the pattern of results for this penalty simulation task qualitatively resembled later findings of Van der Kamp (2006) for in-situ penalty kicking, lending credibility to the validity of the simulated penalty kick task in establishing factors that affect the PNR in real penalties.

One of the factors that may affect the PNR is high-pressure. An increasingly influential theoretical model explaining the adverse effects of high pressure on sporting performance is the attentional control theory (Eysenck et al., 2007; Oudejans & Nieuwenhuys, 2009; Wilson et al., 2009). It claims that stress-inducing high-pressure situations reduce the efficiency of the goal-driven attentional system (e.g., attention to worrying thoughts is associated with the use of more resources to maintain performance accuracy) and increase the reliance on the stimulus-driven attentional system. The goal-driven system is involved in top-down control of attention based on expectations, knowledge and goals. The stimulus-driven system controls attention in a bottom-up fashion by detecting salient or conspicuous stimuli (Corbetta & Shulman, 2002). Recently, Wilson et al. (2009) have shown that under high-pressure, penalty kickers focused more on the goalkeeper than in a low-pressure situation, compromising kick accuracy. This attentional shift is consistent with the proposed increased influence of the stimulus-driven attentional system in high-pressure situations. In the current study, we examine the stress-induced decrease in efficiency of the goal-driven attentional system. Eysenck et al. (2007) argue that the time to respond is an important measure for this efficiency: the more time spent to achieve similar levels of performance accuracy, the less efficient the goal-driven system is. It has been reported for a variety of cognitive tasks that in high-pressure situations performance accuracy can be maintained, but with increased response times relative to low-pressure situations (e.g., Eysenck et al., 2007; Ansari, Derakshan, & Richards, 2008; Derakshan & Eysenck, 2009), although the converse sometimes also occurs: response times are maintained, but accuracy decreases (e.g., Beilock, Kulp, Holt, & Carr, 2004). For motor tasks, high-pressure leads the goal-driven system to invoke a step-by-step control mode, making performance not only significantly slower as in cognitive tasks, but also more prone to error (e.g., Beilock, Bertenthal, McCoy, & Carr, 2004; Masters & Maxwell, 2008). Hence, we hypothesize that in penalty kicking, high-pressure may increase the time needed to respond to goalkeeper

movements or jeopardize kicking accuracy (i.e., a failure to kick to the opposite side the goalkeeper dives). In particular, and also considering that the current simulated penalty kick task is perhaps more comparable to a cognitive task (i.e., success is probably more reliant on attention-demanding processes than on motor processes), it is expected that in high-pressure situations the PNR would occur earlier or else performance cannot be maintained.

The current study employed the validated simulated penalty task developed by Morya, Ranvaud et al. (2003) to uncover the effects of high-pressure on the PNR in penalty kicking. High-pressure was created by having the volunteers performing the simulated penalty task in front of a large participative audience. A participative audience has been shown to be a reliable method to promote pressure and induce high levels of stress in laboratory experiments. That is, previous studies have confirmed a clear association of participative audiences with significant performance decrements, often labeled choking under pressure (e.g., Baumeister & Steinhilber, 1984; Butler & Baumeister, 1998; Carver & Scheier, 1978). We assessed stress by measuring heart rate and cortisol levels in saliva. Cortisol hormone is considered the gold standard physiological method to measure acute stress (Gunnar, Talge & Herrera, 2009; Hellhammer, Wüst, & Kudielka, 2009). Based on attentional control theory, we hypothesized that the participative audience would induce high levels of stress, which in turn would result in participants needing more time than in the low-pressure situation to respond to goalkeeper movement in the simulated penalty task, or conversely, would lead to a decrease in performance accuracy.

Methods

Participants

Thirty-one right-handed undergraduate students (20 males and 11 females, mean age 21.2 years, $SD = 3.2$) with normal or corrected-to-normal vision volunteered to perform the simulated penalty task in low- and high-pressure situations. Local ethical committee approval was obtained before testing, and participants provided informed consent before taking part.

Apparatus

A computer-based simulated penalty kick task developed by Morya, Ranvaud et al. (2003) was used in the current experiment. The software MEL Professional 2.01 (Psychology Software Tools, PST Inc., Pittsburgh, PA) generated white visual stimuli on a black background on the screen. Three lines represented the posts and the cross bar of a goalmouth, while three dots represented a goalkeeper (within the goalmouth area), a ball and a kicker. In each trial, the “kicker” moved vertically upward at a speed of $4.7 \text{ cm}\cdot\text{s}^{-1}$ toward the stationary “ball,” which was located at the center of the display (Figure 1). In the majority of trials, the “goalkeeper” moved either to the left or to the right at different times before kicker–ball contact. Participants responded to the stimuli by manual inclining a vertical lever to the right or to the left, tripping off optical sensors connected to the game port.

The experiment took place under two conditions: a low-pressure and a high-pressure situation. For the low-pressure condition participants were tested alone in a

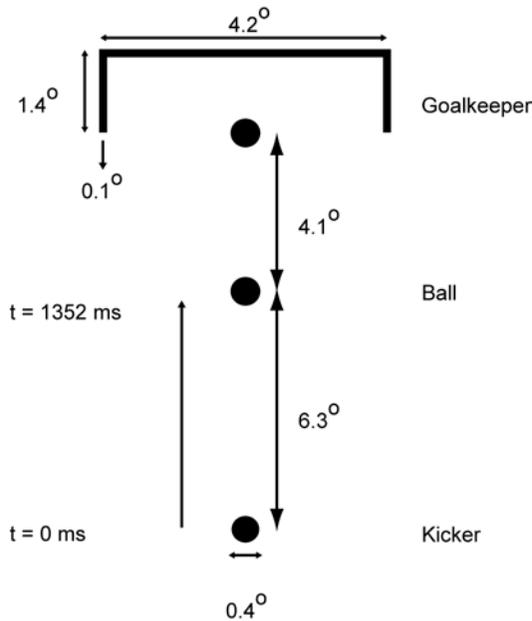


Figure 1 — The stimulus display (see Morya, Ranvaud et al., 2003). The three dots represent the “goalkeeper,” the “ball” and the upward moving “kicker.” The vertical and horizontal lines represent the goalposts and the crossbar.

small, acoustically isolated booth with dimmed lights. For the high-pressure condition they were tested in a large lecture hall in front of a loud participative audience that watched their performance projected on a large screen in (1.90 m × 2.00 m). The audience was composed of more than 70 classmates of the participants, who were enrolled in two different curricula (i.e., physical education and sports science). The audience was encouraged to openly support or boo the participants according to curriculum in which they were enrolled. In both conditions, the participants sat in front of a 17-inch computer monitor (60 Hz) with their eyes at 0.57 m from the monitor by resting their head against a chin and forehead support.

A Suunto T3 heart rate monitor was used to register the heartbeats, and saliva samples were collected and stored to measure cortisol levels using a commercial radioimmunoassay (RIA) according to the procedure of Hellhammer et al. (2009).

Procedure and Design

Each participant faced 100 trials. They were instructed to tilt the lever to the opposite side of the “goalkeeper” motion at the exact moment the “kicker” contacted the “ball,” which occurred 1352 ms after trial onset. On 90% of the trials the “goalkeeper” moved either to the right or to the left at a speed of $4.7 \text{ cm}\cdot\text{s}^{-1}$. The “goalkeeper” remained stationary on the remaining 10% of trials, for which participants were free to choose the side to which they moved the lever. “Goalkeeper”

sideward motion started at 51, 102, 153, 204, 255, 306, 357, 408, or 459 ms before “kicker–ball” contact, resulting in nine available time (AT) intervals.

Measurements for the low-pressure and high-pressure conditions took place on different days. On both days, participants were first instructed and received 10 familiarization trials. They subsequently performed the 100 randomized trials. The order of presentation of the two conditions was counterbalanced across participants. Trials with temporal errors larger than 42 ms (i.e., tilting the lever before 1310 ms or after 1394 ms from the beginning of the trial) were discarded and replaced until participants performed all 100 trials with the required timing accuracy.

At three moments, immediately before, immediately after, and 45 min after completing the experiment, samples of saliva were collected to measure cortisol levels. The heart rate was monitored throughout the experimental sessions. Measurements in the low-pressure and high-pressure conditions were conducted at the same time of the day between 14:00 and 16:00 to avoid confounds with circadian cortisol variations.

Data Analysis

To assess the effect of the protocol in promoting stress, first the average heart rates under low-pressure and high-pressure were submitted to a paired-samples *t* test analysis. Secondly, considering the high variability in cortisol production across the population (Hellhammer et al. 2009), the salivary cortisol levels were individually normalized by calculating a percentage of difference score between the measurement taken immediately after completion of the task and the measurement taken 45 min after task completion (baseline levels) for both the low-pressure and the high-pressure condition. These percentages were also submitted to a paired samples *t* test analysis.

Performance scores were obtained for each participant by calculating the percentage of correct responses for each available time (AT) interval. These were individually fitted to a logistic curve model as proposed by Morya, Ranvaud et al. (2003; see also Van der Kamp, 2006). This model considered average performance for each available time and adjusted the best logistic curve starting with chance performance for the short available times (i.e., 50% of the shots correctly directed to the opposite side of goalkeeper movement) and reaching perfect performance for long available times (i.e., 100% of the shots correctly directed to the opposite side of goalkeeper movement). The fitted model was then used to determine the minimum time needed for 75% of the shots being directed to the correct side of the goal (PNR). In psychophysics, the logistic curve model is typically chosen to describe the relationship between a stimulus varied along a certain dimension (e.g., weight, size, time) and response. The model presumes that for values of the stimulus (in the current study, the time the goalkeeper starts moving) above some threshold participants' responses are accurate (100% correct responses), while below the threshold participants' responses are random (i.e., 50% correct responses, participants are just guessing) (for an overview, see Regan, 2000). To identify the threshold (in the current study, the minimum time needed to respond or PNR), the average performance (percentage of correct responses) for each available time to respond to a stimulus is fitted to a S-shaped logistic curve, presuming chance performance (50%) for the lowest stimulus values and perfect performance (100%) for the highest stimulus values. The stimulus threshold for a reliable correct response

is mostly defined as the stimulus value at the midpoint (75%) between chance performance (50%) and perfect performance (100%) (Regan, 2000). Adhering to these psychophysical conventions, in the current study we define reliable performance (i.e., above chance, but not necessarily always correct), as the time at which in 75% of the attempts the lever is tilted to the correct side (derived from the fitted logistic curve). It is this midpoint between random and perfect performance that is labeled the *point of no return* (PNR, see Morya, Ranvaud et al., 2003). The individual PNR values for the low-pressure and high-pressure conditions were compared.

Finally, the percentages of replaced trials were compared using a 2 (condition: low-pressure situation, high-pressure situation) by 10 (AT: 51 ms, 102 ms, 153 ms, 204 ms, 255 ms, 306 ms, 357 ms, 408 ms, 459 ms catch trials) repeated-measures ANOVA. In the case of a violation of the sphericity assumption, Huynh–Feldt corrections to the degrees of freedom were applied. Post hoc comparisons were carried out with *t* tests using the Bonferroni correction procedures. Effect sizes were calculated using partial eta squared (η^2_p) for analysis of variance comparisons and Cohen's *d* for pairwise comparisons.

Results

Stress Measures

Heart rate and cortisol measures indicated that the high-pressure situation indeed induced higher levels of stress than the low-pressure situation. This was confirmed by a significant difference on average heart rate, $t(30) = 9.5$; $p < .001$, $d = 1.1$, which indicated that the heart rate in high-pressure situation ($M = 89$ beats·min⁻¹, $SD = 10.37$) was significantly higher than in the low-pressure situation ($M = 76$ beats·min⁻¹, $SD = 13.09$), and by a significant difference on percentage increase in cortisol level, $t(30) = 3.2$, $p < .05$, $d = 0.85$, which indicated that the increase in cortisol in the high-pressure situation ($M = 16\%$, $SD = 20.36$) was significantly higher than in the low-pressure situation ($M = 2\%$, $SD = 10.86$). The order of presentation of the two conditions was counterbalanced across participants and no order effect was found.

Performance Measures

Perusal of the individual curves for the percentage of correct responses as function of available time intervals suggested large interindividual differences between participants, in particular under high-pressure. That is, for the low-pressure situation, all individual curves showed the typical S-like shape of a logistic model. Yet, in the high-pressure situation, there were individual curves that had a shape that suggested that a linear model would be more appropriate. In addition, there was a strong suggestion that for some individuals the curves for the two pressure conditions nearly overlapped, whereas for others there was a clear shift to the right for the high-pressure situation. We therefore classified the participants into three groups: “logistic shift” ($n = 11$: participants for whom the S-shape curve for the high-pressure situation was clearly shifted to the right relative to low-pressure situation); “logistic no shift” ($n = 6$: participants for whom the S-shape curves for both conditions [nearly] overlapped); and “linear” ($n = 14$: participants for whom a linear model better fitted the data in the high-pressure situation than a S-shape

logistic model as indicated by r^2 values) (see Figure 2). Table 1 reports the average r^2 values for the logistic and linear models for all three groups for both pressure conditions. These r^2 values were submitted to a 3 (group: logistic no-shift, logistic shift, linear) by 2 (condition: low-pressure situation, high-pressure situation) by 2 (model: logistic, linear) ANOVA with repeated measures on the last factors. This revealed significant effects for various (combination) of factors that were all modulated by a significant interaction effect for model by group by condition, $F(2,60) = 13.18, p < .001, \eta^2_p = 0.57$), which is of crucial importance here. Post hoc comparison indicated that the logistic model provided a better fit in the low-pressure situation than the linear model for all three groups ($ts > 3.61, ps < 0.01$). This was also found for the high-pressure situation ($ts > 2.45, ps < 0.05$), with the exception of the linear group, which showed a better fit for the linear model, $t(13) = 3.94, p < .01$. Hence, group was used as a between-participant factor in the subsequent analyses that scrutinized the effects of pressure on the two performance measures, point of no return (PNR) and the percentage of replaced trials (i.e., timing errors). Condition (i.e., low-pressure situation, high-pressure situation) served as within-participant factor. No effects for the order of presentation of the two conditions were found on the performance measures.

Table 1 Mean (SD) r^2 Values for the Logistic and Linear Models for All Three Groups for the Low-Pressure and the High-Pressure Situations

Group	Low Pressure		High Pressure	
	Logistic	Linear	Logistic	Linear
Logistic no-shift	.82 (.10)	.76 (.11)	.63 (.14)	.49 (.15)
Logistic shift	.69 (.11)	.59 (.18)	.54 (.14)	.46 (.15)
Linear	.69 (.09)	.60 (.10)	.31 (.18)	.43 (.12)

Point of No Return. The PNR is defined as the 75% point on the logistic curve and represents the minimum time needed for a participant to reliably direct the ball to the side opposite to which the goalkeeper moves. However, the logistic model appeared an inappropriate description for the performance of the linear group in the high-pressure situation (see Table 1). The PNR could therefore not be obtained for this group. Hence, we first compared the PNR for the different groups in the low-pressure situation only. An ANOVA showed that the PNR for the linear group ($M = 245$ ms, $SD = 54.8$) was not significantly different from the PNRs in the logistic no-shift ($M = 249$ ms, $SD = 37.6$) and the logistic shift ($M = 228$ ms, $SD = 28.8$) groups, $F(2,30) = 2.29, p > .05, \eta^2_p = 0.05$ (Figure 2).

Secondly, we assessed differences in the effects of pressure on the PNR for the two logistic groups using a 2 (group: logistic no-shift, logistic shift) by 2 (condition: low-pressure situation, high-pressure situation) ANOVA with repeated measures on the last factor. This revealed a significant main effect for condition, $F(1,16) = 18.59, p = .001, \eta^2_p = 0.55$, indicating that the PNR increased from the low-pressure

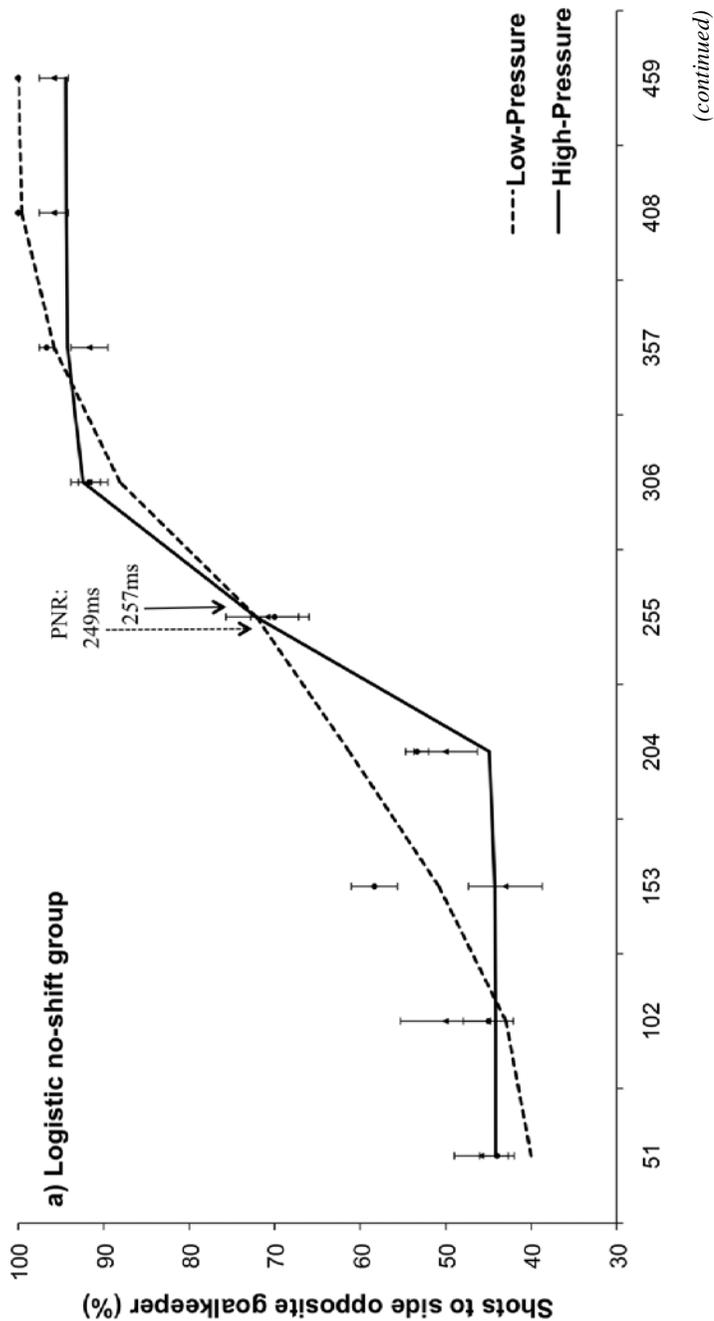
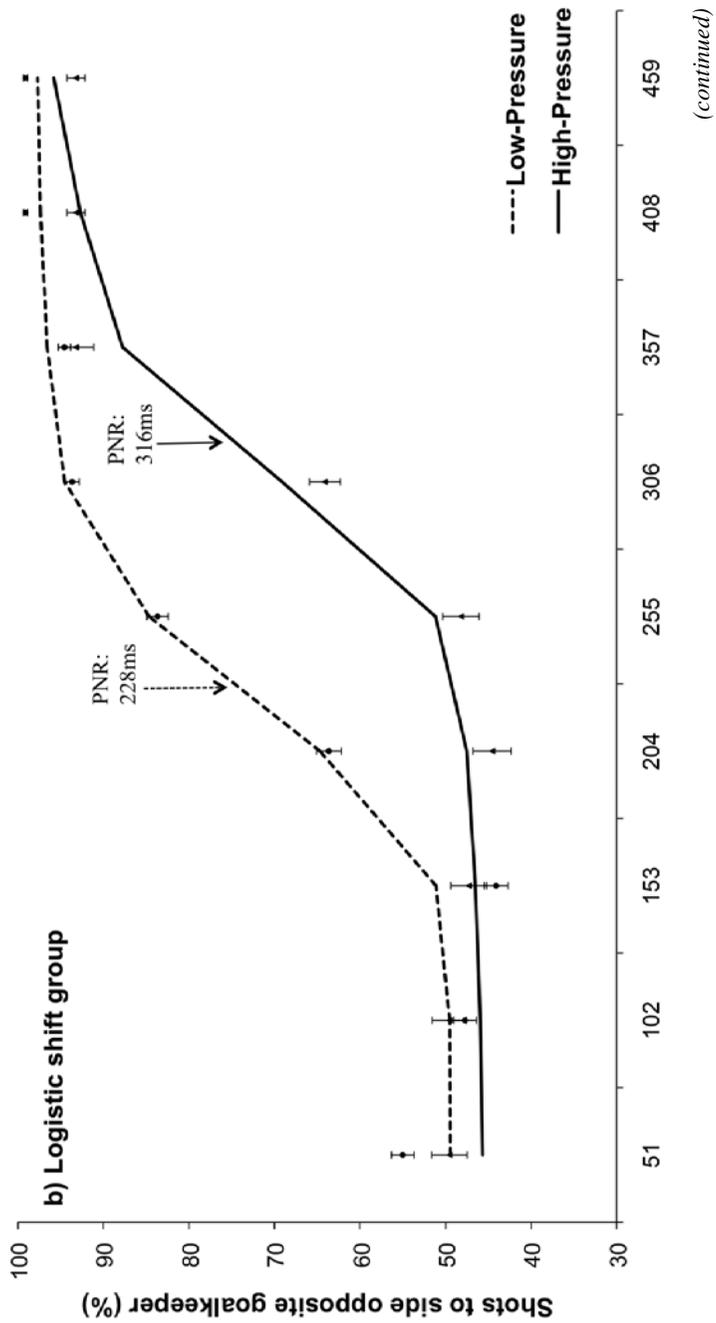


Figure 2 — Percentage of correct responses as a function of available time and condition for the logistic no-shift group (A), the logistic shift group (B), and the linear group (C). Plain lines represent the curves for the best fitting models in the low-pressure and high-pressure situations. *(continued)*



(continued)

Figure 2 — (continued)

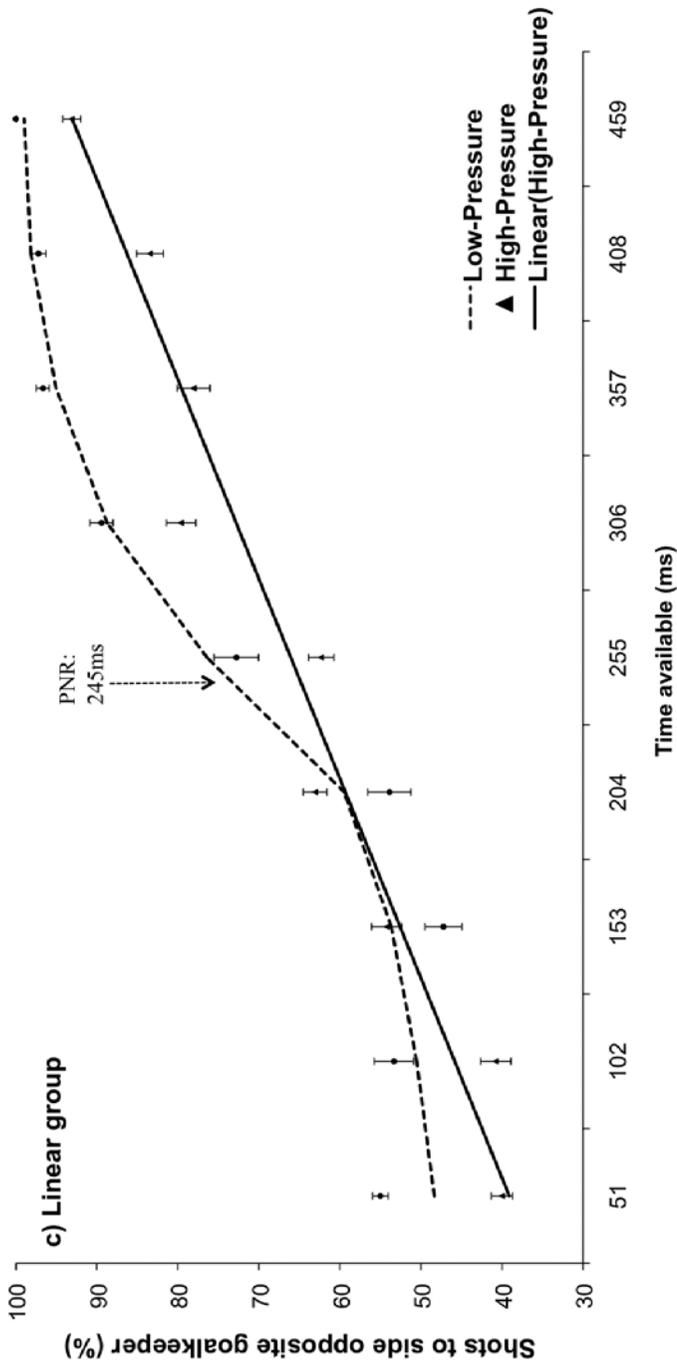


Figure 2 — (continued)

to the high-pressure situation. Yet, as can be seen by comparing Figures 2a and 2b, this increase in PNR only occurred for the logistic shift group. This was confirmed by a significant effect for group, $F(1,16) = 2.126, p = .05, \eta^2_p = 0.15$, and for group by condition, $F(1,16) = 12.77, p < .05, \eta^2_p = 0.46$. Post hoc tests indicated that the logistic shift group showed a clear difference in the PNR values between the low-pressure ($M = 228$ ms, $SD = 28.8$) and the high-pressure situations ($M = 316$ ms, $SD = 38.2$), $t(10) = 5.79, p < .001$ (Figure 2b), whereas for the logistic no-shift group no differences occurred between low-pressure ($M = 249$ ms, $SD = 37.4$) and high-pressure situations ($M = 257$ ms, $SD = 26.1$), $t(5) = 0.75, p > .05$ (Figure 2a).

Percentage of Replaced Trials. A 3 (group: logistic shift, logistic no-shift, linear) by 2 (condition: low-pressure situation, high-pressure situation) ANOVA with repeated measures on the last factor on the percentage of replaced trials only revealed a main effect for condition, $F(1,30) = 32.49, p < .001, \eta^2_p = 0.60$ (Figure 3), indicating that the participants made significantly more temporal errors in high-pressure situation ($M = 75\%$, $SD = 18.84$) than in low-pressure situation ($M = 12\%$, $SD = 4.47$) irrespective of group. To analyze and to compare these temporal errors between groups, the average constant (logistic shift, $M = -20.1$ ms; logistic no-shift, $M = -16.8$ ms; linear group, $M = -16.2$ ms) and variable errors (logistic shift, $M = 105.5$; logistic no-shift, $M = 108.5$; linear group, $M = 112.1$) for the high-pressure condition were submitted to separate one-way ANOVAs. The results did not reveal differences between groups for the constant error, $F(2,30) = 0.08, p > .05, \eta^2_p = 0.01$, or for the variable error, $F(2,30) = 0.16, p > .05, \eta^2_p = 0.01$.

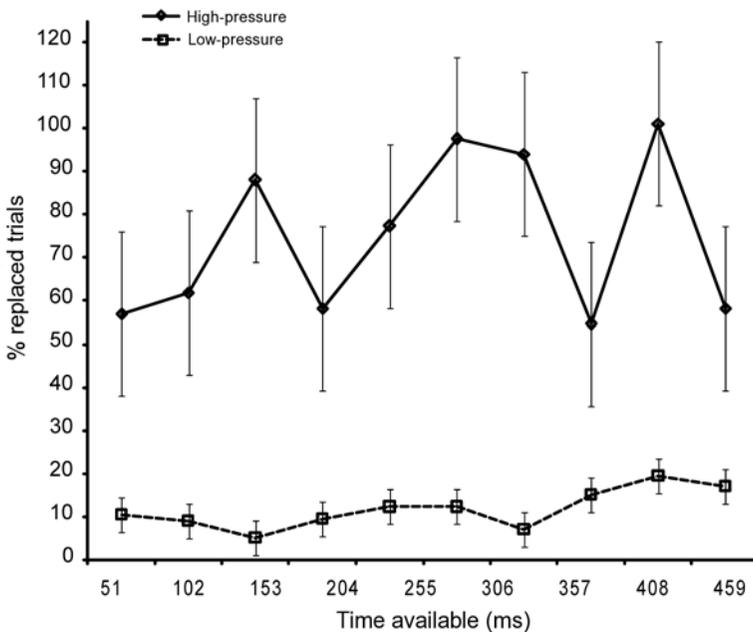


Figure 3 — Percentage of replaced trials as function of available time and condition.

Revisiting Stress Measures

To examine whether the performance differences between groups were associated with different stress levels, average heart rate and percentage increase in cortisol levels were submitted to separate 3 (group: logistic no-shift, logistic shift, linear) by 2 (condition: low-pressure situation, high-pressure situation) ANOVAs with repeated measures on the last factor. Figure 4 illustrates the findings for heart rate, and suggests higher heart rates for the logistic shift and linear groups as compared with the logistic no-shift group in the high-pressure situation only. However, neither the main effect for group, $F(1,30) = 3.05$, $p = .059$, $\eta^2_p = 0.17$, nor the group by condition interaction, $F(2,60) = 2.2$, $p < .10$, $\eta^2_p = 0.13$, was significant. The percentage increase in cortisol level showed a similar pattern (Figure 5). The analysis of variance revealed significant main effect for group, $F(2,60) = 10.92$, $p < .001$, $\eta^2_p = 0.29$, indicating higher increases in cortisol for the logistic shift and linear groups than for the logistic no-shift group, but no significant group by condition interaction $F(2,60) = 1.82$, $p < .10$, $\eta^2_p = 0.06$. Finally, we used independent t tests to examine whether the percentages increase in cortisol level in the high-pressure condition were significantly higher than zero (no increase). This revealed a significant increase in cortisol levels for both the linear ($M = 28\%$, $t(13) = 22.33$, $p < .01$) and the logistic shift groups ($M = 22\%$, $t(10) = 3.02$, $p < .05$), but not for the logistic no-shift group ($M = -10\%$, $t(5) = 1.24$, $p > .05$, Figure 5). For the low-pressure condition the percentage increase in cortisol level did not differ from zero; linear ($M = 3\%$, $t(13) = 0.36$, $p > .05$), logistic shift ($M = 7\%$, $t(10) = 0.76$, $p > .05$).



Figure 4 — Mean heart rate as function of condition and group.

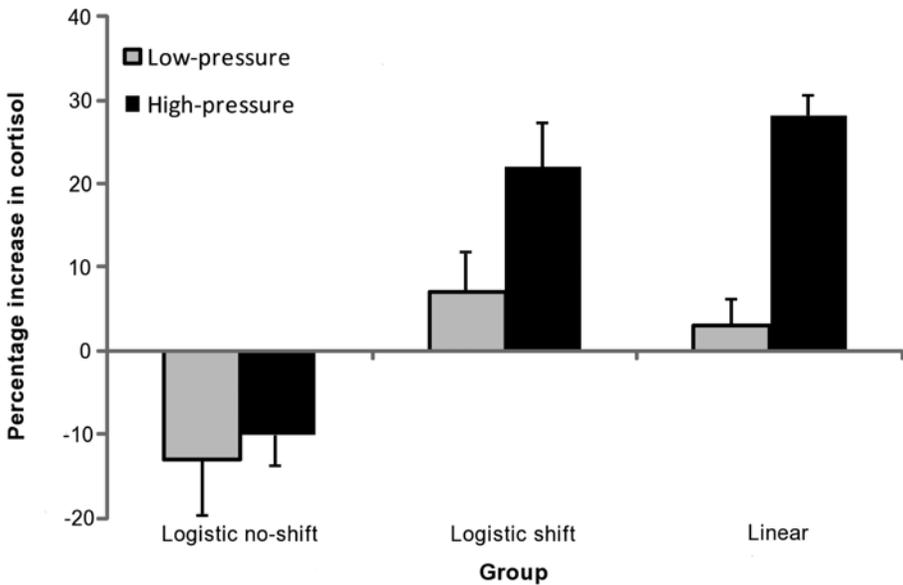


Figure 5 — Percentage increase of salivary cortisol levels between posttask and baseline levels as function of condition and group.

and logistic no shift group ($M = -13\%$, $t_5 = 1.91$, $p > .05$). Together, these results indicate that stress levels in the high-pressure condition were raised in the linear and logistic shift group, but not in the logistic no-shift group.

Discussion

The present study investigated the effect of high-pressure on the performance of a simulated soccer penalty kick task (see Morya, Ranvaud et al., 2003). In particular, we scrutinized whether the minimum time needed (PNR) to make motor decisions (i.e., to respond to goalkeeper movements) increases in high-pressure compared with low-pressure situations. Unexpectedly, this was only confirmed for one-third of the participants. In these participants (i.e., the logistic shift group), the high-pressure situation indeed led to increased stress and a lengthening of the PNR. Yet, there were considerable interindividual differences in how participants responded to the high-pressure. Almost half of the participants (the linear group) showed high stress levels, but rather than affecting the PNR, the increased stress resulted in a qualitatively different relationship between the time available to respond to goalkeeper motion and proportion of correct motor decisions.² Finally, for the remaining participants (the logistic non-shift group), high pressure did not result in significant increase in stress, and the PNR did not change. In the remainder, we will discuss the observations for these three groups of participants separately.

About one-third of the participants behaved as we had expected based on attentional control theory. This group (the logistic shift group) showed a signifi-

cant lengthening of the PNR in the high-pressure situation as compared with the low-pressure situation. That is, the minimum time that this group of participants required to respond to the goalkeeper movement increased under high pressure by more than 30%, from 228 ms to 316 ms. Since cortisol and heart rate measures for this group showed that the high-pressure protocol indeed provoked reliably higher levels of stress, this lengthening of the PNR points to a stress-induced reduction of the efficiency of the goal-driven attentional system (cf. Eysenck et al., 2007). Intriguingly, Eysenck et al. (2007) argued that a key function of the goal-driven system is the deliberate inhibition of automatic or prepotent behaviors. In this respect, it may be useful to compare the current simulated penalty kick task with investigations on antipointing (e.g., Day & Lyon, 2000). In these investigations, targets are shown that unpredictably move to the left or right while participants point at the target. Upon target displacement, however, participants are required to follow the target (pointing) or to point to the opposite direction (antipointing). Contrary to task instructions, during antipointing trials participants often show early corrections in the pointing movement that are in the direction of the target displacement and only after a delay a correction opposite to the target displacement is initiated. Day and Lyon (2000) proposed that the early correction is generated by an automated motor system that is under direct visual control (stimulus driven). This fast visuomotor system is under conscious control of a slower goal-directed or supervisory attentional system, which inhibits the early correction and reverses the direction of pointing (Day & Lyon, 2000; Johnson, van Beers, & Haggard, 2002). Similar findings are reported from the antisaccade paradigm (e.g., Derakshan & Eysenck, 2009; Ansari & Derakshan, 2010), in which the goal-driven attentional system must inhibit a reflexive saccade toward to a stimulus. It has been found that high-anxious individuals show significantly longer antisaccade latencies (i.e., take longer to inhibit the initial reflexive saccade) compared with low-anxious individuals. The current simulated penalty task is comparable to the antipointing and antisaccade tasks: participants are instructed to use a goalkeeper dependent strategy and kick the ball opposite to the side the goalkeeper moves. Hence, the lengthening of the PNR under high pressure may be understood as an impairment of the inhibition function of the goal-driven attentional system (see Eysenck et al., 2007).

A second group of participants (the linear group) was differently affected by the higher levels of stress provoked in the high-pressure situation. Rather than a lengthening of the PNR, this group showed a qualitative change in the relationship between the time available to respond to the goalkeeper movement and the percentage of correct responses under high-pressure. Performance for the shortest times available was below chance (< 50), while even for longest times available performance remained suboptimal ($< 100\%$). The fact that these participants appear to systematically err,³ that is, more often incorrectly directed the ball to the side the goalkeeper moved when little time was available to respond is particularly intriguing. In terms of the antipointing and antisaccade tasks, this seems analogous to the supervisory system being unable to inhibit the behavior of the automatic visuomotor system. As a result, performance becomes stimulus driven. In other words, in line with the attentional control theory we find two distinct effects of increased stress levels. First, the high-pressure situation decreases the efficiency of the goal-driven attentional system, which slowed down performance (the logistic shift group). Secondly, high pressure adversely affects performance effectiveness, supposedly

because the goal-driven system suffered a disruption, impairing its effectiveness in inhibiting automatic or stimulus-driven behaviors. For very short times available, this paradoxically led to automatically and unwittingly tilting the lever exactly to the side the goalkeeper moved (the linear group).

Finally, a relatively small number of participants did not show a difference in the PNR between the two pressure conditions (the logistic no shift group). As can be inferred from the cortisol and heart rate measures, it is likely that these participants were not significantly stressed in the high-pressure-situation. This indicates that apart from situational constraints (different situation may affect athletes in different ways) there may be interindividual differences in susceptibility to high-pressure situation associated with factors such as personality (Adam & van Wieringen, 1983; Masters, 1992) and self-regulation strategies (Masters, Polman, & Hammond, 1993; Mor & Winqvist, 2002) or degree of practice and experience (Mellalieu, Hanton, & O'Brien, 2004). Mellalieu et al. (2004) for instance, demonstrated that situational stress can be effectively controlled with practice and experience. Finally, it must be noted that although the participants in this group did not show increased levels of stress in the high-pressure-situation, they (like the participants in the other groups) did make more temporal errors with the participative audience present. It might be that these errors merely reflect distractions by the noisy environment.

Approximately 25% of penalty kicks in official games are wasted (Morya, Bigatão et al., 2003). Typically, this is attributed to situational stress. Explicit monitoring theories (Masters, 1992; Beilock & Carr, 2001; Pijpers, Oudejans, Holsheimer, & Bakker, 2003; Gray, 2004; Jackson, Ashford, & Norsworthy, 2006) have suggested that anxiety raises self-consciousness, which turns attention inward toward an explicit focus on the execution of movements. Consequently, automatized motor processes that previously ran efficiently outside of consciousness become explicitly controlled in a step-by-step fashion. This theory does well in explaining choking under pressure in skilled athletes, because an explicit step-by-step slows down of and makes control performance more liable for errors. Explicit monitoring theories can easily incorporate the finding that more time is needed in the high-pressure situation to respond to the goalkeeper movement. (Although, it is perhaps neither entirely trivial that the discrete movement of tilting the lever can be explicitly controlled in a step-by-step fashion, nor to what degree the tilting movement is proceduralized.) Yet, it is perhaps more difficult to incorporate for explicit monitoring theories that people make consistent errors rather than performance breaking down (performing at chance level). This is much easier reconciled with attentional control theory, where disruption of the goal-driven system can go together with a lack of inhibition of the stimulus driven system.

The current study is the first that experimentally assessed the adverse effects of stress on the time needed to respond to goalkeeper movements. Obviously, a computer simulation certainly is not the same as the "real thing" and it must also be acknowledged that the participants were not professional football players, nonetheless it did allow us to create a high-pressure situation that much more closely mimics a game than protocols that are commonly used to induce stress in experimental settings (e.g., Wilson et al., 2009; Wood & Wilson, 2010b). The majority of participants were significantly stressed by the high-pressure situation; consequently they either required more time to adjust to the goalkeeper movement, as expected, or unexpectedly, were unable to inhibit automatic responses with short

time available, which resulted in consistent errors. Since in a more ecologically valid in-situ penalty taking task the times necessary to respond to cues were found to be almost twice as long than for the current simulated penalty task (Van der Kamp, 2006), it is not unreasonable to suspect that the adverse effects of high-pressure will be magnified for in-situ penalty taking. In sum, our results provide strong experimental evidence that stress has a major influence in penalty kicks failures.

For practical applications, the present results suggest that coaches should carefully choose their penalty kickers, as was previously suggested by McGarry and Franks (2000). This should take into account the interindividual differences in the extent to which high-pressure causes increased levels of stress. Furthermore, these results may offer a method that could be exploited to identify kickers that are less susceptible to pressure, those that are and need more training, and perhaps, even those that never should take a penalty. In addition, the present findings reiterate the advantages for penalty kickers in using a strategy that disregards the goalkeeper. A keeper-independent strategy provides the kicker with a precise preplanned routine that avoids the need for real time decisions, which have been proven to be very liable to error, particularly in high-pressure situations. Thus, training strategies such as those proposed by Wood and Wilson (2011) that increase penalty takers perceived control may also help to remove the uncertainty associated with waiting to respond to the goalkeeper's movements.

Notes

1. Determination of PNR is based on standard psychophysical procedures (see e.g., Regan, 2000). For a more detailed explanation of this procedure, see the *Procedure and Design* subsection herein.

2. In fact, we cannot rule out that in the linear group high pressure did affect the minimum time needed to respond to a goalkeeper's movement. However, the definition of PNR as a property of a logistic curve on fitting a logistic curve precludes a valid comparison. Anyhow, we deem the qualitative change more important.

3. We used one-tailed sample *t* tests to explore whether the percentage of correct responses was below 50% for the two shortest times available. Results revealed significant differences in percentage of correct answer only for the linear group at 51 ms time available ($M = 40\%$, $SD = 16.8$; $t(13) = 2.14$, $p < .05$) and at 102 ms ($M = 41\%$, $SD = 17.6$; $t(13) = 1.35$, $p < .05$) (see Figure 2c). No such differences were found for the two other groups.

References

- Ansari, T.L., Derakshan, N., & Richards, A. (2008). Effects of anxiety on task switching: Evidence from the mixed antisaccade task. *Cognitive, Affective & Behavioral Neuroscience*, 8, 229–238.
- Ansari, T.L., & Derakshan, N. (2010). Anxiety impairs inhibitory control but not volitional action control. *Cognition and Emotion*, 24, 241–254.
- Armatas, V., Yiannakos, A., Papadopoulou, S., & Galazoulas, C. (2007, October). Analysis of the set-plays in the 18th football World Cup in Germany [online]. *Physical training*. Retrieved from http://ejmas.com/pt/2007pt/ptart_galazoulas_0710.html
- Adam, J.J., & Van Wieringen, P.C.W. (1983). Relationship between anxiety and performance on two aspects of a throwing task. *International Journal of Sport Psychology*, 14, 174–185.

- Bakker, F.C., Oudejans, R.R.D., Binsch, O., & van der Kamp, J. (2006). Penalty shooting and gaze behavior: Unwanted effects of the wish not to miss. *International Journal of Sport Psychology*, *37*, 265–280.
- Beilock, S.L., & Carr, T.H. (2001). On the fragility of skilled performance: What governs choking under pressure? *Journal of Experimental Psychology. General*, *130*, 701–725.
- Beilock, S.L., Bertenthal, B.I., McCoy, A.M., & Carr, T.H. (2004). Haste does not always make waste: Expertise, direction of attention, and speed versus accuracy in performing sensorimotor skills. *Psychonomic Bulletin & Review*, *11*, 373–379.
- Beilock, S.L., Kulp, C.A., Holt, L.E., & Carr, T.H. (2004). More on the fragility of performance: Choking under pressure in mathematical problem solving. *Journal of Experimental Psychology. General*, *133*, 584–600.
- Baumeister, R.F., & Steinhilber, A. (1984). Paradoxical effects of supportive audiences on performance under pressure: The home field disadvantage sports championships. *Journal of Personality and Social Psychology*, *47*, 85–93.
- Butler, J.L., & Baumeister, R.F. (1998). The trouble with friendly faces: Skilled performance with a supportive audience. *Journal of Personality and Social Psychology*, *75*, 1213–1230.
- Carver, C.S., & Scheier, M.F. (1978). Self-focusing effects of dispositional self-consciousness, mirror presence, and audience presence. *Journal of Personality and Social Psychology*, *36*, 324–332.
- Corbetta, M., & Shulman, G.L. (2002). Control of goal-directed and stimulus-driven attention in the brain. *Nature Neuroscience Reviews*, *3*, 201–215.
- Day, B.L., & Lyon, I.N. (2000). Voluntary modification of automatic arm movements evoked by motion of a visual target. *Experimental Brain Research*, *130*, 159–168.
- Derakshan, N., & Eysenck, M.W. (2009). Anxiety, processing efficiency, and cognitive performance: New developments from attentional control theory. *European Psychologist*, *14*, 168–176.
- Eysenck, M.W., Derakshan, N., Santos, R., & Calvo, M.G. (2007). Anxiety and cognitive performance: Attentional control theory. *Emotion (Washington, D.C.)*, *7*, 336–353.
- Gray, R. (2004). Attending to the execution of a complex sensorimotor skill: Expertise differences, choking, and slumps. *Journal of Experimental Psychology. Applied*, *10*, 42–54.
- Gunnar, M.R., Talge, N.M., & Herrera, A. (2009). Stressor paradigms in developmental studies: What does and does not work to produce mean increases in salivary cortisol. *Psychoneuroendocrinology*, *34*, 953–967.
- Hellhammer, D.H., Wüst, S., & Kudielka, B.M. (2009). Salivary cortisol as a biomarker in stress research. *Psychoneuroendocrinology*, *34*, 163–171.
- Jackson, R.C., Ashford, K.J., & Norsworthy, G. (2006). Attentional focus, dispositional reinvestment, and skilled motor performance under pressure. *Journal of Sport & Exercise Psychology*, *28*, 49–68.
- Johnson, H., van Beers, R.J., & Haggard, P. (2002). Action and awareness in pointing tasks. *Experimental Brain Research*, *146*, 451–459.
- Jordet, G. (2009). Why do English players fail in soccer penalty shootouts? A study of team status, self-regulation, and choking under pressure. *Journal of Sports Sciences*, *27*, 97–106.
- Jordet, G., Elferink-Gemser, M.T., Lemmink, K.A.P.M., & Visscher, C. (2007). The “Russian roulette” of soccer? Perceived control and anxiety in a major tournament penalty shootout. *International Journal of Sport Psychology*, *37*, 281–298.
- Jordet, G., & Hartman, E. (2008). Avoidance motivation and choking under pressure in soccer penalty shootouts. *Journal of Sport & Exercise Psychology*, *30*, 450–457.
- Jordet, G., Hartman, E., Visscher, C., & Lemmink, K.A.P.M. (2007). Kicks from the penalty mark in soccer: The roles of stress, skill, and fatigue for kick outcomes. *Journal of Sports Sciences*, *25*, 121–129.

- Masters, R.S.W. (1992). Knowledge, knerves and know-how: The role of explicit versus implicit knowledge in the break-down of a complex motor skill under pressure. *The British Journal of Psychology*, 83, 343–358.
- Masters, R., & Maxwell, J. (2008). The theory of reinvestment. *International Review of Sport and Exercise Psychology*, 1, 160–183.
- Masters, R.S.W., Polman, R.C.J., & Hammond, N.V. (1993). “Reinvestment”: A dimension of personality implicated in skill breakdown under pressure. *Personality and Individual Differences*, 14, 655–666.
- McGarry, T., & Franks, I.M. (2000). On winning the penalty shoot-out in soccer. *Journal of Sports Sciences*, 18, 401–409.
- Mellalieu, S.D., Hanton, S., & O’Brien, M. (2004). Intensity and direction of competitive anxiety as a function of sport type and experience. *Scandinavian Journal of Medicine & Science in Sports*, 14, 326–334.
- Mor, N., & Winquist, J. (2002). Self-focused attention and negative affect: A meta-analysis. *Psychological Bulletin*, 128, 638–662.
- Morya, E., Bigatão, H., Lees, A., & Ranvaud, R. (2003). Evolving penalty kick strategies: World cup and club matches 2000-2002. In T. Reilly, J. Cabri, & D. Araújo (Eds.), *Science and Football V* (pp. 237–242). London: Routledge.
- Morya, E., Ranvaud, R., & Pinheiro, W.M. (2003). Dynamics of visual feedback in a laboratory simulation of a penalty kick. *Journal of Sports Sciences*, 21, 87–95.
- Oudejans, R.R.D., & Nieuwenhuys, A. (2009). Perceiving and moving in sports and other high-pressure contexts. *Progress in Brain Research*, 174, 35–48.
- Owen, M. (2004). *Off the record. My autobiography*. London: CollinsWillow.
- Pijpers, J.R., Oudejans, R.R.D., Holsheimer, F., & Bakker, F.C. (2003). Anxiety-performance relationships in climbing: A process-oriented approach. *Psychology of Sport and Exercise*, 4, 283–304.
- Regan, D.R. (2000). *Human perception of objects. Early visual processing of spatial form defined by luminance, color, texture, motion and binocular disparity*. Sunderland, U.S.A: Sinauer Associates, Inc.
- Van der Kamp, J. (2006). A field simulation study of the effectiveness of penalty kick strategies in soccer: Late alterations of kick direction increase errors and reduce accuracy. *Journal of Sports Sciences*, 24, 467–477.
- Van der Kamp, J. (2011). Exploring the merits of perceptual anticipation in the soccer penalty kick. *Motor Control*, 15, 342–358.
- Wilson, M.R., Wood, G., & Vine, S.J. (2009). Anxiety, attentional control, and performance impairment in penalty kicks. *Journal of Sport & Exercise Psychology*, 31, 761–775.
- Wood, G., & Wilson, M.R. (2010a). A moving goalkeeper distracts penalty takers and impairs shooting accuracy. *Journal of Sports Sciences*, 28, 937–946.
- Wood, G., & Wilson, M.R. (2010b). Gaze behaviour and shooting strategies in football penalty kicks: Implications of a ‘keeper-dependent’ approach. *International Journal of Sport Psychology*, 41, 293–312.
- Wood, G., & Wilson, M.R. (2011). Quiet Eye training for soccer penalty kicks. *Cognitive Processing*, 12, 257–266.

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