

The Relationships between Psychological/Physiological Changes and Behavioral/Performance Changes of a Golf Putting Task under Pressure

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The first purpose of this study was to examine relationships between psychological/physiological and behavioral variables when participants are placed under pressure in a golf-putting task. The second purpose was to examine the relationships between psychological/physiological variables and performance. Sixteen male novices performed 150 acquisition trials, followed by 10 test trials under pressure induced by performance-contingent distractors: a cash reward or a punishment. Following test trials, each participant answered a questionnaire concerning attentional focus, including self-reports of conscious movement control and effects of the distractors. Results indicated successful stress induction indexed by significant increases in state anxiety, negative emotions, and heart rate under pressure. The step-wise multiple regression analyses showed that attention to distractors decreased movement displacements of both the golf club and the participant's right elbow in the follow-through phase. Also during a back-swing, the movement speed of both the club and of a participant's elbow were more likely to increase with those participants whose heart rate increased under pressure. The other multiple-regression analysis showed that the participants who reported increased conscious control of movements under pressure exhibited a greater variability in the terminal locations of their putted balls. Previous studies concerning the conscious processing hypothesis and the distraction hypothesis have suggested that two types of changes in attention cause poor performance under pressure. The findings of this study indicate that under pressure both types of attention shifts were shown to be associated with poor performance or with kinematic changes during golf-putting. In addition, it can be assumed that physiological emotional responses are also associated with kinematic changes under pressure.

Keywords: stress, attention, arousal, kinematics, electromyogram

1. Introduction

Athletes are commonly required to perform under various types of pressure that originate from different sources, such as spectators, the need to obtain prizes, and evaluation by coaches, peers and others. It is well known that many athletes experience deterioration in performance under such pressures. Therefore, an important task for athletes involves learning to overcome negative effects of pressure. Pressure is defined as "any factor or

combination of factors that increases the importance of performing well on a particular occasion (Baumeister, 1984)." As such, pressure functions as a psychological stressor that tells athletes they must perform well.

Generally, responses to a stressor are experienced not only psychologically, but also physiologically and in various behavioral manifestations (Lang, 1971). Consequently, for athletes under pressure, their motor performance is likely to be affected by stress responses evident in all three of these

domains. A number of previous studies have examined athletes' responses within each domain when they are under pressure. However, human motor behaviors are complex and final performance levels are regulated by relationships among psychological, physiological, and behavioral domains. Therefore, studies on motor behaviors under pressure need to take relationships among these domains into consideration. However, few studies have addressed these relationships. For this reason, the present research focused on relationships among psychological, physiological, and behavioral aspects in a task where participants executed a skilled motor pattern under pressure.

Previous studies have reported that emotions and cognition are the primary psychological factors that influence performance under pressure. Emotional changes, such as increased state anxiety (de Mojà and de Mojà, 1986) and lowered self-confidence (Williams et al., 2002), have been observed when athletes are performing under pressure. In addition, it has been demonstrated that various cognitive changes emerge when performing under pressure; these take the form of shifts in attention, increased self-awareness (Liao and Masters, 2002) and increased mental effort (Mullen and Hardy, 2000; Williams et al., 2002) directed towards task completion. Therefore, psychological variables such as emotional states and attention were investigated in this study.

In terms of physiological responses to pressure-induced stress, previous studies have examined activities of autonomic nervous system and the endocrinological system. It has been shown that pressure from external stressors increases activities in the sympathetic nervous system, such as increased heart rate (HR) (e.g., Beuter et al., 1989) and decreased percentages of high-frequency sub-band in HR variability (Mullen et al., 2005). Moreover, endocrinological changes have also been observed in the form of increased production of adrenal cortex hormones, such as cortisol (Salvador et al., 2003). Accordingly, the present study focused on physiological changes in the autonomic nervous system and investigated the level of physiological arousal under pressure.

Research concerned with behavioral aspects of performance has focused upon kinematic and kinetic characteristics that emerge under pressure. For instance, a decrease in kinematic functions

under pressure has been observed with movement displacement (Higuchi et al., 2002; Tanaka and Sekiya, in press), speed (Tanaka and Sekiya, in press), and movement coordination (Higuchi et al., 2002; Tanaka et al., 2009). However, previous findings on variability in kinematic functions under pressure have reported contradictory results, involving both decreases (Court et al., 2005; Higuchi, 2000; Higuchi et al., 2002; Tanaka et al., 2009) and increases (Gray, 2004; Tanaka and Sekiya, 2006) in variability as a function of increases in pressure. Effects of pressure on kinetic functions have also been reported. These include increases in electromyograms (EMG) dwell time (Weinberg and Hunt, 1976) and rate of co-contraction between prime movers (agonists) and antagonists (Weinberg and Hunt, 1976; Yoshie et al., 2008, 2009). These findings suggest that performance of athletes is affected by pressure through kinematic and kinetic changes. Therefore, this study investigated kinematic variables and EMG activities related to the behavioral aspect of performing under pressure.

Returning to the issue of inter-relationships among psychological factors and other domains that may influence motor performance, one aim of the present research was to examine relationships between attention, which is one of psychological aspects, and behavioral characteristics in determining performance levels. In particular, two attention hypotheses have been identified as a source of poor motor performance in a number of previous studies. These hypotheses propose different ways in which changes in attention can lead to poor performance: one hypothesis holds that *more attention* directed to movements causes poor performances (Baumeister, 1984; Masters, 1992); the other has argued that poor performance is due to distraction, meaning that *less attention* is directed to performing relevant motor acts (Eysenck, 1979; Eysenck and Calvo, 1992; Wine, 1971). These have been termed, respectively, the conscious processing hypothesis and the distraction hypothesis. The validity of these two hypotheses in explaining the impact of attention on failing performance in golf-putting tasks has been investigated (Beilock and Carr, 2001; Lewis and Linder, 1997; Mullen et al., 2005). However, to date these researches have not examined about behavioral characteristics, which may serve as important intervening variables between attention and final performance measures.

Other research has considered the relationship between performance and an individual's emotional state. This includes physiological arousal levels. For instance, it has been suggested that physiological arousal level and human performance in general conforms to an inverse U-shaped relationship (Yerkes and Dodson, 1908). It has also been reported that this U-shaped function relationship remains constant when performing a motor task under pressure (Martens and Landers, 1970). Different models and theories have been proposed to identify the nature of the relationship between psychological and physiological changes and performance in skill-related tasks. The catastrophe model (Hardy, 1990) estimates performance based on a two-factor interaction between cognitive anxiety and physiological arousal level. The multi-dimensional theory of anxiety (Martens et al., 1990) has been proposed to account for the relationship between motor performance and three measurements: cognitive anxiety, somatic anxiety and self-confidence. Although these previous studies reported that performance under pressure was influenced by the emotional and arousal changes, it has not been investigated that how changes in performance aspect, such as consistency and variability, were led by psychological and/or physiological changes. In addition, these models and theories also have not taken into consideration behavioral aspects of performance, such as kinematics and kinetics.

Given this background, the first purpose of the present study was to clarify the relationship between psychological (attention and emotion)/physiological (arousal level) aspects and behavioral aspects (kinematics and EMG activity) of a motor skill under pressure. The second purpose was to clarify the relationship between psychological (attention and emotion)/physiological (arousal level) aspects and performance aspect (consistency and variability). To pursue these purposes, a golf-putting was used as an experimental task in this study because it has been used in many previous studies that examined human motor behavior under pressure (Beilock and Carr, 2001; Lewis and Linder, 1997; Masters, 1992; Mullen et al., 2005; Tanaka and Sekiya, in press). It would be possible to compare the results of this study with that in the previous studies by using the golf-putting task.

2. Method

2.1. Participants

Sixteen right-handed male university students aged 19-22 years (mean \pm SD = 19.6 \pm 0.5) who had no experience playing golf participated. Informed consent was obtained from all participants.

2.2. Task and apparatus

The participants performed a golf-putting task in a laboratory. They hit a golf ball on artificial turf toward a target that was 1.5 m from the putting point. Each target comprised nine concentric circles. The outermost circle had a diameter of 90 cm, and each consecutive circle was reduced by 10 cm, such that the innermost circle was 10 cm in diameter. For scoring purposes, areas between one circle and the next were assigned values of 9, 8, 7, 6, 5, 4, 3, 2, and 1 points (from inner to outer circle). No points were awarded for a putted ball that landed outside the outermost circle. All participants putted right-handed, and were told to score as many points as possible on each trial. All participants used the same standard golf putter and the same standard golf balls.

Putting movements were videotaped with a digital high-speed camera (DKH B cam), with a sampling frequency of 100 Hz. The camera was placed in front of the participant in order to capture movement in the frontal plane. Movement kinematics were analyzed using a two-dimensional analysis (DKH Frame-DIAS for Windows). A digital video camera (Sony DCR-TRV70K) was placed above the target in order to videotape the golf ball locations on the target. EMG activities of the flexor carpi ulnaris (FCU) and extensor carpi radialis (ECR) muscles were recorded (sampling frequency = 1000 Hz, bandpass = 10-1000 Hz, range = 5 mV) with bipolar surface electrodes and an analog-to-digital converter (AD Instruments PowerLab/4st). The State-Trait Anxiety Inventory-Form JYZ (STAI Y-1; Hidano et al., 2000) was used to measure state anxiety. The Japanese version of Positive and Negative Affect Schedule (PANAS; Sato and Yasuda, 2001) was used to measure positive and negative affect. HR was measured during the golf-putting task with an HR monitor (Canon Bandage XL).

2.3. Procedure

Participants were tested individually. After each participant entered the laboratory, the transmitter of the HR monitor was attached to his chest, and a receiver was attached to his left wrist. A reflecting marker for movement analysis was attached to the right elbow (capitulum). Bipolar surface electrodes were placed on the FCU and ECR muscles of the right forearm. The participant was instructed to hold the putter with a normal grip. The following three instructions, derived from the advice of two professional golf instructors from the Japan Professional Golf Association, were given to each participant: (1) Hold the putter with optimal force, (2) Keep the lower half of the body in a fixed position, keep the elbow and wrist straight, and swing the putter from the shoulder, and (3) Swing the putter back with precise speed and then swing it forward.

After receiving general instructions, the participants performed 150 acquisition trials (15 blocks of 10 trials each), in order to acquire the golf-putting task and become familiarized with the experimental setting. State anxiety, positive and negative affect were measured before the last block of acquisition trials. During the last acquisition block, putting movements, ball location on the target, EMG activity, and HR were all recorded. The participants were provided with instructions designed to produce pressure in the following test session. Each participant was told that he would receive a cash reward of 2,000 JPY if his test score exceeded the highest score of any acquisition trial block. He was also told that an electric stimulus, which is as 10 times strong as common static electricity, would be given if the test score was less than the average score of the 11-15th acquisition blocks. Indeed, because this instruction about the electric shock was false, the shock was not given even if the test score was less than mean score of acquisition trials. This false instruction about punishment was created based on Higuchi et al.'s (2002) study in which a similar false instruction produced a low level of psychological stress. Following these instructions, participants answered the STAI Y-1 and the PANAS.

Next participants performed 10 trials in a final test block. During testing, putting movements, ball location on the target, EMG activity, and HR were

Table 1 Questionnaire items measuring participant's attentional focus

1. During the test, how much attention did you pay to movement (i.e., strength to hit the ball, timing to hit, golf putting form) that you were consciously aware of during the last block of acquisition trials?
2. During the test, how much attention did you pay to movement that you were not consciously aware of during the last block of acquisition trials?
3. How much attention did you pay to distractors (i.e., prize, electric shock, anxiety) during the test?
4. During the test, how much attention did you pay to other things that were not answered in Q1 through Q3.

all recorded. The putting score was provided to each participant as feedback after each trial, and after each block in both acquisition and test phases. Following the block of test trials, participants answered a questionnaire, comprising four questions (Q1-Q4), that was designed to measure attentional focus during test trials (see Table 1). In the previous studies concerning attentional focus under pressure, conscious control of movements (e.g., Masters, 1992) and distraction (e.g., Wine, 1971) led to poor motor performance. Therefore, Q1 and Q2 were designed to investigate conscious control of movements and Q3 was designed to investigate distractors under pressure in the present study. Other attentional focuses are not included in Q1 through Q3 were asked in Q4.

A structured interview was conducted in which an experimenter recorded participants' self-reported answers to the questionnaire. If an experimenter judged that a participant's response did not appropriately address a question, the participant was instructed to provide a more appropriate response. For example, if a participant answered about distractors when he was supposed to answer about conscious control, an appropriate response was requested. For Q1 and Q4, the participants were instructed to describe certain changes in attention that started in test trials relative to their experience in the final (15th) block of acquisition trials; using a 9-point scale, anchored between 9 (*I started paying a close attention*) and 1 (*I started paying no attention*). For Q2 and Q3, the participants were instructed to describe the degree to which their attention was directed to the test, also by using a 9-point scale, anchored between 9 (*my attention was very much directed to it*) and 1 (*my attention was not directed to it at all*). In addition, for Q1, Q2 and Q4, the participants first gave a self-report regarding the

specific object or focus of their attention (using multiple responses if necessary) before indicating this element on a point on the 9-point scale. After the participants provided their responses to the all questions, they were told that the section of the instructions regarding the electric shock was not true.

2.4. Dependent Measures

As indices of the psychological aspect, state anxiety, positive and negative affect were measured via the STAI Y-1 and the PANAS before the last block of acquisition trials, and again before the test phase. Answers to the questionnaire were taken as indices of attentional focuses. As an index of physiological arousal, HR was measured during the last block of acquisition trials and during the test at 5-second intervals.

In order to analyze movement kinematics, reflective markers were videotaped during the last block of acquisition trials and during the test. The digitized data were smoothed with an every three points filter after time-domain waveforms at 6 Hz. The putting movements were classified into backswing (BS), downswing (DS), and follow-through (FT) phases, based on club movement.

The linear movement amplitudes of the right elbow and club head during the BS and FT phases were examined, as spatial aspects of the movement. The averaged velocities of the right elbow and club during the BS, DS and FT phases were used to reflect the speed of the movement. The averaged accelerations of the right elbow and club during the BS, DS and FT phases were used to reflect acceleration. The movement times for the club during the BS, DS and FT phases were examined as temporal aspects. The standard deviations (over trials) of these kinematic measures were used to reflect inter-trial variability within each participant's performance. We analyzed the two markers in the frontal plane because the golf-putting task required participants to control club head movement in the frontal plane. Previous studies that used a golf-putting task also measured spatial and temporal aspects of club head movement (Coello et al., 2000; Craig et al., 2000; Delay et al., 1997; Mullen and Hardy, 2000). Furthermore, the upper-arms, forearms, hands, and club movements in the golf-putting task were produced by the abduction and

adduction movements of shoulder joints in the frontal plane with fixing the lower half of the body and trunk. The abduction and adduction movements of shoulder joints were measured by capturing the elbow kinematics in the frontal plane. Therefore, in the present study, elbow kinematics was taken to represent the movement of the arm.

The EMG activities of the forearm muscles were measured in this study because the forearm muscles controlled the grip force and hand movement during the golf-putting task. Kinetic variables of forearm muscles were measured to evaluate the golf-putting task with a pressure condition (Tanaka and Sekiya, 2006) and with yips' participants (Smith et al., 2000). The data for EMG activities were smoothed for every three points after time-domain waveforms were rectified. Averages (over trials within a block) of the rectified EMG data from the right wrist flexors and extensors were calculated for the BS, DS and FT phases. Moreover, before the participants began the acquisition phase, maximum voluntary contraction was measured for each of the muscles with the stance and grip for putting that were involved in the acquisition and testing phases. Ratios between the maximum voluntary contractions and the averaged rectified EMG were calculated and used as indices of the strength of each of the muscles. Furthermore, since the rate of co-contraction between the agonist and antagonist reflects the amount of effort dedicated to the executed task, rates of co-contraction between the FCU and ECR in the BS, DS, and FT phases were also calculated. The rate of co-contraction was calculated by superimposing the rectified EMG of the FCU and ECR (with time represented on the x-axis and EMG data represented on the y-axis) and using the following formula (Winter, 1990).

$$\left\{ \frac{\text{(the integral value of the co-contracting regions of the FCU and ECR)} \times 2}{\text{(the integral value of the FCU + the integral value of the ECR)}} \right\} \times 100$$

Furthermore, for each of these factors, the standard deviation was calculated for each block (10 trials). Also, with each of the trials in the 15th block and those in the test block, a signal indicating the start of filming with the high-speed camera was entered into PowerLab/4st. The starting point of each trial was determined by this signal and marked on the EMG.

As an index of performance, total putting score was obtained for each block of 10 trials. In addition,

absolute error (AE(x)), constant error (CE(x)), absolute constant error (ACE(x)), and variable error (VE(x)) were measured to reflect width errors of golf ball locations on the target from the viewpoint of the initial ball position. The AE(y), CE(y), ACE (y), and VE(y) were measured to reflect depth errors of golf ball locations.

2.5. Data Analysis

In order to examine the manipulation of added pressure, paired *t*-tests were conducted with state anxiety, positive affect, negative affect, and HR. Changes that occurred between the 15th acquisition block and the test were examined. With state anxiety, each of the participants' total points throughout the acquisition block and the test were converted to *t*-scores using the average and standard deviation of 1088 male university students taken from the STAI manual (Hidano et al., 2000) and *t*-tests were performed with the standardized state anxiety. Moreover, in order to determine the level of acquisition of the task in the total 150 trials in the acquisition phase, one-factor repeated measures analysis of variance was conducted on the putting points with blocks (16) as the factor. Since blocks were a repetitive factor, we used Bonferroni's method to determine the ranking. In order to examine the changes in attention throughout the final acquisition block (15th block) and the test block (16th block), the average points for Q1 and Q4 from the questionnaire data of all the participants were compared with 5 using *t*-tests; we designated the null hypothesis as a neutral rating score of 5 (for a scale of 1-9); this corresponds to the standard point of participants in evaluating no changes in the degree of attention to movement from the last block of acquisition trials to the test. In addition, the average points of Q2 and Q3 of all the participants were compared with 1 using *t*-tests; we also designated the null hypothesis as a neutral rating score of 1 (for a scale of 1-9); this corresponds to the standard point of participants in evaluating appearance of new attentional focus under pressure. In other words, if a participant answered Q2 with the score of 1, it means that no new attentional focus on movement was developed during the test. Answering Q3 with the score of 1 means that his attention was not directed to distractors at all.

Percent changes between the 15th block and the

test were calculated for the state anxiety, positive affect, and negative affect, which are psychological indices, for HR, which is a physiological index, for kinematic variables and each of the factors in EMG, which are behavioral indices, and the putting points, AE(x), AE(y), ACE(x), ACE(y), VE(x), and VE(y), which are performance indices¹. Since the performance factors CE(x) and CE(y) could have either negative or positive values, variations between the 15th block and the test block were calculated so that positive and negative values were included². In order to examine the relationship between psychological and physiological changes and behavioral changes, step-wise multiple regression analyses were performed with changes in each of the behavioral factors as response variables and changes in psychological and physiological factors as predictor variables. Finally, other step-wise multiple regression analyses were performed to examine the relation between psychological and physiological changes and performance measures with changes in the performance factors as response variables and changes in psychological and physiological variables as predictor variables. The significance level for all the analyses was less than 5%.

3. Results

3.1. Induced Pressure: Validation

Table 2 shows the means and standard deviations

Table 2 Means and standard deviations of state anxiety, positive affect, negative affect, and HR in the 15th block of acquisition trials and the test

	Acquisition	Test
State anxiety score (T-score)	44.30 ± 8.69	51.12 ± 9.60
Positive affect score	37.43 ± 7.58	36.44 ± 9.84
Negative affect score	20.44 ± 6.75	24.94 ± 8.55
HR (bpm)	89.34 ± 14.36	95.17 ± 15.61

Note. Acquisition = the 15th block of acquisitions; Test = the 10 trials in the pressure condition.

¹ For each of the measurements, we used (the average of 10 trials in the test)/(the average of the 10 trials in the 15th block) × 100 as an index of percent changes between the 15th block and the test.

² For each of the measurements, we used (the average of 10 trials in the test)-(the average of the 10 trials in the 15th block) as an index of variations between the 15th block and the test.

of state anxiety, positive affect, and negative affect scores before the 15th block and the test, and HR during the 15th block and the test block. The *t*-test showed that state anxiety ($t(15) = 5.58, p < .001$), negative affect ($t(15) = 3.80, p < .01$), and HR ($t(15) = 3.22, p < .01$) increased significantly from the 15th block to the test. However, positive affect showed no significant change.

3.2. Performance

There was a significant main effect for block in putting scores, $F(15, 225) = 5.89, p < .001$. The post-hoc test showed that the putting score in the 1st block of acquisition trials was significantly lower than the 7th, 8th, 9th, 10th, 12th, 13th, 14th, and 15th blocks. Moreover, the putting score in the 2nd block was significantly lower than the 9th and 14th blocks. There were no significant differences among putting scores of the 3rd through 15th blocks, indicating that performance reached a plateau after the first two acquisition trial blocks. A significant change in putting score from the last block of acquisition trials to the test was not shown. Only one participant earned the cash reward.

3.3. Attention

Table 3 shows means and standard deviations of all scores on attentional variables and main self-reports, which were answered by more than two participants, for Q1, Q2, and Q4. The *t*-test showed that mean score of Q1 ($t(15) = 3.15, p < .01$) was significantly higher compared with 5, which corresponds to no change in the degree of attention to movement from the last block of acquisition trials to the test. This result indicates that participants started to pay more attention to movement during the test. The mean scores of Q2 ($t(15) = 2.21, < .05$)

Table 3 Means and standard deviations of scores of the attentional variables and self-reports concerning attentional focus

	Mean \pm SD	Points of attentional focuses (number of participants)
Q1	6.38 \pm .87	Force control during DS and at impact (9), amplitude in BS (5)
Q2	2.56 \pm 1.41	Force control at impact (2)
Q3	6.81 \pm .89	—
Q4	4.88 \pm .83	Scores (9)

and Q3 ($t(15) = 15.81, p < .001$) were also significantly higher compared with 1, indicating that their attention was directed to the additional points of putting movement and the distractors in the test.

3.4. Relationship between psychological/physiological aspects and behavioral aspect

Table 4 shows the predictors with significant adjusted R^2 in the multiple regression analyses of psychological and physiological variables on behavioral variables. The standardized regression coefficients of Q3 ($\beta = -.834, p < .01$) and positive affect ($\beta = .461, p < .05$) were significant for club amplitude in FT. The coefficient of Q3 was also negative for elbow amplitude in FT ($\beta = -.610, p < .05$). These results indicate that movement amplitudes become smaller with distraction, or with decreased positive affect. The coefficient of state anxiety was positive for elbow amplitude variability in BS ($\beta = .517, p < .05$), indicating that movement variability increased when state anxiety increased. The coefficient of Q3 was negative for the elbow amplitude variability in FT ($\beta = -.618, p < .05$), indicating that movement variability decreased with distraction.

The coefficients of Q3 ($\beta = -.526, p < .05$) and HR ($\beta = .797, p < .01$) were significant for club velocity in BS. The coefficient of HR was also positive for elbow velocity in BS ($\beta = .533, p < .05$). These results indicate that increased arousal was related to increased movement velocity and that increased distraction was related to decreased movement velocity. The coefficients of state anxiety were positive for club velocity variability in BS ($\beta = .616, p < .05$) and elbow velocity variability in BS ($\beta = .674, p < .01$). The coefficient of negative affect was positive for club velocity variability in DS ($\beta = .627, p < .01$). These results indicate that movement velocity varied when state anxiety or negative affect increased.

The coefficients of Q2 ($\beta = -.472, p < .05$) and negative affect ($\beta = .832, p < .01$) were significant for variability of movement time of club in BS. The coefficient of Q2 was positive for variability of movement time of club in DS ($\beta = .546, p < .05$). The coefficient of Q3 was negative for variability of movement time of club in FT ($\beta = -.541, p < .05$). These results indicate that increased attention to movement and decreased negative affect were related

Table 4 Results of stepwise multiple regression analyses of psychological and physiological variables on behavioral variables

Response variables	Predictor variables (β)	adjusted R^2
Change of linear amplitude	Change of psychological and physiological variables	
Club in FT	Q3 (-.834**), positive affect (.461*)	.522**
Right elbow in FT	Q3 (-.610*)	.327*
Change of variability of linear amplitude		
Right elbow in BS	state anxiety (.517*)	.267*
Right elbow in FT	Q3 (-.618*)	.337*
Change of averaged velocity		
Club in BS	Q3 (-.526*), HR (.797**)	.435*
Right elbow in BS	HR (.533*)	.233*
Change of variability of averaged velocity		
Club in BS	state anxiety (.616*)	.415**
Right elbow in BS	state anxiety (.674**)	.335*
Club in DS	negative affect (.627**)	.350**
Change of variability of movement time		
Club in BS	Q2 (-.472*), negative affect (.832**)	.522**
Club in DS	Q2 (.546*)	.248*
Club in FT	Q3 (-.541*)	.242*
Change of %MIC-EMG		
ECR in BS	state anxiety (-.570*)	.276*
Change of variability of %MIC-EMG		
ECR in BS	Q4 (-.553*)	.256*
Change of co-contraction		
BS	Q1 (-.558**)	.552**

Note. β = standardized regression coefficient; adjusted R^2 = squared multiple correlation coefficient adjusted for the degrees of freedom; ** $p < .01$, * $p < .05$

Table 5 Results of stepwise multiple regression analyses of psychological variables on performance variables

Response variables	Predictor variables (β)	adjusted R^2
Change of performance	Change of psychological variables	
ACE(x)	positive affect (-.572*)	.327*
VE(y)	Q1 (.508*), Q2 (.606*)	.490**

Note. β = standardized regression coefficient; adjusted R^2 = squared multiple correlation coefficient adjusted for the degrees of freedom; ** $p < .01$, * $p < .05$

to decreased variability of BS movement duration. However, the variability of DS movement duration increased when it was consciously controlled. Additionally, variability of FT movement duration decreased when attention to distractors increased. Moreover, the state anxiety coefficient for EMG activity of ECR in BS was negative ($\beta = -.570$, $p < .05$), indicating that EMG activity decreased when state anxiety increased. The coefficient of Q4 was negative for variability of EMG activity of ECR in BS ($\beta = -.553$, $p < .05$). The coefficient of Q1 was negative for co-contraction in BS ($\beta = -.558$, $p < .05$), indicating that the amount of co-contraction decreased with increased conscious control.

3.5. Relationship between psychological/physiological aspects and performance

Table 5 shows significant predictors in the multiple regression analyses of psychological variables on performance variables. The standardized regression coefficients of positive affect ($\beta = -.572$, $p < .05$) was negative for ACE (x), indicating that the response bias in the final ball location decreased with increased positive affect. The coefficients of Q1 ($\beta = .508$, $p < .05$) and Q2 ($\beta = .606$, $p < .05$) were positive for VE (y), indicating that the variability of the final ball location increased with increased attention to movement.

4. Discussion

The first purpose of the present study was to examine relationships between psychological/physiological aspects and behavioral aspects of the golf-putting task under pressure. The second purpose was to examine the relationships between psychological/physiological aspects and performance. Before examining these relationships, however, it was necessary to observe psychological and physiological states induced under the pressure condition, because they determined the relationships with behavioral and performance aspects.

A significant increase was observed in various stress measures in the test block relative to levels observed on the final acquisition block. State anxiety, negative affect, and HR measures were all higher due to pressure applied in the test block. These findings suggest that the stipulation of a cash reward-plus-punishment, used in this study, had an effect on the participants' emotional state and arousal level. Although they also suggest that the induction of stress through pressure was effective, it should be noted that state anxiety increased, on average, by approximately 7 points and HR increased on average by approximately 6 bpm; this indicates that the stress created in the study was rather weak. It has been reported that HR can increase by 20 to 40 bpm due to pressure during actual athletic events (McArdle et al., 1967; Yoshie et al., 2009). Therefore, our results indicate the difficulty of creating a realistic stress level in experimental settings that compares reliably with actual athletic events (Williams et al., 2002).

Analysis of questionnaire responses indicated that thirteen of the sixteen participants reported their attention was focused upon properties of movements, such as control of force and displacement during the putting task and this focus appeared to increase from the 15 acquisition blocks to the test block. Moreover, all participants reported, as well, that their attention was directed toward the reward and the electronic shock stressor. According to the conscious processing hypothesis and the distraction hypothesis, pressure causes poor motor performance due to, respectively, increased attention to movements or increased attention to distractors (e.g., in this case stressors). The results of the present study suggest that both factors play a role in attentional focus in this task; one possibility

is that participants under pressure simultaneously divide their attention to both movement properties and stressors. In this case, if we assume a limit to attentional resources (Kahneman, 1973), and if instructions about rewards/punishment lead to task demands for divided attention then attentional resources will be allocated to both movement properties and distractors.

Even with the relatively low level of stress induced in the present study, it was possible to demonstrate certain relationships between psychological/physiological and behavioral variables. For example, we found that movement displacement of a golf club and the right elbow in the FT phase decreased if attention was directed toward the stressor or to anxiety. This is consistent with previous research showing that a decrease in movement displacement results from participants' distraction even in non-pressure conditions (Beach et al., 2006). In addition with pressure, others have reported finding a decrease in movement displacement (e.g., Higuchi et al., 2002; Tanaka and Sekiya, in press). Therefore, it is reasonable to assume that the decrease in movement displacement under a low level of stress we observe in the present study is due to increased distraction.

This study also found that the movement speed of a golf club and the elbow in the BS phase were more likely to increase with participants whose HR increased under pressure. Recent studies have suggested the possibility that kinematic and kinetic changes due to pressure are caused by psychophysiological responses in addition to changes in attention (Hatfield, 2007; Tanaka and Sekiya, 2006). Previous studies have also examined the effects of increased arousal, due to emotional changes, on movement kinematics (Chen and Bargh, 1999; Coombes et al., 2005). These studies found that movement speed increased due to negative emotions; the investigators hypothesized that increased movement speed with emotional changes is a consequence of the impact of emotional responses on motor control. Therefore, it is conceivable that movement speed increases with increments in arousal level that are elicited by added pressure; this is attributed to effects that physiological emotional responses have on motor control. As such, it can be assumed that both changes in attention and physiological emotional responses are associated with kinematic changes

under a low level of stress.

Furthermore, this study also suggested a relationship between psychological/physiological variables and performance. The results of a step-wise multiple regression analysis that examined the relation between the changes in attention and performance of participants show that the participants who reported increased attention toward movements under pressure exhibited a higher variability in the terminal locations of putted golf balls compared with the last block of acquisition trials. This finding reveals that although participants report attending to both movements and distractors, only the attention to movement appears to result in reduced motor performance indexed by this variability measure. This result supports the conscious processing hypothesis, according to which motor performance suffers from increased conscious control of movements under pressure. In the present case, this hypothesis successfully explains variability of final destinations of golf putts.

Previous studies concerning the conscious processing hypothesis and the distraction hypothesis have suggested that two types of changes in attention cause poor performance under pressure. The debate remains surrounding the exact change responsible for poor performance under pressure (Beilock and Carr, 2001; Lewis and Linder, 1997; Mullen et al., 2005). However, the findings of this study indicate that under a low level of stress both types of attention shifts, namely increased attention to movements and increased attention to distractors (here stressors), were shown to be associated with poor performance or with kinematic changes during golf-putting. Therefore, the results of this study suggest that both increased attention toward movements and increased distraction can cause poor motor performances when athletes are under pressure.

Finally, this study also examined EMG activities and the rate of co-contraction of agonist and antagonist as kinetic characteristics. However, the relationships among psychological/physiological characteristics and kinetic changes could not be identified, although previous studies have indicated that pressure increased the duration of EMG activities and the rate of co-contraction between agonists and antagonists (Weinberg and Hunt, 1976; Yoshie et al., 2008, 2009). There are two possible

reasons as to why no kinetic changes were observed in the present study. The first reason relates to differences in level of stress induced in the present and previous studies. EMG activity may have been influenced if a higher level of stress had been induced in the present study. The second reason relates to the selection of muscles for EMG measurement. In the present study, the EMG activity was measured only in the forearm muscles that control the wrist joint and hand movements. If EMG activity was measured in the upper-arm and shoulder muscles, such as biceps and trapezius, which control the shoulder and elbow joints, different EMG activities might have been seen even under the low level of stress used in this study. Therefore, the relationship between kinetic changes on the one hand and psychological and physiological variables on the other needs to be addressed in future research.

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