

# EFFECT OF PSYCHOLOGICAL PRESSURE ON EYE, HEAD, HEART & BREATHING RESPONSES DURING THE GOLF PUTTING STROKE

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## Abstract

*This study investigated the effect of psychological pressure on physiological responses during the golf putting stroke. Six young adults (four males and two females) participated in the study. The experiment was comprised of a contest that consisted of four sessions, with a dinner prize awarded to the winner. In each session, the subject was instructed to attempt 20, 9-foot putts. Eye, head, and putter motions, as well as heart rate and breathing rate, were objectively recorded during each trial. For all sessions, each successful putt was awarded a score of +2 points. However, as the four sessions progressed, any missed putt was given progressively greater negative scores: -2, -3, -4, and -5 points, respectively. At the end of the experiment, the subject rated the perceived pressure during each session on a scale of 1 to 5, with 1 corresponding to no pressure and 5 corresponding to extreme pressure. Overall, the results demonstrated that the apparently simple act of putting involves a complex interplay among various physiological and neurological control parameters, hence reflecting a myriad of emo-*

*tions that are magnified under increased psychological pressure.*

## Key Words

*breathing rate, eye movement, golf putting, head movement, heart rate, stress*

## INTRODUCTION

In recent years, there has been increased interest in physiological measurements to quantify functions of the human body during sports performance.<sup>1-3</sup> These parameters can provide valuable information regarding the internal physiological state of the athlete. For example, in skiing, sensors worn by professional skiers have provided important information on forces generated during ski runs.<sup>1</sup> In soccer, multiple sensors have been used to record heart rate (HR), body motion, and other physiological parameters to assess the relationship between the player's physiological responses and performance.<sup>4</sup> In golf, sensors have been used to measure eye movement (EM) and head movements (HM) during the putting stroke. These measures provide insight into the golfer's physiological and mental state.<sup>5-8</sup> These golf studies are the latest in a growing literature that attempts to unlock some of the mysteries surrounding this apparently simple act of putting.<sup>9-13</sup> The importance of putting is evident, as it comprises approximately 40% of one's total golf strokes during a typical round of golf.<sup>14</sup> Books, drills, and professional advice constantly describe the importance of minimizing EM and HM during the putting stroke.<sup>7,9,10</sup> One drill suggested that improved putting involves keeping one eye closed during the putting stroke. This drill is meant to improve stillness of

both the head and the body during the putting stroke by concentrating on the ball.<sup>15</sup> However, such drills that are often practiced in one's backyard may not translate into success on the golf course. This could be due to increased psychological pressure during actual competition, or simply one's perceived pressure of having to make a putt even in an ordinary round of golf. Robert Wyatt, from the United States Golf Teachers Federation, has suggested that putters often suffer under psychological pressure reflected in unnecessary body movement.<sup>16</sup> The extra motions during one's putting stroke could cause an increase in eye movement, which could decrease putting success.<sup>9</sup> The causes of this extra movement are not well understood; however, the movements could be due to changes in physiological functions, such as HR and breathing rates (BR). The main questions then become whether or not a quantifiable form of stress can be imposed under laboratory conditions. Do the effects from this psychological pressure affect the physiological parameters associated with putting success? Some links are known between psychological pressure, or perceived extraordinary emotional demands and simple physiological processes.<sup>17,18</sup> In addition, there are relationships between these physiological functions and attention. From a study on child development and attention, it was shown that increased attention to a task results in decreased HR.<sup>19</sup> On the other hand, external stress causes increased HR.<sup>20</sup> Hence, such increased pressure may lessen one's attentional focus on the task at hand, such as putting. These relationships might prove to be crucial in affecting body movements during the putting stroke, and in turn, putting accuracy. It is well known that prior to

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addressing a putt, the perception of distance and direction is provided by visual inspection of the putting green terrain. This occurs even while walking about the intended line of the putt. However, during the execution of a putt, head and eye stability is crucial in maintaining a constant visual environment.<sup>7,9</sup> A single task of focusing, or concentrating, to minimize eye movement during putting, is said to have a large impact on putting success.<sup>21</sup> Thus, any deviation away from normal conditions, such as under a stressful environment, could increase one's HR, and thereby decrease one's ability to concentrate. Lastly, another study demonstrated that increased physiological arousal, leading to an increase in HR, increases one's susceptibility to "choke," i.e., miss the putt.<sup>22</sup>

HR variability (HRV), which is a measure related to HR, has been shown to be an important indicator of the body's response to stress.<sup>23</sup> It is defined as the variation (standard deviation) in the RR interval (i.e., the time interval between the peaks of successive beats) of an electrocardiogram recording, or the variation in the beat-to-beat interval.<sup>24</sup> In an experiment studying patterns in HRV in the presence of mental tasks, it was shown that mental activity increased sympathetic nervous system activity. This activity was in proportion to the amount of stress involved with each particular activity.<sup>25</sup> Increased sympathetic activity results in an increased HR and a decrease in HRV. Another study measured HR and HRV in the presence of a reaction time activity, as well as mental arithmetic activities.<sup>26</sup> The results demonstrated that during the reaction time activity, HRV decreased, while HR increased. However, no significant change in HRV was present during the mental arithmetic tasks. This could have been due to respiratory interference of the HRV measurement during the recording resulting from verbal interaction of the subjects and the mediator. The links between mental and physical arousal, and their affects on sympathetic activity (and in turn, HRV), may indicate methods to improve one's ability to concentrate. Therefore, the impact of pressure and its consequent physiological arousal on HRV becomes important when considering the ability to increase attentional focus and concentrate on a specific activity, such as putting.

Common methods for increasing stress in a laboratory environment include mental tasks, such as mental arithmetic

or puzzles, and physical tasks, such as lifting small weights.<sup>26</sup> These tasks are considered stressors in that they are both mentally and physically demanding.

Thus, the purpose of this study was to examine the relationships among average HR, BR, EM, HM, and putting accuracy under increasing psychological pressure conditions. The stress-induced protocol included a contest based on performance that gave a prize for the top performer.

Additional stressors were a rating scale that increased the penalty for missed putts as the rounds progressed, and the presence of a video camera to record the responses.

## METHODS

The study was performed using six Rutgers University undergraduate students (four males and two females) ranging in age from 19 to 22 years. One of the subjects had significant golfing experience, and the remainder had varying amounts of experience ranging from zero to moderate. The subjects completed written consent forms prior to participating in the study, and the forms were signed by the administrator of the experiment. The study was approved by the Rutgers University Institutional Review Board committee.

## Apparatus

Subjects wore a visor apparatus containing wireless Shoane-Biomedical biosensor devices<sup>a</sup> for measuring eye and head motion,<sup>8,27</sup> along with the infrared sensors for measuring HR and BR (Biopac Model MP30,<sup>b</sup> Figure 1). The measured parameters included EM, HM, BR, and HR. The eye sensor system consisted of an infrared reflection limbal tracking system,<sup>28</sup> which had a resolution of 15 min arc, a linear range of  $\pm 25^\circ$ , and a bandwidth of 200 Hz. The head sensor consisted of an accelerometer in a circuit board mounted on the visor. The head position signal, which is derived from the accelerometer signal, had a resolution of 0.5 cm (equivalent displacement on the putting platform) and a range of  $\pm 25$  cm. The putter sensor consisted of an accelerometer mounted on a circuit board attached to the putter shaft. The putter position, which is derived from the accelerometer signal had a resolution and range of

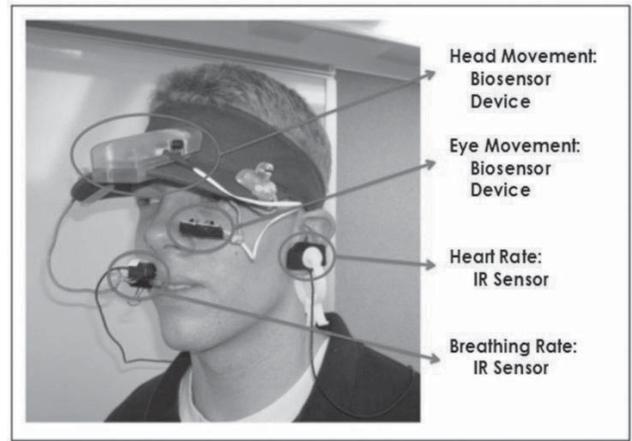


Figure 1. Subject wearing multi-sensor device mounted on a visor.

0.25 cm and  $\pm 45$  cm, respectively. The electronic signals from the eye, head, and putter sensors were transmitted wirelessly to a circuit board connected via the USB port on a conventional laptop computer. This computer ran the Shoane-Biomedical program for recording the signals from the eye, head and putter movement sensor systems. The entire recording system had a sampling rate of 100 Hz.<sup>8,27</sup> The breathing and heart signals were recorded using infrared reflection transducers (SS4LA) in a Biopac system (Model MP30). The device has a maximum sampling rate of 100 KHz. One of the transducers was clipped on the earlobe to measure the blood flow, and in turn the heart pulse. Also, a small rectangular piece of paper was taped to a transducer and placed in front of the right nostril. Air flow from the nostril deflected the paper, and in turn the infrared reflection signal, thereby providing the BR response. Since only the HR and BR were required in this study, no calibration of response level was performed for these transducers. The wires from these transducers were situated behind the subject in an unobtrusive manner during putting.

## Experimental Procedure

The golf putting competition consisted of four sessions in a laboratory environment. Each subject participated on two separate days for the competition, with sessions 1 and 2 on day one, and sessions 3 and 4 on day two. During each session, the subject attempted 20 putts. The distance from the ball to the target was 9 feet for all sessions (Figure 2). A compact disc (12 cm, or 4.7 inches in diameter) was used to represent the golf cup, and a stretch of green artificial turf was used as the putting surface.<sup>7,8</sup> A putt was considered successful if more than half the ball was inside the disc, and furthermore the ball speed was moderate



Figure 2. Subject putting while wearing the multi-sensor device.

enough so it would have dropped into an actual cup. Each putt was then scored on a simple “made versus missed” basis, and the putting results were recorded accordingly. Putting performance was determined by the percentage of successful putts.

### Scoring System and Pressure Protocol

Scores were given for each individual putt, and these score values were changed as the sessions progressed. Positive scores were awarded for successful putts, and negative scores were awarded for missed putts. In all four sessions, each successful putt was awarded a score of +2 points. However, the penalty for missed putts became increasingly negative as the sessions progressed. The penalties for missed putts in rounds 1-4 were -2, -3, -4, and -5, respectively. The subjects were periodically informed of their present score. Upon completion of the four rounds of putting, each subject submitted a feedback form. The subjects rated the amount of perceived pressure felt, on a scale of 1-5 (1 for no pressure and 5 for extreme pressure), for each of the sessions. The winner of this contest was awarded a dinner prize.

### Data Analysis

For each putt, the root mean square (RMS) values of the EM and HM were calculated over the range from the beginning of the

**Table 1. Individual subject’s EM and HM RMS values**

Subjects	CH	DH	WK	NN	RP	JS
Putt (%)	68.5	59.2	44.7	42.1	36.8	31.8
EM RMS	17.0	27.8	9.4	14.6	9.9	14.7
HM RMS	25.5	40.5	41.6	28.0	41.1	43.9

**Table 2. Average values for the four test sessions across subjects.**

	Average putts made (%)	Average EM RMS	Average HM RMS	Average BR	Average HR
Session 1	31.6	15.4	37.7	13.7	81.1
Session 2	52.6	10.5	36.8	13.1	81.6
Session 3	47.4	4.7	44.7	12.5	92.5
Session 4	47.4	6.8	47.3	13.7	94.6

EM - eye movements; HM - head movements; RMS - root mean square; BR - breathing rate; HR - heart rate

stroke to the point of ball impact. Also, HR and BR were analyzed over the continuously-recorded session, and the average HR, HRV, and average BR per session were calculated. The percentage of putts made per session was calculated. In addition, the perceived pressure score assessed by the subject per session was tabulated.

After these results were obtained on each subject, an intra-subject comparison of any two of the parameters was obtained using a Matlab<sup>29</sup> program by calculating the correlation coefficient of the parameters over the four sessions. This was performed among all paired-combinations of parameters. Finally, for each paired-combination, the correlations were displayed across the subjects, and then they were ranked from best to worst putting performance. For simplicity, only those combinations showing a substantial trend (i.e., showing more than just a random variation) across subject-performance are presented in the results.

## RESULTS

### Individual Subject

A typical record of the putting, eye, and head traces is shown in Figure 3, and a typical record of the breathing, heart-pulse, and interval marker traces for the same subject is shown in Figure 4.

### Individual Subjects

**RMS Values.** Table 1 shows the individual subject’s RMS values for EM and HM ranked from the best (1) to worst (6) putting performance. While EM RMS did

not exhibit a trend with decreased putting performance, HM RMS showed a mild trend (with one exception) of increased HM RMS values with decreased putting performance. This trend for HM RMS suggests that the better performers may either have learned or were naturally inclined towards holding their heads steady while putting.

### Across Subjects

**Average Values.** Table 2 shows the average values across subjects for each session. Average EM RMS decreased, average HM RMS increased, average HR increased, and BR remained relatively constant, as the sessions progressed. Average putting percentage increased relative to the first session. EM and HM values are in equivalent displacement on the putting platform (in cm) based on EM and HM rotation. BR is in breaths/min, and HR is in beats/min.

**Effect of Perceived Pressure.** Two group trends were found when the subjects were ranked in order of decreasing putting performance: The correlation between perceived pressure and HM RMS increased (Figure 5), while the correlation between perceived pressure and HRV decreased, becoming more negative for the worse performers (Figure 6). The trends were not monotonic, as there were a few exceptions. It is, however, very suggestive of a relationship between the psychological impact and physiological response as performance decreased.

In addition, an interesting finding was the very similar patterns for the plots of

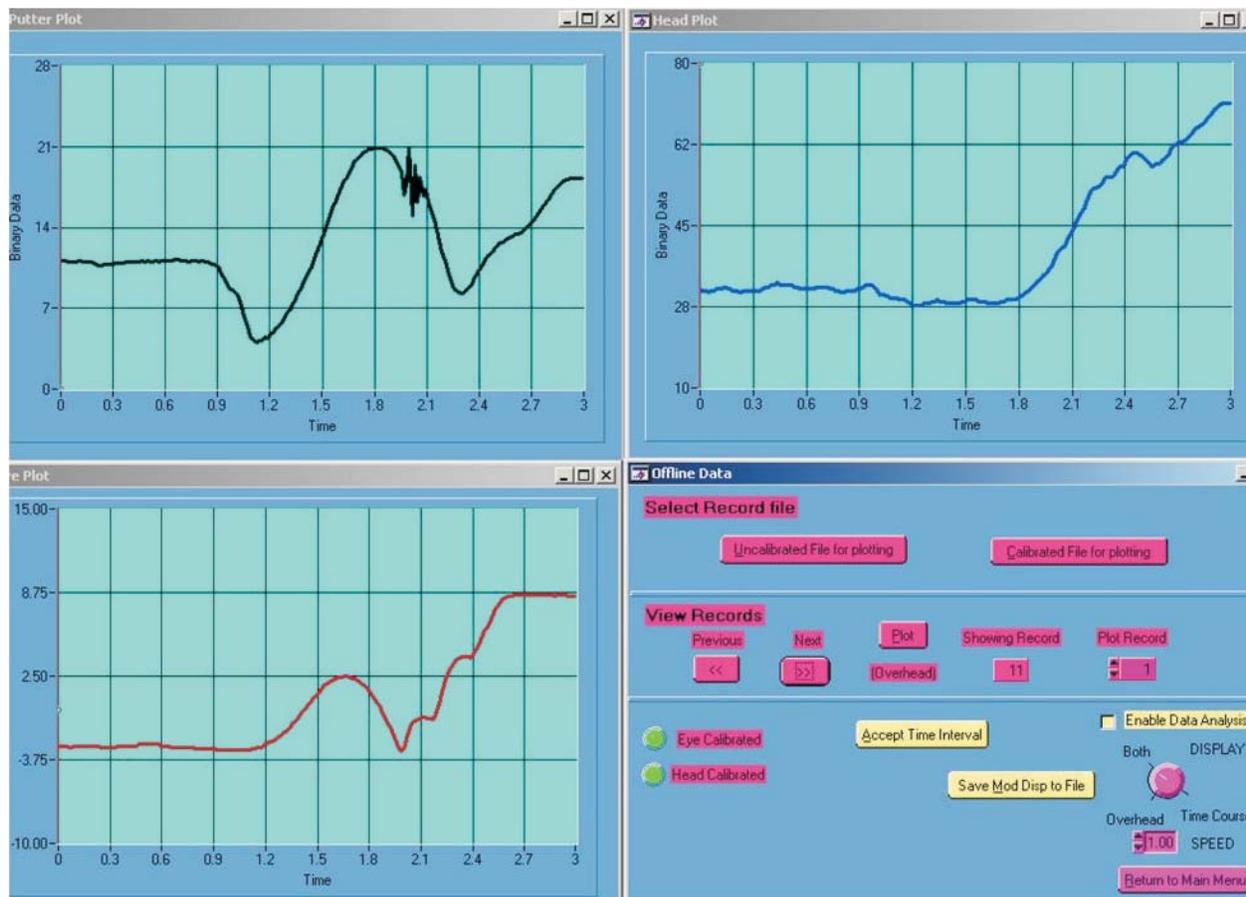


Figure 3. Typical Putting (Top Left), Eye Movement (Bottom Left), and Head Movement (Top Right) traces over a 3 sec interval. Ordinate values for all three plots are in units of cm of equivalent displacement on the putting platform. The computer panel (bottom right) controls the recording of the putting trials. Transient noise in the putting trace indicates putter impact on the ball.

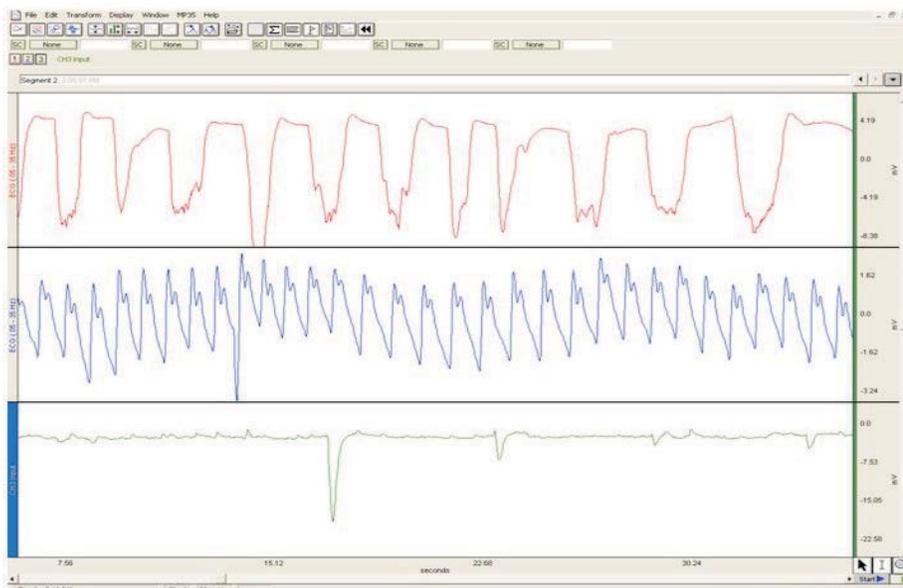


Figure 4. Typical breathing (top), heart-pulse (middle), and interval marker (bottom) traces over a 30 sec interval. Downward spikes (4 shown in this figure) in the interval-marker trace indicate the beginning of each putting trial. These marker signals were obtained by an infrared sensor attached to the index finger of the experimenter for pressing down on the mouse key to start a trial. The small variations in the trace are due to the experimenter's finger pulse and random movement.

correlation between perceived pressure and putting performance (Figure 7, top), and between perceived pressure and EM RMS (Figure 7, bottom). This suggests an underlying relationship between EM variation and putting performance, perhaps being modulated by the subjective perception of pressure.

**HM RMS versus EM RMS.** There was a pattern of a decrease in correlation between head RMS and eye RMS as performance rank decreased (Figure 8). This suggests a poorer neural coordination between the head and the eye position signals for the poorer performers.

## DISCUSSION

In golf, pressure plays as an important a role in a small wager among friends as it does in a multi-million dollar professional tournament. It is difficult to define, but golfers know it and feel it when certain critical situations arise.<sup>17</sup> A 5-foot left-to-right downhiller to decide the wager, or to win a major championship, will get the heart to race, the palms to sweat, and the mouth to dry up. Some players succumb to the pressure and miss badly,

### Correlation: Perceived Pressure and Head Movement RMS

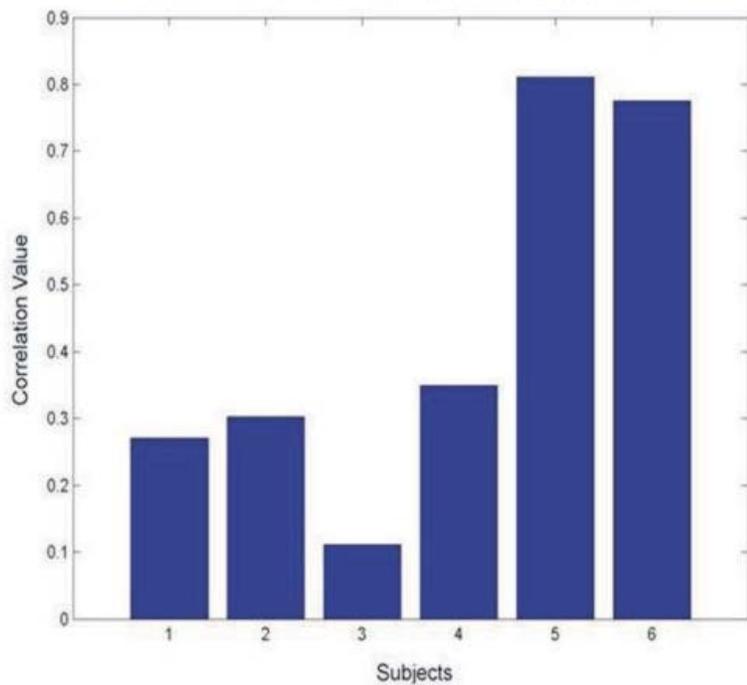


Figure 5. Trend across subjects showing the correlation between perceived pressure and head movement RMS increased as subject performance decreased. Subject ranked according to putting performance from best (1) to worst (6).

### Correlation: Perceived Pressure and Heart Rate Variability

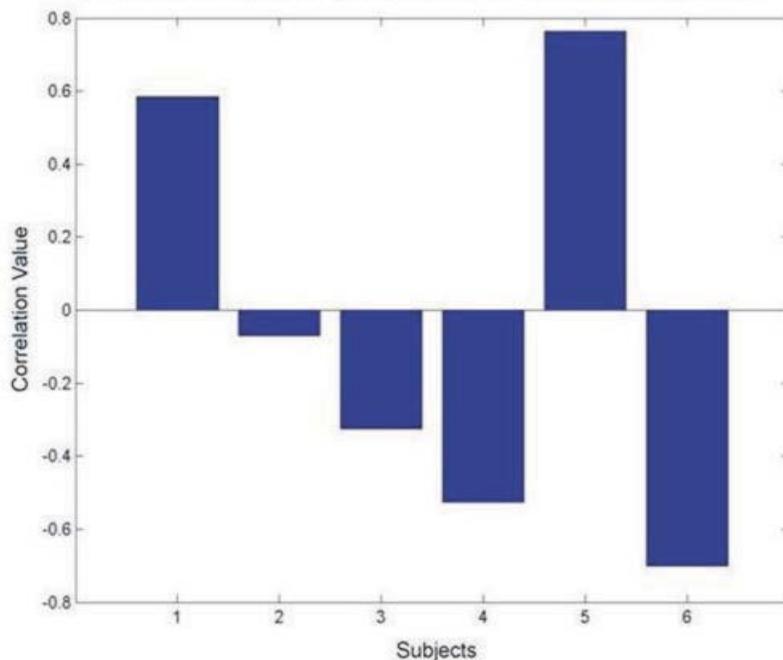
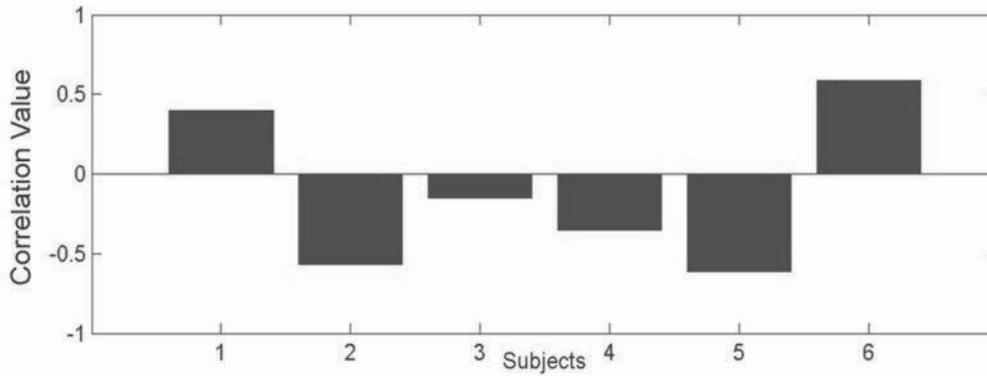


Figure 6. Trend across subjects showing the correlation between perceived pressure and heart rate variability decreased with poorer performance.

while others, like Jack Nicklaus and Tiger Woods,<sup>9,30</sup> thrive on this pressure with even greater concentration and superior performance.

How does pressure affect physiological responses and putting performance under less severe (i.e., laboratory) conditions? This was the scope of the present study. The subjective assessment of this pressure provided a measure of the internal psychological state of the individual. Comparing this with the individual's physiological responses provided a relative measure of the effects of pressure. Ranking these comparisons across individuals, based on performance, provided an overall assessment of trends that may not be evident in the within-subject data. The increase in correlation between perceived pressure and HM RMS suggests a greater affect of pressure on the ability of poorer performers to maintain head stability. The decrease in correlation between perceived pressure and HRV suggests that pressure has a greater influence on the sympathetic physiological response of the poorer performers. This is consistent with the literature, which shows that as pressure increases, sympathetic activity increases, while HRV decreases.<sup>23</sup> The finding of very similar patterns for the plots of the correlation between perceived pressure and putting performance, and between perceived pressure and EM RMS is suggestive of a relationship between eye movement variation and putting performance. Although the individual data (Table 1) did not show a trend between EM RMS and putting performance, other higher level factors may have been involved that resulted in a relationship, via the pressure perceived by different individuals. These underlying relationships have been found in other studies which showed an association between decreased EM RMS and improved putting performance.<sup>7,27,31</sup> Lastly, the group trend showing the negative correlation between EM RMS and HM RMS (Figure 8) suggests a trade off between eye and head variation. This trade off can also be seen in the decrease in the EM RMS values with the increase in HM RMS values as the pressure increased from session 1 to session 4 (Table 2). It is also consistent with earlier findings on the effect of wearing different progressive addition lenses (PALs) on putting performance.<sup>7</sup> In that study, it was found that subjects wearing the progressive addition lens with the narrower intermediate zone (PAL2) exhibited slightly smaller EM

### Correlation: Perceived Pressure and Performance



### Correlation: Perceived Pressure and Eye Movement RMS

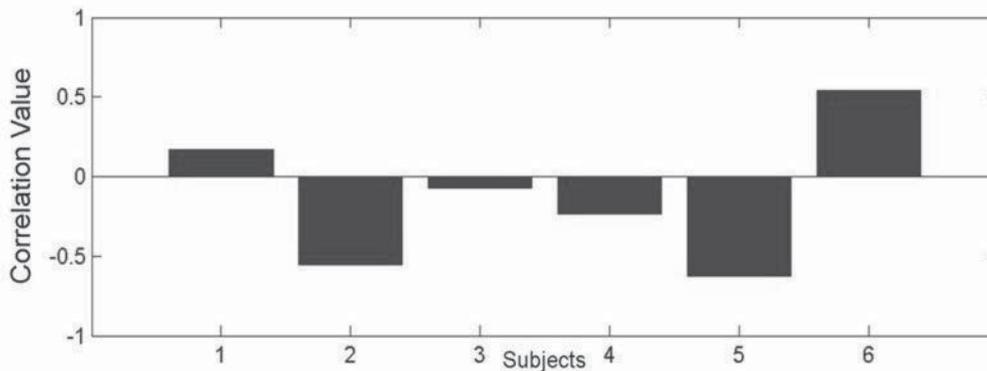


Figure 7. Similarity of correlation between perceived pressure and putting performance (top), and between perceived pressure and eye movement RMS (bottom), for each subject.

### Correlation: Eye Movement RMS and Head Movement RMS

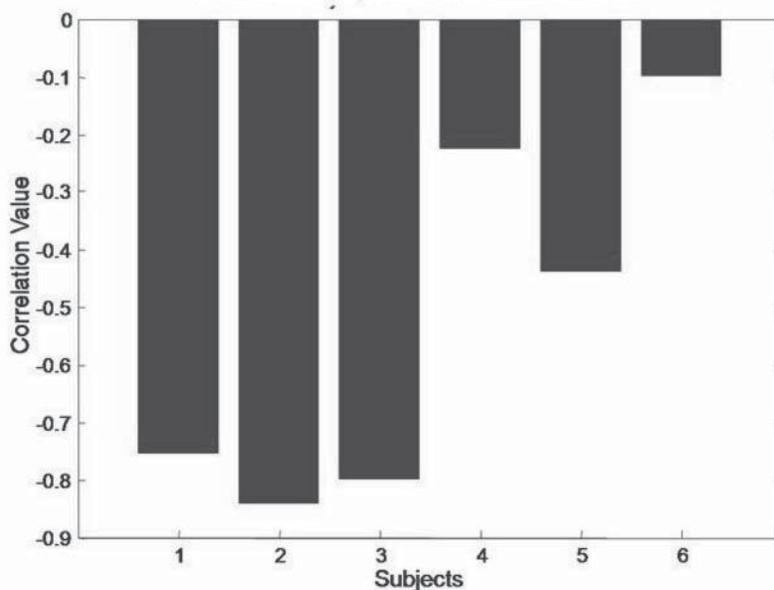


Figure 8. Trend across subjects showing the negative correlation between eye movement RMS and head movement RMS decreased in magnitude with poorer performance.

than with the lens having a wider intermediate zone (PAL1). On the other hand, in apparent compensation for the restricted clear field-of-view, subjects wearing the PAL2 exhibited greater HM than PAL1. Thus, there appears to be a trade-off between the amount of HM and EM for maintenance of fixation stability. This may be due to a poor neural coordination between the head and the eye, which would result in a disassociation between HM and EM where, for example, the head is held fixed while the eye exhibits instability. In the present study, the decrease in correlation between HM RMS and EM RMS for the poorer performers suggests a reduced ability to provide an appropriate trade off between EM and HM.

### CONCLUSIONS

This study investigated the relationships among the physiological parameters affecting the golf putting stroke under laboratory-simulated psychological pressure conditions. The use of multi-sensor recordings provided valuable information regarding the individual's mental state as reflected in the physiological responses and putting performance under increased psychological pressure. It was shown in the relationships between perceived pressure and EM RMS, HM RMS, and HRV. In addition, there appeared to be a trade off between EM RMS and HM RMS. Thus, the present study showed that the apparently simple task of putting a golf ball masks a complex interplay among psychological, physiological, and neurological control processes that are manifest under pressure conditions.

## SOURCES

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