ABSTRACT

Background: Putting represents one of the most important components of golf. However, associated with it is the ‘yips,’ which is involuntary motions of the body of a presumed psychological and physiological nature that adversely affect performance. Many golfers are afflicted with the yips, especially those with long-term experience in golf. In the current study, selected body movements and physiological functions, as well as perceived stress level, were monitored under conditions that modulated the golfer’s stress level.

Methods: Five young-adult, visually-normal students who were experienced golfers participated in the investigation. Putting was assessed for 6-foot and 3-foot putts, with a reward/penalty system that favored the former but not the latter, to create a sensation of ‘stress’ as would be found in a real golf tournament. Eye, head, and putter movements were assessed objectively, as well as heart and breathing rates. In addition, a 5-point subjective rating scale was used to quantify the perceived level of stress during the test conditions.

Results: Heart rate significantly increased for the stressed 3-foot versus the unstressed 6-foot putts, while breathing rate remained unchanged. Also, eye movement variation increased in three of the five subjects under the more stressful putting condition.

Conclusions: The results suggest that the increased stress level imposed by the different putting conditions was reflected in changes in both physiological and psychological states. It is hypothesized that the yips is produced by the corruption of the central command motor control signal by the avoidance reflex associated with the shorter putts under pressure conditions.

Keywords: breathing rate, eye movements, heart rate, putting, yips

Introduction

Putting, like most athletic movements, is based on muscle memory, attentional focus, and knowledge of the environment. It is one of the most important elements of the golf game. This was demonstrated by statistics compiled by the Professional Golfers Association, which showed that the best players in the world expend approximately 40% of their total strokes in a round on putting. Because putting requires intense concentration and fine motor control, under pressure situations, the physical act of putting may break down.

When experienced golfers have the ‘yips,’ defined as involuntary motions that affect the putting stroke, especially for short putts, they are seen to suffer from severe performance anxiety. This causes some physical symptoms, which lead to unexpected outcomes on the putting green. Some golfers experience jerks and tremors of their muscles, and others find their arms freeze when lining up a putt. These symptoms lead to poor performance on the putting green. In a survey of about 500 professional and amateur golfers, 28% indicated they experienced the yips. Even some of the best golfers in the world find it difficult to avoid this recurring ailment, including both younger and older players. For example, Bernhard Langer had the yips early in his career, whereas Ben Hogan developed it late in his career.

Numerous studies have been conducted to understand the underlying causes of the yips. In their comprehensive review of previous work, Smith et al. characterized the cause of the yips among golfers as being a continuum between focal dystonia and “choking.” Focal dystonia is a movement disorder of neurological origin that causes the muscles to contract and spasm involuntarily while performing a specific task. On the other hand, choking is the deterioration of motor performance due to extreme performance anxiety and distracted attention. In their self-assessment survey of 72 low-handicap golfers manifesting the yips, Smith et al. found that 56% were due to focal dystonia, 20% were due to choking, and 34% were due to a combination of these factors. They noted that the mean age of those manifesting the yips was...
recorded. A scoring system was used that rewarded made putts but penalized missed ones. A survey assessing the subjective perceived level of stress was also conducted. They found that the poorer-performing subjects had a greater correlation between perceived pressure and head movement variability, as well as between perceived pressure and heart rate variability. These individuals also exhibited an inverse relationship between eye and head movement variation. Borkowski et al. concluded that this indicated a greater dysfunction of motor coordination in the poorer-performing individuals.

The aim of the present study was to expand on our earlier study by investigating the difference in selected physiological parameters between non-pressure 6-ft putts and pressure 3-ft putts, thus simulating as much as possible the yips condition. The reason 6-ft putts were used instead of 9-ft putts as in our previous study was that these were easier to make than the 9-ft putts, and hence served as a more reliable reference.

Methods

A. Apparatus

Subjects were tested using a portable artificial green, which mimicked the normal putting green environment. This artificial green had two holes that were 3 and 6 feet from the golfer (Figure 1). It was arranged in a laboratory setting which recorded. A scoring system was used that rewarded made putts but penalized missed ones. A survey assessing the subjective perceived level of stress was also conducted. They found that the poorer-performing subjects had a greater correlation between perceived pressure and head movement variability, as well as between perceived pressure and heart rate variability. These individuals also exhibited an inverse relationship between eye and head movement variation. Borkowski et al. concluded that this indicated a greater dysfunction of motor coordination in the poorer-performing individuals.

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<table>
<thead>
<tr>
<th>Measure of Interest</th>
<th>Significance (p&lt;0.01)</th>
<th>3 Ft Mean Value</th>
<th>6 Ft Mean Value</th>
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<td>HR (beats per min)</td>
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<td>BR (breaths per min)</td>
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<td>RMS Head (cm)</td>
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<tr>
<td>Putt Amplitude (cm)</td>
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<td>45.0</td>
</tr>
</tbody>
</table>

RMS = root mean square, + = significant difference, x = no significant difference.

Figure 1: Artificial putting green showing locations of holes for 6-ft and 3-ft putts. The experimental setup shown is for the 6-ft putt. For the 3-ft putts, the subject moved to the right and lined up with that hole. The accelerometer board was mounted on the putter shaft.
was free of any external forces (e.g., wind) and had minimal noise interference.

The physiological parameters were measured using two different devices: the Rutgers Oculomotor Device (ROD) and the Biopac-MP35 (Goleta, CA) recording hardware. The ROD was used to measure head and eye movements (Figure 2) and putter motion (Figure 1), while the Biopac-MP35 was used to measure breathing and heart rates (Figure 2).

Head and eye movements were assessed with an accelerometer and an infrared eye sensor, respectively, which were both mounted on a visor (Figure 2). The head accelerometer had a resolution of 0.5 cm and a range of ± 25 cm, while the eye sensor had a resolution of 15 min arc, a linear range of ± 25º, and a bandwidth of 200 Hz.

Putter movements were measured using an accelerometer in a circuit board which was mounted on the putter (Figure 1). It had a resolution of 0.25 cm and a range of ± 45 cm as measured by its linear displacement on the artificial putting surface.

The eye, head, and putter motion signals from the ROD were transmitted wirelessly to a receiver board. The receiver board was connected to a conventional laptop via a USB port. The recorded data were analyzed using Labview C-language software.

The Biopac-MP35 recorded breathing rate and heart rate, as well as the experimenter’s fingertip motion, which was used to mark the beginning of each record. Breathing rate was measured by strategically attaching a small piece of paper in front of a second plethysmogram unit (Figure 2). As the subject breathed, the movement of the paper resulted in the change in the infrared reflected signal of the plethysmogram, which was recorded by the Biopac system. Heart rate was measured using a second plethysmogram unit, which was attached to the earlobe of the subject (Figure 2). The Biopac system recorded its data continuously, whereas the ROD had a fixed 3-second record length. Therefore, a log book was used to record the start and stop timings of the putts and the corresponding sample times from the Biopac system.

Moreover, to synchronize the ROD with the Biopac signals, the experimenter wore a third plethysmogram unit on the index finger. As the experimenter clicked the mouse to initiate the experimental session, the pressure on the plethysmogram created a sharp spike in the Biopac data recording. This spike was used to mark the beginning of each putt.

B. Subjects and Procedure

The subjects were five avid young-adult golfers (ages 19 to 21 years), all of whom played more than twice a week during the golfing season. They were tested over four sessions consisting of three sets per session and six putts per set (five 6-ft putts and one 3-ft putt), thus resulting in a total of 72 putts per subject. To simulate the pressure associated with the yips, a scoring system along with a promised prize (a dinner gift certificate) was implemented. The scoring system assigned one point to each 6-ft putt made. Moreover, if the 3-ft putt was missed following the five attempted 6-ft putts, then all of the previous points accumulated from the 6-ft putts were lost. At the end of a session, each golfer reported the amount of subjective psychological pressure felt, on a scale of 1-5, with 1 being no pressure and 5 being extreme pressure.

Results

A. Data Records

Dynamic recordings are presented in the next two figures. Typical records for eye, head, and putter motions are shown in Figure 3, while those for heart rate, breathing rate, and record-initiation pulse are shown in Figure 4.

B. Statistical Analysis

The mean parameter values for the 6-ft putts and the immediately-following 3-ft putt were matched and compared (Table 1). The putt amplitude measure was based on the difference between the value at the end of the backstroke (indicated by the bottom of the first dip in Figure 3, top left graph) and peak value at the point of impact (indicated by the sudden reversal in the trace, followed by reverberations, due to impact with the ball, in Figure 3, top left graph). Significant differences (t-test) were observed in heart rate, head movements, and putt amplitudes. Heart rate was greater for the 3-ft putts, whereas head movements and putt amplitude were greater for the 6-ft putts. These differences can also be seen in the scatter subplots in Figure 5. In these scatter subplots, the physiological parameter [heart rate, root mean square (RMS) head movement, or putt amplitude] data values for the averaged 6-ft putts and the corresponding 3-ft putt were compared to the 1:1 line, so that data falling on the line would represent no difference between 3- and 6-ft putts.

Figure 6 shows the difference in the ratio of eye RMS (3-ft/6-ft) between the highest and lowest subjective stress levels for each of the three subjects who reported changes in stress level. The other two subjects did not report a change.
Discussion

Short putts in golf are notorious for inducing increased stress.\(^4\) The yips is hypothesized to manifest itself through focal dystonia, a neurological condition that causes involuntary muscular contractions due to an overlap of discrete subsets of the sensorimotor cortex. Its presence can result in abnormal jerks and tremors in an athlete’s motion.\(^4\) Our study used two different putting distances, with a steep penalty associated with missing the shorter 3-ft putts, to simulate this phenomenon. We also quantified the physiological changes that accompanied the attempted putts. The higher heart rate found for the 3-ft vs. 6-ft putts indicates that subjects reacted to the increased psychological pressure. In some cases, the heart rate changes occurred before the putting motion, thus suggesting that subtle changes in physiological state may have begun even before the subjects were aware of those changes.

Under the relatively non-extreme experimental conditions of this study, head movements exhibited larger RMS values for 6-ft versus 3-ft putts, as would be expected of general larger gross motor movements. It might be the case that in actual course-playing conditions, the golfer suffering from the yips may jerk his head significantly for the 3-ft putts, but not for the 6-ft putts. On the other hand, the more subtle eye movements did exhibit the effect of stress in our study, where the eye RMS was greater for the 3-ft than the 6-ft putts.

When there was an awareness of perceived stress, it was also revealed by increased physiological variations, such as eye RMS. However, interpreting the results based on the stress...
that each subject reported was not consistent for all subjects, because the assessed values on the pressure scale are highly subjective. It provided the possibility of a subject either exaggerating or underestimating the amount of stress felt at the end of each session. In the present study, most subjects reported increased pressure values between 2 and 4 (over a range of 1 to 5). This possible subjective bias effect was accounted for, via normalization, by taking the difference between parameter values for the individual’s high and low subjective assessed values.

The present study used a tiered penalty system to induce stress, and it demonstrated that increased eye movements and heart rate accompanied raised penalties and increased perceived pressure. These are consistent with the results of previous experimental findings. Borkowski et al. also found changes in breathing rate with perceived stress which were not found in this study. This may be due to the differences in experimental paradigm, as they did not include the shorter 3-ft putts.

There have been various proposed mechanisms for the yips. Uitti et al. characterized dystonia as an involuntary posturing superimposed on a voluntary movement. Lewis and Linder considered choking, which is related to the yips, as an extreme manifestation of performance anxiety, resulting from self-focused or distracted attention. Davis et al. suggested that fear of failure underlies the development of the yips. Based on these proposed mechanisms and our present findings, we hypothesize that the origin of the yips is the corruption of the central command under pressure conditions, so that the reflex to withdraw from a perceived threat interferes with the motor command for executing the normal putting stroke.

Some limitations of the experimental design were due to the laboratory environment and equipment used. Inducing stress on the subjects proved to be difficult because they were not tested under actual normal or tournament playing conditions. The expectation is that in real game situations, stress levels will be even more pronounced, which may be manifested in greater increases in eye movement, heart rate, and breathing rate, as well as subjective stress levels.

Future studies in this area should aim to obtain physiological measurements under more dramatic conditions that better simulate the pressure associated with the yips. This might include a substantial award and testing in front of a large peer-based audience. Another possibility is for the individual competitors to use their own money in a competitive environment. A third scenario is to monitor heart rate, breathing rate, and eye movements wirelessly under actual play conditions. These and other venues may be explored in the effort to understand better the physiological mechanisms underlying the yips.

**Conclusions**

This study investigated differences in physiological parameters between non-pressure 6-ft putts and pressure 3-ft putts. Heart rate, head movements, and eye movements were quantitatively assessed to determine their correlation with subjective pressure induced by a reward/penalty paradigm. Although the pressure induced in the present study was lower than what would be typically felt during an actual golfing round, physiological changes still occurred. It was found that heart rate was greater for the stressed 3-ft than the unstressed 6-ft putts, and that eye movement variations increased with perceived stress level. Based on our results and previous findings, it is hypothesized that the occurrence of the yips may be due to the central nervous system associating the shorter putts with an avoidance reflex. Although there is much more to explore, the present study was able to shed light on some of the many psychological and physiological intricacies that are associated with subjective pressure and the yips’ phenomenon.

**References**