Examining the Time Course of Attention During Golf Putts of Two Different Lengths in Experienced Golfers

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Abstract:

A dual-task paradigm was used to investigate the time course of attention during putting relative to task difficulty (6 ft vs. 12 ft). Putting performance and reaction time (RT) were measured while 20 experienced golfers responded verbally to an auditory tone presented at 3 probe positions (PP) during the putt: backswing initiation (PP1), backswing peak (PP2), and before impact (PP3). There were 2 significant main effects for putting performance: task difficulty (better performance on the short putt) and probe position (worse performance at PP1 vs. PP3 and Catch Trials). During the short putt, there were no significant differences in RT as a function of PP, indicating that attentional demand remained constant throughout the stroke. RT of the long putt was significantly longer than the short putt, indicating that the long putt required greater attention. Skill level was examined as a potential moderating factor but did not significantly moderate results.

Keywords: Putting | Golf | Putting performance | Golf performance

Article:

Attention is important to consider in sport psychology because it is implicated in everything that one does, including perception, cognition, and action (Abernethy, Maxwell, Masters, Van Der Kamp, & Jackson, 2007; Styles, 2006). The capacity theory of attention implies that an individual has a fixed, limited pool of attentional resources that may be allocated freely and in varying degrees between multiple tasks (Kahneman, 1973). According to this theory, multiple tasks require more attentional resources than one task, and difficult tasks require more attentional resources than simple tasks. Because this pool of resources is limited, interference occurs any time a person performs multiple tasks regardless of the sensory modalities that are being utilized (i.e., whether a stimulus is primarily auditory, visual, or kinesthetic) and posits that interference depends primarily on the difficulty level and subsequent demands of the tasks that are being performed (Abernethy, 2001). If the maximum capacity of attentional resources is exceeded, performance can fail altogether.

Within the capacity theory of attention, researchers have identified two forms of attentional processing that are described as unconscious (automatic) processing and conscious (controlled) processing. Automatic processing occurs rapidly, is parallel in nature (i.e., several tasks may be performed at once), and is carried out involuntarily. In contrast, controlled processing is deliberate and serial in nature and can be used only to deal with a limited amount of information at a particular time (Schmidt & Wrisberg, 2008). In sport, performance may require a combination of both controlled skills and automatic skills. As physical skills are practiced over time, they become more reliant on automatic processing and subsequently require less attention (Wulf, 2007).

Under a dual-task paradigm, which is commonly used to assess attentional resources during task performance, a participant is asked to perform a primary task (e.g., the sport skill) while also performing a less demanding secondary task (e.g., a reaction time [RT] task) that acts as the mechanism through which attentional demand is assessed on the primary task (Abernethy, 1988). Researchers have examined the time course of attention during performance of a variety of sport skills including tennis and volleyball serves (Castiello & Umilta, 1988), pistol-shooting (Rose & Christina, 1990), horseshoe pitching (Prezuhy & Etnier, 2001), basketball free-throw shooting (Price, Gill, Etnier, & Kornatz, 2009), rugby passing (Gabbett & Abernethy, 2011, 2012), and soccer penalty kicks (Carr, Etnier, & Fisher, 2013). In this context, the time course of attention refers to fluctuations in the distribution of attentional resources over time from the initiation to the conclusion of a specific movement (Sibley & Etnier, 2004).

Although research on the time course of attention in sport activities is currently limited, the existing evidence implies two broad attentional patterns for sport activities: one for the situation in which the athlete receives and redirects a moving object and one for the situation in which the athlete propels an object. When an athlete is about to receive and redirect a moving object, researchers have concluded that attentional demand is highest when the athlete is attempting to determine information such as its direction and velocity. This information is acquired at varying time points as the object approaches. For example, Castiello and Umilta (1988) found that when receiving a volleyball serve, attention was greatest just before the ball was contacted by the receiver. In addition, Castiello and Umilta found that when tennis players received a serve, attentional demand was greatest when the ball contacted the ground just prior to contact. The authors concluded that these time points represent critical moments for collecting perceptual information necessary for successful performance. In a study of the time course of attention during a volleyball set, Sibley and Etnier (2004) found that attentional demand was greatest at the beginning of the ball flight and during the last portion of the ball flight. The authors concluded that attention was high at these points because participants were making judgments about the type of set to be made (beginning) and were processing proprioceptive information to make accuracy adjustments before contact (last portion). As capacity theory would imply, these aspects of the movement required higher levels of attention due to increased task demands.

Researchers have also explored attentional demands when an athlete is required to propel a stationary object toward a target. In a study of precision pistol-shooting as a function of skill level, Rose and Christina (1990) found that the level of attention directed toward the primary task of shooting increased linearly until the point immediately prior to the shot and that patterns of attention were similar across skill levels. Rather than examining attentional demands relative to differences in skill, Prezuhy and Etnier (2001) examined differences relative to task difficulty. Experienced horseshoe pitchers were asked to perform horseshoe throws under dual-task conditions at two levels of task difficulty by manipulating the height of the stake. Results showed that attentional demands were moderate at the initiation of the throw, low during the backswing, and high just before release. Furthermore, attentional demands were higher during the difficult task condition when compared with the easy task condition. Gabbett and Abernethy (2012) have found similar results with regard to attentional demand and task complexity. A group of elite rugby players were assessed on their ability to draw in a defender and successfully execute a pass in either a 2-on-1 (less complex condition) or 3-on-2 situation (more complex condition). Results indicated that performance was worse and attentional demands were greatest in the situation of increased complexity. In a similarly designed study that tested the effects of task difficulty and skill level on the attentional demands of a rugby pass, Gabbett, Wake, and Abernethy (2011) found that although there were no performance differences in passing performance between high-skilled and lesser skilled players, the high-skilled players experienced less of a performance decrement and lower levels of attentional demand than lesser skilled players when performing under dual-task conditions.

Other sport-related tasks such as basketball free throw shooting and soccer penalty kicks have also been examined in previous research. With regards to free throw shooting, Price, Gill, Etnier, and Kornatz (2009) concluded that the greatest attentional demand was evident during the upward motion of the ball just before release. In Carr et al. (2013), experienced soccer players performed a penalty kick under dual-task conditions using both their dominant and nondominant foot. Results indicated that attentional demand was the highest at the initiation of the kick (i.e., the first step). These results showed an attentional pattern similar to those of Prezuhy and Etnier (2001) in that attentional demand was lowest at the midpoint of the sport skill, but in Carr et al., demand was the highest at the initiation of the approach rather than just prior to impact of the ball. Of interest, results also showed that RT was slower while kicking with the dominant foot rather than the nondominant foot, implying that experienced soccer players are engaging in more complex planning processes with the dominant foot. Overall, these studies imply that attentional demands are high at the beginning of the movement and immediately before propulsion. According to capacity theory, task demands are increased at these points because the athlete is attempting to process important sensory information at the initiation of the task and when making last-second adjustments to produce a successful outcome.

Currently, the time course of attention has not been examined during a golf putt. This is an intriguing sport skill to examine because although a golf putt requires propulsion of a stationary object (the ball) toward a target (the cup), the use of the golf club to propel the ball may mean that this sport skill has a different pattern of attentional demands than do the aforementioned sport skills in which the stationary object is propelled directly by the participant (e.g., horseshoe pitching, rugby pass, basketball free throw, soccer penalty kick). There are a number of studies that have used golf to study the effects of attentional focus on performance (Beilock, Carr, MacMahon, & Starkes, 2002; Maxwell, Masters, Kerr, & Weedon, 2001; Perkins-Ceccato, Passmore, & Lee, 2003). Some of these studies have incorporated a dual-task condition as a means of directing the performer's attention externally so that the effects on performance could be observed (Beilock et al., 2002; Maxwell et al., 2001), but changes in attentional demand during performance of the golf putt have not been assessed.

Therefore, the purpose of this study was to use a dual-task paradigm to determine the time course of attention during a golf putt in a group of experienced golfers. In this study, the effect of task difficulty on attentional demands was examined by asking participants to perform golf putts of two different lengths. Understanding the attentional demands of this type of motor skill and examining potential differences as a function of task difficulty extends previous psychology and motor control literature concerning the time course of attention in sport. As mentioned, the golf putt may exhibit different attentional requirements than have previously been observed as a result of the need to control the putter to strike and propel the golf ball with accuracy. The findings of this study may help improve putting performance and training techniques by identifying patterns of attentional demand during a putt and contributing to a better understanding of attentional processes on putts of different lengths.

Because previous research concerning attention and sport activities has not examined tasks that require the performer to strike a stationary object with an implement, it is difficult to predict where attentional demand will be the highest for this skill. However, due to the experienced nature of the participants in this study, it is expected that automatic processes will primarily take over during the performance of the primary task. In addition to the improvements in physical skills that occur with practice and experience, improvements in the use of attentional skills are also evident as a result of training. Individuals who have become experienced through practice require less attention to perform both cognitive and motor aspects of a task because these aspects of task performance have become automatic (Styles, 2006). Thus, the first hypothesis of this study is that the highest attentional demand will occur at the initiation of the stroke as motor programming is finalized. Based on the early results of Posner and Keele (1969) and the results of Prezuhy and Etnier (2001) and Gabbett and Abernethy (2012), the second hypothesis is that the overall attentional demand of the more difficult putt (longer putt) will be greater than that of the less difficult putt (shorter putt). This expectation regarding task difficulty is based upon Fitts' Law, which defines the index of movement difficulty as a function of movement amplitude and target width (Schmidt & Wrisberg, 2008). The index of difficulty increases as movement amplitude increases and/or target width decreases. Therefore, the longer putt was considered more difficult than the shorter putt because of the increased movement amplitude required to propel the ball to the same target.

Finally, although all participants in this study were considered to be experienced golfers, there was a wide range of handicaps present. As a result of this range, the participants were divided into two groups based on handicap in order to determine if any differences exist in task performance or attentional demand as a function of skill level within experienced golfers. As Wulf (2007) implied, performers who demonstrate higher levels of expertise tend to perform using more automatic processes than less-experienced counterparts. These differences could have implications for both performance and attentional demand. As a result, skill level was examined as a potential moderator.

METHOD

Participants

To determine the appropriate number of participants, a power analysis was conducted. Data from Sibley and Etnier (2004) showed an effect for the task difficulty by probe position interaction, $F(3, 57) = 3.03$, $p <.05$, partial $\eta 2 = 0.14$. Based on a power analysis from these data, 18 participants would result in sufficient statistical power ($1-\beta = 0.80$) to detect a significant interaction between probe position and task complexity.

Participants consisted of 20 right-handed male golfers ranging in age from 20 to 71 years ($M = 35.85$ years, $SD = 17.78$). All participants had at least 2 years of high school varsity golf experience (e.g., Beilock et al., 2002) or a self-reported handicap of 15 or better. Regardless of experience level, all participants were asked to estimate their current handicap. This number was based on the average number of strokes over or under par that they typically shoot. Participants' handicaps ranged from 16 to +2.4 strokes ($M = 9.31$, $SD = 5.83$ strokes) with a 16 indicating that they typically shoot 16 strokes over par and a +2.4 indicating that they typically shoot approximately two to three strokes under par (e.g., a golfer whose handicap is +2 may shoot 70 but will have two strokes added to his or her score to receive 72). Each participant also reported their cumulative number of years playing golf. The distribution of cumulative number of years playing golf was significantly skewed ($z = 2.35$, $p <.01$), with the range from 9 to 56 years ($Mdn = 15.00$ years). In addition, 10 out of 20 participants had competitive golf experience at the high school level and, out of these 10, three had competitive golf experience at the college level.

Dual Task Paradigm

Performance on each task was first measured independently to establish a baseline for performance prior to both tasks being performed simultaneously. In the present study, the primary task was golf putting and the secondary task was an RT task. The RT task was administered at various probe positions during performance of the golf putt. Slow RTs indicated a large amount of attention being devoted to the primary task, whereas fast RTs indicate a small amount of attention being devoted to the primary task.

Materials

Putting green

A putting green was constructed out of plywood and measured 8 ft wide, 16 ft long, and 4 in. high. A regulation size golf cup (4.25 in.) was placed in the center of the platform width-wise and approximately 36 in. from one end, and the surface was covered with green indoor/outdoor carpet. Two black dots were placed on the carpet to mark the distances of 6 ft and 12 ft from the golf cup. Participants used their own putter and were provided with 12 Titleist Pro V1 golf balls. The auditory stimulus in this study consisted of a brief tone (beep) that was generated by the computer software program Lab View 2010. There were three software programs that were used in conjunction with each of the three probe positions. The appropriate program was chosen prior to each trial based on a sequence of randomly generated numbers, and this sequence was the same for all participants. The software program had to be manually started by the experimenter prior to each trial.

The tone was generated by computer speakers when the putter broke a beam of light emitted by one of two photocells near the putter. The first photocell was used for Probe Position 1 (PP1, initiation of the backswing) and Probe Position 3 (PP3, prior to impact with the golf ball) whereas the second photocell was used for Probe Position 2 (PP2, the end of the backswing). Due to the fact that the putter shaft is very thin, a 3 × 5 in. index card was taped to the shaft of the putter so that the photocells would work consistently. The index card provided a surface area that was large enough to break the beam of light emitted by the photocell. An Olympus WS-400S Digital Voice Recorder was used to record participants' verbal responses to the auditory stimulus. An Olympus microphone was used in conjunction with the voice recorder and the audio software program Audacity 1.3 was used to analyze participants' verbal responses and acquire RT data.

Procedure

Baseline performance on the primary task

Prior to the start of each session, participants reviewed and signed an informed consent agreement that had been previously approved by the university's institutional review board for research with human subjects and filled out a demographic questionnaire. The experimenter provided instructions to each participant. Participants were then asked to select a piece of paper at random to determine whether they would perform the short putt first or the long putt first for baseline and experimental trials. Baseline performance was established on the primary task (putting) by allowing participants to hit 12 putts. Because the dual task paradigm relies on measures of average performance rather than on measures of variability of performance, performance was scored by manually measuring the distance from the edge of the cup to the center of the golf ball to the nearest quarter inch after each trial. A putt that was made was counted as zero inches. A putt that went off of the putting surface was counted as a performance error and later recalculated by scoring it as three standard deviations from the individual's mean score (Dail & Christina, 2004). The average score of these baseline trials served as a baseline performance score. An average was calculated for the short putt and the long putt separately.

Baseline performance on the secondary task

Participants performed 12 trials in which they verbally responded to an auditory tone by saying the word "ball" as quickly as possible. All 12 of these trials were used to ensure that the equipment was properly recording each response. For the duration of these trials, participants took their putting stance and addressed the golf ball as if they were going to putt, and the experimenter generated the auditory tones by breaking the beam of light being emitted from the photocell from behind a partition so that participants would not be able to see movement and potentially anticipate the auditory tone. The average RT of these baseline trials served as a baseline RT score.

In the next stage of the study, participants performed under dual-task conditions, in which they putted (the primary task) while monitoring the auditory tone and responding verbally as quickly as possible (the secondary task). Participants were instructed to respond to the auditory tone as quickly as possible, but it was emphasized that the primary goal was to make as many putts as possible. Putting performance was measured during the experimental trials using the same methods as in the baseline trials, and separate averages were calculated for short and long putts. Catch trials, in which there was no auditory stimulus during randomly selected dual-task trials, were used to prevent anticipatory effects that might result as participants became accustomed to hearing the auditory tone. The experimenter informed participants that such trials would be randomly included. Because there was no auditory tone during these trials, only putting performance data were collected during catch trials.

Dual-task conditions

Participants were asked to perform a total of 54 experimental trials for data collection at each distance (for a total of 108 experimental trials). Of the 54 trials at each location, 12 trials were presented relative to each of the three probe positions and 18 catch trials were performed. This number of experimental trials was chosen based on previous research on golf putting with experienced golfers that assessed performance over approximately 100 trials (e.g., Beilock et al., 2004; Beilock & Gonso, 2008) and subjective feedback about fatigue from pilot subjects. The number of catch trials was chosen based on the recommendation by Abernethy (1988) that at least 33% of the total experimental trials should be catch trials. The order for the presentation of probe position trials and catch trials on both putts was chosen using a random number generator. The lack of a response to the auditory tone or a response to a catch trial was recorded as a RT error on the data collection sheet.

Once the golfer placed his putter behind the golf ball, the equipment was then activated to generate the auditory tone. The first photocell, which measured PP1 and PP3 remained in the same position for each participant, and the second photocell was adjusted for each participant based on the length of the putting stroke, which varied between individuals, and by putting distance. This action had to be performed at the beginning of the short experimental trials and the long experimental trials. For consistency in the administration of the auditory tone, the photocells were not moved for the remainder of the trials once they were properly placed.

Data Reduction

The auditory software Audacity 1.3 was employed to identify the moment when the auditory tone began and verbal response to the tone began. As in Price et al. (2009), RT was defined as the time from the start of the auditory tone to when the verbal response reached an amplitude of 0.1 dB. Audio files from the digital voice recorder were loaded onto the computer, and audio waveforms were then analyzed in Audacity 1.3 to determine RT. Within the Audacity software program, the envelope editing tool was used to mark the point at which the waveform reached 0.1 dB. By zooming in on the waveform, RT was measured with a resolution of 0.0001 s. The time at which the auditory stimulus began was then subtracted from the time at which the verbal response began in order to achieve a RT for each trial. Of importance, the trial number and probe position remained hidden during data reduction so that the experimenter was blind to probe position when identifying the critical points within the waveforms.

Data Analysis

Skill level

Participants were divided into two different skill-level groups based on their golf handicap. Golfers with a handicap ranging from 10 to 16 made up the high-skill-level group ($n = 10$), and golfers with a handicap ranging from 9 to +2.4 made up the low-skill-level group ($n = 10$). This division was chosen based on the average handicap of the sample ($M = 9.31$). The resultant skill level groups were significantly different in handicap level, $F(1, 18) = 33.76$, $p <.001$, with the low skill-level group having a higher handicap ($M = 13.46$, $SD = 2.66$) than the high skill-level group ($M = 4.23$, $SD = 4.38$). Handicap level was not significantly associated with age ($r =.05$, $p >.05$).

Putting performance

To ensure that primary task performance was maintained from baseline to experimental trials, a task difficulty (short putt, long putt) × skill level (low, high) × trial block (baseline, PP1, PP2, PP3, catch) mixed analysis of variance (ANOVA) was performed. For this analysis, performance (distance from the cup) was the dependent variable. In addition, the number of putting performance errors was counted.

RT

To compare performance at baseline to performance during the dual task, a mixed ANOVA was conducted to test RT data as a function of putting condition (baseline, short putt, long putt) by skill level (low, high). To examine the time course of attention during the dual task, RT data were examined using a task difficulty (short putt, long putt) × skill level (low, high) × Probe Position (PP1, PP2, PP3) mixed ANOVA. RT errors were defined as saying the word “ball” when no auditory tone was present or forgetting to say the word “ball” after the tone. The number of RT errors was counted for each participant.

Tests of sphericity were examined, and Huynh-Feldt adjustments were used to adjust the degrees of freedom when necessary. To describe the nature of significant main effects, Bonferroni post hoc analyses were used. Significant interactions were followed up by describing the nature of the interaction and conducting tests of simple effects. Analyses were conducted using SPSS Version 19 and alpha was set at.05.

RESULTS

Errors

With regards to putting performance, 13 errors were committed across all participants and trials, and no participant committed more than three errors in any block. With regards to RT, 10 errors were committed across all participants and trials, and no participant committed more than three errors. Because of the low level of errors committed, they were not examined further.

Putting Performance

A 2 (task difficulty) × 2 (skill level) × 5 (trial block) ANOVA for putting performance indicated that there was a main effect for performance based on task difficulty, $F(1, 18) = 19.425$, $p = .000$, partial $\eta 2 = 0.52$, such that performance was better on the short putt ($M = 3.67$, $SD = 6.86$) than the long putt ($M = 6.01$, $SD = 5.61$). After a Huynh-Feldt adjustment, results indicated a significant main effect for trial block, $F(2.99, 53.85) = 4.81$, $p = .005$, partial $\eta 2 = 0.21$. A post hoc analysis indicated that performance was significantly worse when the auditory stimulus was administered at PP1 ($M = 5.73$, $SD = 3.41$) than when it was administered at PP3 ($M = 4.10$, $SD = 2.87$) or when it was a catch trial ($M = 3.90$, $SD = 2.44$). However, baseline performance ($M = 5.98$, $SD = 3.60$) and performance when the auditory stimulus was administered at PP2 ($M = 4.51$, $SD = 2.92$) were not significantly different from any other trial blocks. The main effect for skill level was not statistically significant, $F(1, 18) = 1.64$, $p > .05$, partial $\eta 2 = 0.08$. The interactions for task difficulty by skill level, $F(1, 18) = 3.22$, $p > .05$, partial $\eta 2 = 0.15$; trial block by skill level, $F(2.99, 53.85) = 1.00$, $p > .05$, partial $\eta 2 = 0.05$; and task difficulty by skill level by trial block, $F(2.98, 53.62) = .04$, $p > .05$, partial $\eta 2 = 0.002$, were nonsignificant. The interaction for task difficulty by trial block, $F(2.98, 53.62) = 3.96$, $p = .013$, partial $\eta 2 = 0.18$, was significant. A post hoc analysis of the data indicated no main effect for trial block, $F(4, 76) = .399$, $p > .05$, for the short putt but a significant main effect for trial block, $F(2.59, 49.17) = 7.17$, $p = .001$, for the long putt. The main effect for trial block indicated that performance was significantly better for catch trials ($M = 4.41$, $SD = 2.59$) and when the probe was administered at PP3 ($M = 5.01$, $SD = 2.91$) as compared to baseline trials ($M = 8.17$, $SD = 5.21$) and when the probe was administered at PP1 ($M = 7.59$, $SD = 3.84$). Performance when the probe was administered at PP2 was not significantly different from any other trial block ($p > .05$; see Figure 1). See Table 1 for a summary of reaction times for each condition.

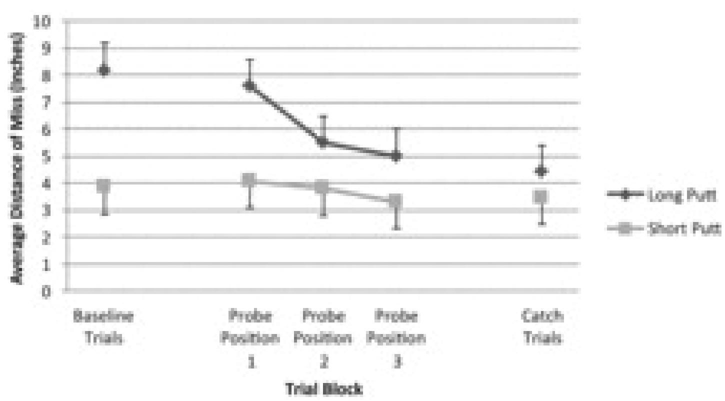

Figure 1 Mean performance by task difficulty and trial block. Note. Standard error bars are shown. Performance was significantly worse ($p < .05$) for the long putt than the short putt and when the auditory signal was administered at PP1 as compared to PP3 or the catch trials.

Table 1 A Comparison of Reaction Times for Each Condition

Condition	**M (s)**	**SD**
Baseline	0.319	0.060

Table 1 A Comparison of Reaction Times for Each Condition

Condition	**M (s)**	**SD**
Short putt overall	0.391	0.112
Long putt overall	0.424	0.133
PP 1	0.403	0.137
PP 2	0.403	0.107
PP 3	0.417	0.127
Short PP1	0.383	0.116
Short PP2	0.394	0.100
Short PP3	0.397	0.119
Long PP1	0.422	0.152
Long PP2	0.413	0.113
Long PP3	0.436	0.132

Note. PP = probe position.

Table 1 A Comparison of Reaction Times for Each Condition

RT

Differences in RT across the three conditions (baseline, short putt, long putt) were assessed. After making the required Huynh-Feldt adjustment to the degrees of freedom, results indicated that there was a statistically significant difference in RT as a function of condition, $F(1.41, 25.38) = 26.02$, $p <.001$, partial $\eta2 = 0.59$, such that RT was significantly different across all periods (baseline: $M = 319$ ms, $SD = 0.03$; short putt: $M = 392$ ms, $SD = 0.06$; long putt: $M = 423$ ms, $SD = 0.08$;). Neither the skill level, $F(1,18) = 0.62$, nor the condition × skill level, $F(1.41, 25.38) = 0.30$, effects were statistically significant. See Table 2 for a summary of putting performance for each condition.

Table 2 A Comparison of Putting Performance for Each Condition

Condition	**M (in.)**	**SD**
Short baseline	3.52	3.60
Short putt overall	3.64	7.99
Long baseline	5.93	4.62
Long putt overall	5.49	9.09
PP 1 overall	5.83	10.07
PP 2 overall	4.64	9.16
PP 3 overall	4.16	7.51
Catch overall	3.94	7.72
Short PP 1	4.07	8.71
Short PP 2	3.79	8.67
Short PP 3	3.32	7.20
Short catch	3.47	7.52
Long PP 1	7.59	11.01
Long PP 2	5.48	9.56
Long PP 3	5.00	7.72
Long catch	4.41	7.91

Note. PP = probe position; catch = catch trials.

Table 2 A Comparison of Putting Performance for Each Condition

For putting trials performed under the dual task condition, a 2 (task difficulty) × 2 (skill level) × 3 (probe position) ANOVA for RT indicated that there was a main effect for RT based on task difficulty, $F(1, 18) = 12.35$, $p = .002$, partial $\eta2 = 0.41$. Overall RT was significantly longer for the long putt condition ($M = 0.42$, $SD = 0.13$) when compared with the short putt condition ($M = 0.392$, $SD = 0.110$; see Figure 2). Neither the main effect for probe position, $F(1.63, 29.27) = 0.85$, $p > .05$, partial $\eta2 = 0.05$, nor the main effect for skill level, $F(1, 18) = 0.13$, $p > .05$, partial $\eta2 = 0.01$, were statistically significant. The interactions of task difficulty by skill level, $F(1, 18) = 0.07$, $p > .05$, partial $\eta2 = 0.00$; probe position by skill level, $F(1.63, 29.27) = 0.67$, $p > .05$, partial $\eta2 = 0.04$; task difficulty by probe position, $F(2, 36) = 1.12$, $p > .05$, partial $\eta2 = 0.06$; and task difficulty by skill level by probe position, $F(2, 36) = 1.49$, $p > .05$, partial $\eta2 = 0.08$, were nonsignificant. See Table 3 for a summary of putting performance and reaction times by handicap.

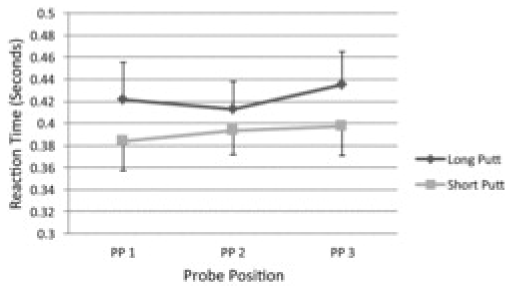

Figure 2 Reaction time by probe position and task difficulty. Note. Standard error bars are shown. Reaction time was significantly slower ($p < .05$) during the long putt than during the short putt.

Table 3 A Comparison of Putting Performance and Reaction Times by Handicap

	Performance		Reaction time	
PP	**M (s)**	**SD**	**M (in.)**	**SD**
High handicap				
Short PP 1	4.53	4.72	0.382	0.088
Short PP 2	4.62	4.11	0.391	0.080
Short PP 3	3.42	3.82	0.390	0.040
Short catch	3.42	3.63	N/A	N/A
Long PP 1	9.05	3.23	0.420	0.134
Long PP 2	6.96	2.87	0.409	0.103
Long PP 3	5.98	2.98	0.410	0.050
Long catch	5.26	2.29	N/A	N/A
Low handicap				
Short PP 1	3.51	3.10	0.391	0.090
Short PP 2	2.78	2.76	0.400	0.072
Short PP 3	3.19	3.55	0.398	0.060
Short catch	3.63	2.51	N/A	N/A
Long PP 1	5.80	3.92	0.420	0.090
Long PP 2	3.67	2.76	0.411	0.082
Long PP 3	3.82	2.48	0.458	0.089
Long catch	3.37	2.70	N/A	N/A

Note. PP = probe position; catch = catch trials.

DISCUSSION

There was a main effect of task difficulty on putting performance such that performance was worse on the long putt than the short putt. This was anticipated as the increased distance of the putt was intended to make the long putt more difficult than the short putt. These results are in line with those of Gabbett and Abernethy (2012) regarding task difficulty and provide evidence that a 12-ft putt is sufficiently more difficult than a 6-ft putt to elicit performance differences in experienced golfers. There was also a main effect for probe position such that putting performance was worse at PP1 when compared with PP2, PP3, and catch trials, and there was a significant interaction between task difficulty and trial block, indicating that differences in putting performance as a function of the timing of the probe were significantly more impactful during the long putt as compared to the short putt. Based on the capacity theory of attention, these findings imply that the attentional requirements of the dual-task condition exceeded the threshold that was necessary to maintain a consistent level of performance across probe positions. These results were not anticipated and limit our ability to draw conclusions regarding the implications of the RT data relative to attentional demands. Because primary task performance was not maintained when the auditory stimulus was administered at PP1, some researchers argue that attentional demand cannot be accurately assessed because it is likely that participants either reprioritized the primary and secondary task or found the putt to be too difficult to maintain a consistent level of performance while also attempting to respond to the RT probe administered early in the putting motion (Abernethy, 1988; Rolfe, 1971). However, other authors (e.g., Chiles, 1982) imply that such a comprehensive exclusion may be too restrictive because valuable information about primary and secondary task interactions can still be drawn.

If this latter interpretation is entertained, then the performance data and the RT data can be examined to make some conclusions regarding attentional demands of a putting task. As such, the RT data did not support the first hypothesis of this study, which implied that attentional demand would be the highest at the initiation of the stroke. In contrast, attentional demand was consistent throughout the putting stroke. In support of the second hypothesis of this study, there was a main effect for difficulty level on RT. RT was significantly longer for both the short putt and the long putt when compared with baseline performance, implying that the putting task was attentionally demanding for participants. In addition, RT was significantly slower for the long putt when compared with the short putt, implying that the long putt required greater attentional resources. This finding is in line with previous research that has examined the effects of task difficulty on attentional demand (Gabbett & Abernethy, 2012; Prezuhy & Etnier, 2001). This result is interesting because the mechanics of the putting stroke remain identical from the short putt to the long putt, whereas only one parameter—movement amplitude—changed.

Performance suffered during the long putt when participants were asked to respond to the RT probe administered early in the swing, but this decrement was not evident for the short putt. Beilock et al. (2002) implies that dual-task conditions produce an improvement in putting performance among experienced golfers because they enhance the participant's use of automatic processing. However, the results of the present study imply that the auditory tone used in the dual-task paradigm may hurt performance depending on its timing and the difficulty of the putt.

At PP1 (initiation), performance on the long putt was significantly worse than performance at other probe positions and catch trials that featured no auditory tone. This implies that even skilled golfers do not deal well with attentional distractions that occur early in a more difficult putt, whereas increased attentional loading later in the stroke does not have such negative consequences for performance. This finding has implications for teaching golfers to manage distractions during a putt to help maintain their performance levels. In a sport such as golf, in which the players have lengthy amounts of time between shots, players can benefit from having strategies to focus and refocus their attention, especially after a long pause or a poor shot. Using an auditory tone as a form of distraction early in a putt would be an excellent opportunity for applied practitioners to work with golfers on refocusing strategies, which could then be applied to other shots such as the full swing. Such drills could also help golfers prepare for instances in competition in which they may need to stop their swing due to distraction and restart their preshot routine.

These results could also have implications for coaches who are training novice golfers to improve their putting. If experienced performers utilize a consistent level of attentional resources throughout the stroke, this implies that all parts of the stroke are important for successful performance and deserve equal emphasis. In addition, if experienced golfers' attentional capacity can be exceeded via secondary task loading, it is reasonable to assume that novice golfers will be more susceptible to such issues. As a result, coaches should carefully manage the amount of information being presented and the type of training to ensure that novices' resources are not overloaded.

Potential differences in skill level were examined based on the broad range of handicap scores in the present study. This analysis created a dichotomy featuring a highly skilled group and a lesser skilled group. According to Wulf (2007), the higher skilled golfers should be relying on automatic modes of processing to a greater extent than the lesser skilled golfers and, thus, should have lower attentional demands. Of interest, in this study there were no significant differences between the two groups on measures of putting performance or RT, and the two groups showed a similar pattern of attentional demand throughout the putting stroke. These results, however, should be interpreted cautiously, as the two putts used in this study may not have been challenging enough to elicit differences in putting performance between the two groups. For straight putts of 5 or 10 ft, these results imply that experienced golfers across a broad range of handicaps experience similar attentional demands throughout performance of a golf putt rather than experiencing variability in attentional demands while performing a sport skill as has been demonstrated in other sport-related tasks (e.g., Prezuhy & Etnier, 2001; Price et al., 2009; Rose & Christina, 1990; Sibley & Etnier, 2004).

Limitations

Before discussing conclusions and future directions, it is important to identify the limitations of this study. The foremost limitation relates to the fact that the golfers in this study were not able to maintain performance on the primary task while performing the auditory RT task. Because golfers use both hands to putt, it is challenging to identify an appropriate secondary task for measuring attentional fluctuations that does not result in a structural conflict. For example, previous studies such as that by Prezuhy and Etnier (2001) have used handheld devices that require the participant to press a button as part of the secondary task. But in that study, the device was held in the nondominant hand. Given that both hands are used on the putter, it was likely that a manual button press would have interfered with the mechanics of the putting task, and hence this was not a possible method for this study. Results from this study may indicate that an oral response to an auditory stimulus is not the answer. This may be because golfers are conditioned to practice in essentially silent conditions and, hence, an auditory stimulus and an oral response may not be appropriate. Another potential reason for the failure of participants to maintain primary task performance could be their skill level. Whereas the golfers in the present study were experienced, they may not have been skillful and experienced enough to be considered experts. It may be the case that the putts chosen require expert skill level to maintain performance from single-task to dual-task conditions.

The ecological validity of this study could have been impacted by two limitations: the use of an index card to activate the photocells and the use of an artificial putting surface. The photocells used in this study were not sensitive enough to detect the narrow shaft of the putter and an index card had to be attached to the putter shaft in order to compensate for this problem. This technological limitation of the study was accepted as the best course of action due to the fact that the alternative would have forced the experimenter to subjectively determine when the auditory tone should be sounded for each probe position. The photocells were used as an attempt to overcome this limitation of previous studies within this line of research. Last, participants performed inside the controlled environment of a lab and were putting on a carpeted platform that was created specifically for the purposes of this study. Although this design featured a cup rather than a target, it is unknown how the results of this study would transfer to golfers performing the putts on an outdoor green.

Conclusions and Future Directions

The results of this study support past literature that implies that a task that is high in difficulty will result in longer RTs and greater attentional demand when compared with a task that is low in task difficulty. These results are in line with those presented in Prezuhy and Etnier (2001). This study is unique when compared with past literature involving the dual-task paradigm because of the examination of the time course of attention during a putting stroke. Sport-specific studies in past literature have demonstrated declines and peaks in attentional demand throughout a movement. However, the results of this study imply that attentional demand remains consistent throughout the putting stroke, and the initiation of the putting stroke is especially susceptible to auditory distraction and/or additional attentional loading.

Future studies concerning attentional demand and putting should examine differences in task difficulty to ascertain the distance at which a putt becomes too difficult to maintain a consistent level of primary task performance. As described in this study, a 6-ft putt was insufficiently difficult to disrupt primary task performance, whereas a 12-ft putt was difficult enough to disrupt performance. There may be a definitive distance in between this range at which primary task performance begins to suffer. A study such as this one may determine the distance at which experienced golfers of varying skill levels perceive a putt to be consistently makeable versus inconsistently makeable. Such a determination could help understand the mindset of a golfer who alternates between goals of making a short putt and simply getting a long putt close. In addition to further research on putting, future studies should examine the full swing to determine if differences in patterns of attentional demand exist. This information could be valuable for better understanding the nature of attentional disruption and helping golfers train to ignore and recover from distraction.

Notes

Note. PP = probe position.
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