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James Bordieri
Southern Illinois University Carbondale

Mark R. Dixon
Southern Illinois University, mdixon@siu.edu

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BRAIN ACTIVITY OF RECREATIONAL GOLFERS UNDER CONDITIONS OF GAMBLING AND NON-GAMBLING

James Bordieri and Mark R. Dixon
Southern Illinois University

This research examined the behavior and corresponding brain activity of recreational golfers. Experiment 1 examined four recreational golfers' brain activity in the absence of any task demands. Following this resting baseline, participants were then instructed to putt 10 golf balls from six feet without consequences for accuracy. Following a return to baseline, a final condition was then instituted whereby monetary compensation ($20 gift card) was made contingent upon successfully making 8 of 10 putts. As measured by EEG, levels of alpha, beta, and theta waves, increased during the putting task compared to resting states. Monetary gambling enhanced activity for participants. Experiment 2 extended these findings. It used a condition of uncertain monetary contingencies while continuing to produce similar EEG levels as noted in Experiment 1. Finally, it appears that certain activations and suppressions of brain waves may have an impact on putting accuracy, and that they may be altered when gambling for money.

Key words: Golf, biofeedback, sports psychology, putting, brain waves.

Sport psychology is a rapidly growing area of scientific investigation, and applications encompass many professional and amateur sports including football, soccer, tennis, basketball and golf. Research has indicated that performance in golf chipping shots (Pates & Maynard, 2000), approach shots (Brouziyne & Molinaro, 2005) and putting (Short, Bruggeman, Engel, Marback, Wang, Willadsen; & Short, 2002; Taylor & Shaw, 2002) can be enhanced using relaxation and imagery techniques.

A golfer's performance often varies dramatically (Valiante & Stachura, 2005) for a variety of reasons, with anxiety and stress implicated as primary causes (Cunningham, 2000; Cunningham & Ashley, 2002; Hassmen, Koivula, & Hansson, 1998; Nicholls, 2007). In addition to self reports of anxiety and physiological responses in the body, understanding the brain activity of the golfer may provide insight as to why a player's performance may vary dramatically. Previous research has shown that when golfers were asked to visualize their swing while lying in an fMRI brain scanner, those with higher handicaps (less skill) had more total brain activation than golfers with lower handicaps (more skill) (Ross, Tkach, Ruggieri, Lieber, & Lapresto, 2003) and professional golfers (Milton, Small, & Solodkin, 2004). While these studies provide information on brain activity during simulated, imagined swings, the fMRI is not currently possible to use during the actual movements of golf.

While "stress" has been claimed to impact performance, operationally defining what this "stress" is, remains open to debate. In previous research by Bordieri, Bordieri, and Dixon, (2008) it was shown that when a pathological gambler engaged in a golfing simulation under conditions of money or no-money for shot accuracy, this participant's performance suffered upon introduction of the financial contingencies. It was suggested by these authors that "stress" might be defined as poor performance, the product of risk taking when

Address all correspondence to:
Mark R. Dixon
Behavior Analysis and Therapy Program
Rehabilitation Institute
Southern Illinois Carbondale
Carbondale, IL 62901
Email: mdixon@siu.edu

the outcomes of performance are coupled with money. However, poor performance is the outcome of such risk or gambling, it is not the cause of it. It may be possible that entering into such environmental contingencies produces changes within the skin of the gambler, perhaps at a physiological level that is more difficult to examine. Therefore, the purpose of Experiment 1 was to evaluate whether it was possible to measure brain activity of golfers while putting under conditions of gambling and non-gambling contingencies for putt accuracy. Experiment 2 attempted to replicate the findings of Experiment 1 along with introduction of an uncertain monetary contingency arrangement to evaluate potential additional stress such a condition may produce.

EXPERIMENT 1

METHOD

Participants, Apparatus and Setting

Participants in the current study consisted of 2 men and 2 women between the ages of 22 and 26 (M = 24). All participants had prior experience playing golf, yet no participant but had never played competitively in tournaments, for money, or at a college or professional level. None reported a USGA handicap index. None were self-reported pathological gamblers. All sessions were conducted using a DELL Dimension 2500 laptop computer with a 15 inch monitor and an external optical mouse. The laptop computer was interfaced with a ProComp 2.0 multi-channel physiological/biofeedback system, which allowed for the recording of brain activity as measured by electroencephalography (EEG) brain waves. All brain activity was recorded through the use of three electrodes placed on the participants' forehead (active) and cheekbone (referent). Experimental sessions were conducted in a research laboratory at Southern Illinois University and ranged in duration from 15 minutes to 1 hour depending on the participants' progress. Golf putting took place on a 4 foot by 8 foot putting platform surfaced with outdoor carpet and elevated 4 inches off the main laboratory floor. The putting platform contained a regulation size golf hole 1 foot from the far end of the platform. Participants were instructed to select a putter from three available and to attempt to make a six-foot putt. The available putters included 2 standard length (34 and 35 inches) right handed Ping Anser putters and 1 standard length (35 inches) left handed Ping Anser putter.

Procedures

The experiment consisted of four conditions, each with attempted to assess three types brain activity of the participant.

Phase 1. Baseline. During this initial condition, participants were instructed to stand on the golf platform, close their eyes, and try and relax for one minute. The experimenter informed the participant when this time period started and when it terminated. No other demands were presented and no other instructions were given by the experimenter. The purpose of this phase was to evaluate brain activity in the absence of any challenges of either a physical or mental nature.

Phase 2. Golf Putting without gambling. During this second condition, all participants were instructed to putt 10 golf balls, one at a time, from a six-foot distance. No statements were made about putting accuracy. The purpose of this phase was to evaluate shot accuracy and brain activity under golfing conditions of non-gambling.

Phase 3. Baseline. During this third condition, participants were re-exposed to Phase 1 conditions under which they were to close their eyes and relax for 1 minute. The purpose of the re-exposure to baseline was to evaluate if brain activity would return to pre-Phase 2 levels, or if there were residual effects of Phase 2 on activity present in Phase 3.

Phase 4. Golf Putting with gambling. During this final condition, all participants were

again instructed to putt 10 golf balls, as done in Phase 2. However, during Phase 4, the experimenter instructed the participant that if 8 or more of the 10 putts were sunk in the hole, a $20 gift card to a local retailer would be awarded. The purpose of this final phase was to induce a gambling contingency and examine putt accuracy and brain activity under its influence.

Dependent Measures and Observer Reliability

Three types of brain activity; alpha, beta, and theta waves, were recorded. The most common frequencies of EEG activity range from 1 and 40 Hz. Lower numbers indicate lower brain activity and higher numbers indicate greater activity. In addition to brain activity, each participants' putting accuracy was recording during Phases 2 and 4 as a behavioral correlate. A second observer recorded the numbers of putts made by each participant on 100% of all experimental sessions. Interobserver agreement was obtained by calculating the two observers' agreement on numbers of putts made by each participant divided by the two observers' agreement plus disagreement X 100%. Resulting interobserver agreement was 100%. EEG measures were recorded by the computer interface and needed no assessment of observer reliability.

EXPERIMENT 1 RESULTS AND DISCUSSION

Figure 1 displays the three types of brain activity for each participant. The top panel displays the mean theta wave activity that occurred during each of the four phases of the experiment. The middle panel displays the mean beta wave activity, while the bottom panel displays the mean alpha wave. From review of this figure it is clear that for all participants, brain activity was relatively low during Phases 1 and 3 compared with Phases 2 and 4. This suggests that when the participants' were instructed to engage in the behavior of putting the golf ball, all three types of brain activity increased compared to the resting baseline. While the finding that task demands (in this case putting) increases physiological activity is not surprising or novel, it does suggest that brain waves of golfers change very quickly. Such changes can quickly reverse upon allowing the golfer to "rest" for a short period of time. Players that find themselves too aroused or unable to focus might wish to use a relaxation activity such as that presented in Phase 1 and 3 to reduce brain activity and increase concentration.

Player putting accuracy varied widely across the 4 participants with only participant 3 successfully making 8 putts during Phase 4. His data provides additional insight as to what optimal levels of brain activation should be during conditions of stress and non-stress. This participant had the lowest overall levels of theta waves (too high of levels suggests inattention and too much relaxation), and the most minimal change in theta from Phase 2 to Phase 4. In fact Phase 2 and Phase 4 theta levels were almost identical, suggesting that perhaps the money conditions of Phase 4 were not perceived by this participant as much different as the conditions of Phase 2. Other participants' theta levels rose dramatically for Participant 1 and 4 during Phase 4, and although decreased slightly for Participant 2, were still much higher than other participants. In summary, the low theta waves of Participant 3 may have allowed for more concentration and resulting putt accuracy during Phase 4. Alpha and Beta waves produced similar resting-golfing activity patterns, yet no additional within subject patterns that correlated with golf performance were observed.

The conditions of "gambling" that we attempted to instate during Phase 4 of the current experiment may have been mitigated by putting accuracy during the first few initial putts of the required 10. If a participant failed

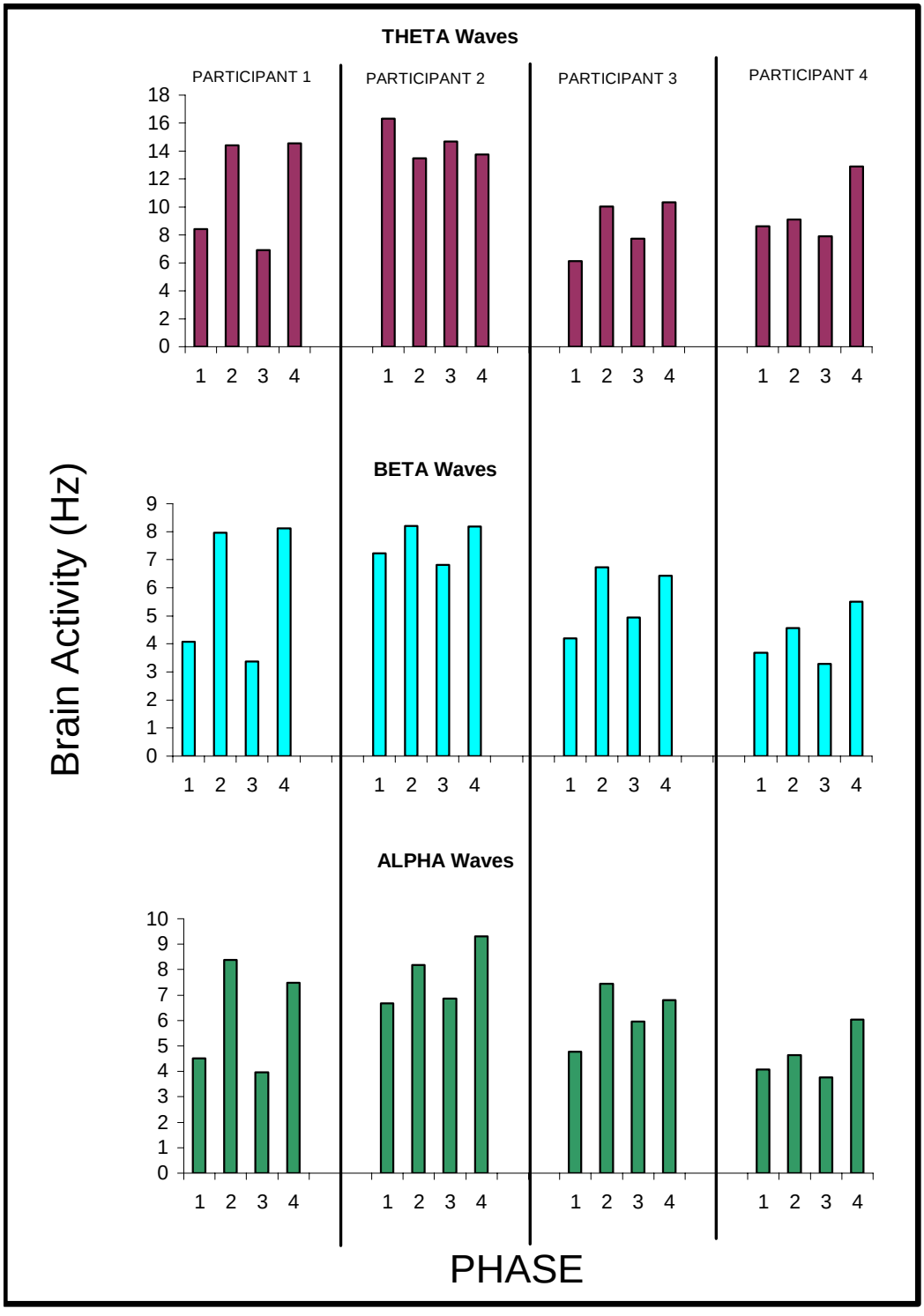

Figure 1. EEG levels of the four participants of Experiment 1.

to make the first three putts during Phase 4, it would be considered impossible to attain the monetary consequences for accurately putting 8 of 10 shots. Thus, for a participant who has missed the first few putts, Phase 4 may have been functional equivalent to Phase 2 at this time and produced minimal changes in brain activity across the two phases. Experiment 2 attempted to sustain participants' actively engaged in the task with potential for monetary compensation during all 10 of Phase 4's putts by exposing participants to conditions of more uncertain gambling outcomes.

EXPERIMENT 2
METHOD

Participants, Apparatus and Setting

Participants in the current study consisted of 1 man and 3 women between the ages of 21 and 29 (M = 25). Of this sample, all participants had prior experience playing golf or miniature golf, yet no participant had a history of playing competitively in tournaments, for money, or at a college or professional level. Similar to Experiment 1, none of the participants reported a USGA handicap index. All other apparatus and environmental arrangements were identical to Experiment 1.

Procedures

Phases 1-3 remained identical to those of Experiment 1. Phase 4 was altered such that instead of participants being required to successfully putt 8 of 10 balls into the cup, the participant was instructed to draw two of ten folded pieces of paper from a small 3in diameter cup. Each piece of paper contained a different number between 1 and 10, which was instructed to the participant to represent the putts that had to be made in order to obtain a 25 dollar gift card to the campus bookstore. Participants were told they should pick two pieces of paper, hand them to the experimenter, and proceed to take their 10 putts. Only after completing the 10 putts would the experimenter inform them of which two "money" putts were required to have been made in order to obtain the gift card.

Dependent Measures and Observer Reliability

The dependent measures of Experiment 2 were identical to those of Experiment 1. Using a second observer on 100% of all putts for all participants, resulting agreement was 100%.

EXPERIMENT 2 RESULTS AND DISCUSSION

Figure 2 displays the three types of brain activity for each participant. The top panel displays the mean theta wave activity that occurred during each of the four phases of the experiment. The middle panel displays the mean beta wave activity, while the bottom panel displays the mean alpha wave. From review of this figure it is clear that for all participants, brain activity was relatively low during Phases 1 and 3 compared with Phases 2 and 4. Replicating the effects of Experiment 1, these data also suggest that putting increases brain activity compared to resting baselines.

Also as in Experiment 1, putting accuracy varied widely across the 4 participants, however in Experiment 2 shot accuracy decreased relatively less than it did in Experiment 1. Table 1 depicts the numbers of putts made by each participant across Phase 2 and Phase 4. As can be observed in this figure, only slight reductions in accuracy occurred, suggesting that perhaps the alterations to Phase 4 during Experiment 2 did not induce the intended additional conditions of stress as they were expected to.

Support for the relatively minimal impact of the altered Phase 4 contingencies is also shown in the resulting theta wave data for each participant. It was expected that Phase 4 theta levels would have been substantially greater than those produced during Phase 2, and this was the case for three of the four par-

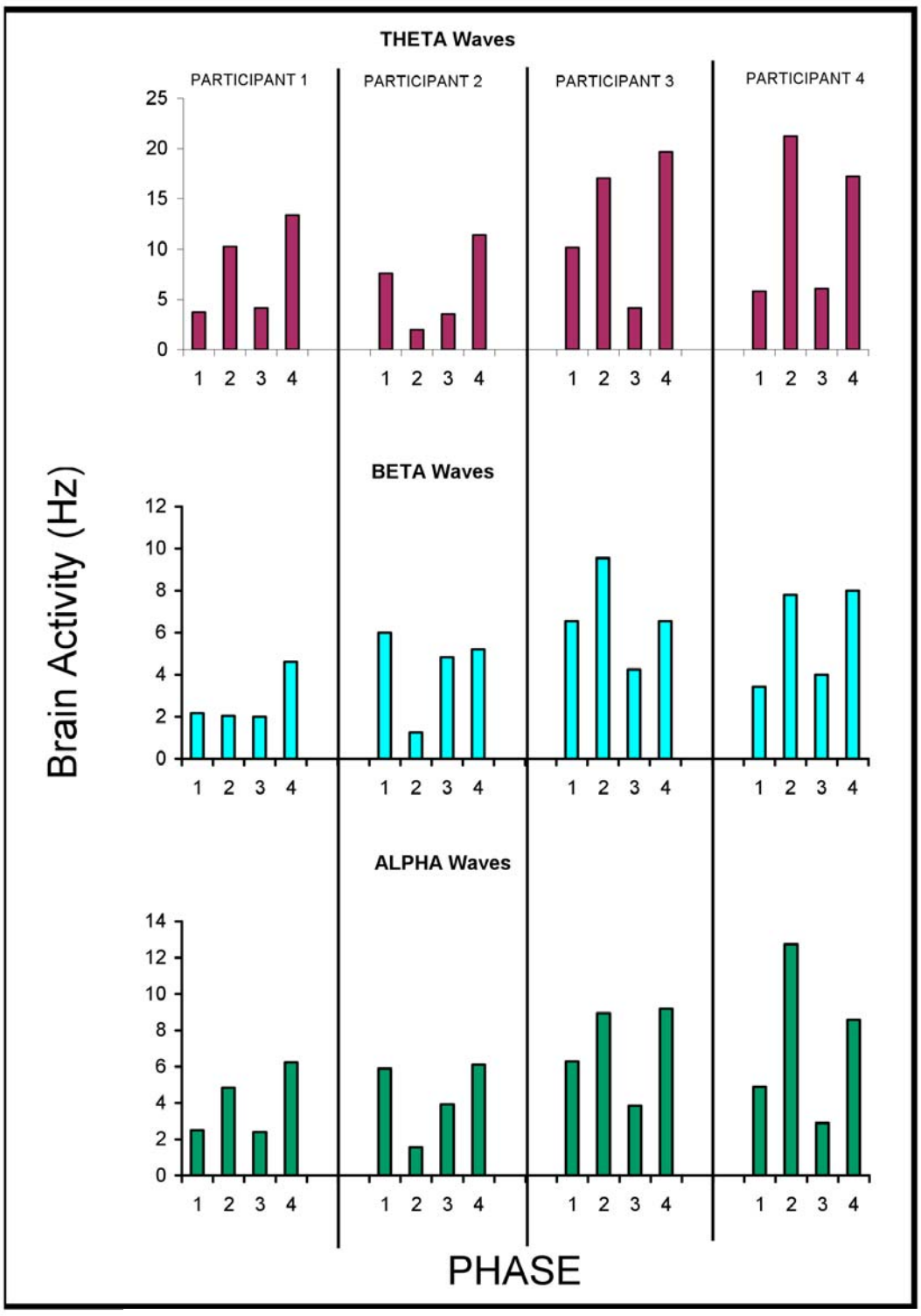

Figure 2. EEG levels of the five participants of Experiment 2.

Table 1. Number of Putts Made (out of 10) for the 5 participants of Experiment 2.

Participant	*Phase 2*	*Phase 4*
1	1	3
2	5	2
3	2	2
4	3	2

ticipants. Only Participant 4 deviated from this pattern. Interestingly, relatively low changes in theta waves were present in Participant 1, across experimental conditions, and this participant improved putting performance from Phases 2 to Phase 4. Similar to that of participant 3 of Experiment 1, the relative theta wave changes were modest in these two participants, suggesting that suppression of theta waves under conditions of stress may be important to sustaining putting performance.

GENERAL DISCUSSION

The data from the two current experiments support prior research by Bordieri, Bordieri, and Dixon (2008) that financial wagers can impact golf performance. These data also extend the previous literature because the exploration of brain activity of golfers during actual playing for actual money is relatively a new endeavor. Unlike prior studies that investigated golfer brain activity outside of the actual game of golf (e.g., McKay et al., 1997; Ross et all., 2003) the present investigation incorporated live capture of brain waves during actual putting for money. The present study suggests that brain waves do in fact change when golfers are placed under conditions of rest and activity. While the data are preliminary, it appears that there may be a relationship between theta wave activity and putting accuracy. Future research should explore relaxation training and incorporate supplemental measures of stress to gain a further understanding of the key to golf optimally. Additionally, future research should utilize much more complex physiological devices, as those used in the present study are considered relatively "low-tech" in today's standards.

Behavior analysts often limit observation to behavior that is readily observed. While physiology is not ignored or considered unimportant to a scientific analysis, it usually is not addressed in behavioral observation. The current data suggest that perhaps behavior analysts should explore physiological assessment as a supplemental measure to explain variability across experimental participants. Using the data obtained through physiological instruments, we may be better prepared to construct interventions that not only impact resulting behavioral performance, but also the underlying physiological contributions to that very performance. Previous research in the field of behavior analysis has incorporated interventions targeted at changing physiological states, and it appears at least plausible that such interventions may be important at improving putting accuracy of golfers.

While the current investigation did in fact yield relatively clear data between resting and active golf EEG levels, it is very possible that any task, be it golf or something else, will produce enhanced EEG levels than resting alone. The avenues which future research should proceed include examining the relative differences between different types of golf-related establishing operations. Our current conditions of gambling and non-gambling were modest and do not necessarily represent the much greater differences between winning and losing thousands of dollars in professional tournaments. Furthermore none of our

participants were considered as pathological gamblers, thus potentially limiting external validity to this population. Another limitation of the present investigation is that it did not utilize professional or highly skilled golfers as experimental participants. Our use of recreational golfers may have limited our understanding of the impact of EEG activity on golf performance, as our golfers were rather poor performers to begin with. Future research may wish to explore the use of more highly skilled participants and compare the obtained findings with those of the present study.

In summary, behavior analysts have much to gain by incorporating physiological measures into the battery of behavioral assessments commonly used. In the realm of professional sports, behavior analysts have made minimal impact, while our objective approach to scientific investigation is significant. Many sporting events incorporate an element of gambling, which entwines the subject areas and can lead to some cross-subject research opportunities. As current technologies become more affordable and more easily adapted for applied research, the behavior of the golfer who plays for money should not be limited to only the study of shot accuracy, but include supplemental measures of underlying physiological arousal.

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