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Exploring attentional mechanisms of self-talk through heart-rate variability in a golf-putting task

By

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Abstract

The aim of this study was to investigate the effects of a strategic self-talk intervention on performance and the psychophysiological state of the participants during a golf putting task through measures of heart-rate variability. Participants were 40 male sport science students with no prior experience in golf, who were randomly assigned to control and experimental groups. The experiment comprised four sessions, baseline assessment, two training sessions, and final assessment. Participants received the same training, with participants of the experimental group training using strategic self-talk and developing personal self-talk plans for the final assessment. Performance and heart rate variability were recorded during the baseline and final assessment. Repeated measures analysis of variance showed that the experimental group showed greater performance improvement from baseline to final assessment compared to the control group. In addition, analysis of the HRV data showed that the experimental group showed higher RMSSD values, indicating higher activation of the parasympathetic nervous system, suggesting a more relaxed and focused state and greater attention during the final assessment. Interestingly, when analyzing heart rate variability by golf putting set by set, it was revealed that in the final assessment, the experimental group exhibited an improvement in RMSSD values during the task, whereas the control group had a decline within the measurement. The findings of the present study provide support for an attentional interpretation of self-talk effectiveness and, in addition, indicate that the detrimental effects of ego depletion induced by the requirements of the task were mitigated by strategic self-talk.

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Introduction

Strategic self-talk interventions have been extensively studied in the context of sport performance and have been found to be effective. Two reviews published in 2011, a systematic review (Tod et al., 2011) and a meta-analysis (Hatzigeorgiadis et al., 2011), provide compelling evidence in support of the efficacy of these interventions. The systematic review revealed that the majority of studies utilizing strategic self-talk reported statistically significant improvements in performance. The meta-analysis, on the other hand, showed a moderate effect size, indicating that strategic self-talk can have a meaningful impact on sport performance. Taken together, these findings suggest that strategic self-talk interventions represent a valuable tool for athletes, coaches, and sport psychologists seeking to optimize athletic performance. Despite strategic self-talk being able to improve performance, it is not always necessarily beneficial (Beilock, Carr, MacMahon, 2002). Specifically, it was suggested that self-talk can be detrimental to performance when not correctly implemented, as it can lead to loss of attention or focusing on irrelevant stimuli (Bell & Hardy, 2009).

Matching hypothesis

In an attempt to investigate the makings of successful strategic self-talk interventions, Theodorakis et al. (2000) proposed the matching hypothesis, according to which the type of self-talk should match with the nature of the task. In particular, it was suggested that for task requiring accuracy and precision, instructional self-talk would be more beneficial, whereas for tasks requiring strength or endurance, motivational self-talk would be more effective. Hatzigeorgiadis et al.'s (2011) meta-analysis provided support for both aspects of the matching hypothesis. Subsequently Hatzigeorgiadis et al. (2014)

expanded the hypothesis considering additional matching factors. Specifically, they argued that instructional self-talk is advantageous for novice learners because it can help them direct their attention towards the appropriate stimuli and guide their execution. In contrast, skilled athletes may benefit more from motivational self-talk, as excessive control over their movements is not necessarily beneficial, given their highly-automated execution. Regarding performance context, Hatzigeorgiadis et al. (2014) postulated that in competitive settings, motivational self-talk would be more valuable as emotional regulation is the primary concern, whereas in training settings instructional self-talk would be more fitting as athletes aim to enhance or master their skills.

Self-talk mechanisms

As self-talk effectiveness has already been extensively documented, academic interest has shifted from, what Hardy et al. (2008) called, ‘’first-generation questions’’, focusing mainly on examining the effectiveness of self-talk, to ‘’second-generation questions’’ referring to the investigation of the mechanisms underlying this effectiveness. These mechanisms refer to the specific process involved in the transition from self-talk cue to improved performance (Latinjak & Hatzigeorgiadis, 2020). Researchers seek to elucidate how self-talk impacts athletes’ cognition, behavior, and psychophysiological state that ultimately leads to enhanced performance.

Galanis et al. (2016) proposed a model that identifies two primary clusters of mechanisms responsible for the effects of self-talk on performance. The first cluster involves motivational mechanisms, including cognitive, affective, and behavioral aspects of motivation. Within this cluster, self-talk can lead to a range of outcomes such as increased self-efficacy, self-confidence, anxiety regulation, effort, and persistence. The second cluster, which is particularly relevant for fine tasks, relates to the attentional interpretation of the facilitative effects of self-talk. This cluster includes various dimensions of attention such as intensity, vigilance, selectivity, decision making, spatial orienting, distractibility, mental effort, and mental fatigue. While these two distinct clusters appear in literature, Hardy et al. (2009) suggested that self-talk can operate through different mechanisms, on different levels, that operate in tandem ultimately leading to the effect of self-talk.

Attentional interpretation

Regarding attentional regulation, Hatzigeorgiadis and Galanis (2017) hypothesized that implementation of strategic instructional self-talk can facilitate the guidance of attention towards the relevant stimuli, shifting attention across different attentional styles, and ultimately optimizing attention performance. In an attempt to directly examine attention, Galanis et al. (2016) conducted a study comprising six experiments and 17 computerized tests, in total, measuring six functions of attention (alertness, vigilance, focused, selective, divided, and spatial). In 16 of the 17 experiments, self-talk groups exhibited higher attentional performance and faster reaction times than the control groups, thus providing direct evidence for self-talk facilitating attentional processes. Although laboratory-based evidence is important in advancing self-talk literature, attention in sports is a complex phenomenon, for this reason the majority of researchers have concentrated on conducting ecologically valid studies, which seek to replicate training or competitive conditions. For indirectly measuring the effects of self-talk on attention, a different line of studies have been conducted focusing on the effectiveness of self-talk on fine task performance under attentionally challenging conditions; in particular, physical fatigue, external distraction, and mitigating ego-depletion.

Physical fatigue

In his investigation of the effects of physical exhaustion on mental performance, Davey (1973) observed that participants exhibited a significant decline in attention and attention capacity on a mental task following a strenuous workload. In the competitive sports field, where physical demands are on the extreme, the need to maintain performance and attention under physical exertion is pronounced. Galanis et al. (2022a) investigated the potential of strategic self-talk to mitigate the decline in attention-related performance during a fine task, specifically free-throw shooting. The study revealed that, despite physical exertion, the self-talk group demonstrated an improvement in performance while the control group exhibited the anticipated decline. On a study focused more directly on attention, Galanis et al. (2022b) investigated the effects of self-talk on a computerized attention test following a near-exhaustion treadmill run, the self-talk group achieved better reaction times and higher percentage of correct responses compared to the control group.

Distraction

Another factor that differentiates lab studies from the complex sport conditions is the existence of irrelevant stimuli and challenging environmental factors. Athletes frequently face situations where they must perform amidst crowds, loud noises, music, extreme temperatures, and other unpredictable circumstances. Distractions can impede performance by diverting attention and reducing processing efficiency ultimately hindering performance (Eysenck, 2015). Galanis et al. (2017), simulated noises similar to the ones heard in sports competitions in both lab and field conditions (computer task and basketball free throw shooting). In both experiments it was found that the self-talk group had higher performance compared to the control. Two potential interpretations we considered to explain these findings; that self-talk helped reducing or blocking the intensity of the distracting stimuli, or enhancing focused attention, thus facilitating the use of more resources. In an experiment were minimizing the intensity of the stimuli wasn't possible, Wallace et al. (2017) found that self-talk helped participants to improve their decision-making under heat conditions, improving both reaction time and accuracy of response.

Ego depletion

Hagger et al. (2010) in a meta-analysis found that ego-depletion has significant, detrimental effects on performance. Baumeister et al. (2007) argued that ego-depletion primarily impairs attention functions, so naturally it would be more debilitative in fine tasks. Gregersen et al. (2017) suggested that self-talk can help with preservation or replenishment of attentional resources, thus counter the effect of ego-depletion on attention tasks. Their study, which utilized a computerized attention task in a lab setting, provided initial support for their hypothesis. Galanis et al. (2022) extended this line of research by using a golf-putting task and examining performance under divided attention and ego-depletion conditions. Their results showed that the self-talk group performed better in both conditions, thus supporting the counter ego depletion effect of strategic self-talk.

Psychophysiological perspective

Summarizing the literature presented above, there has been strong evidence that self-talk affects attention through various mechanisms contingent on the needs and the nature of the task. Most of the research focus has been on either measuring attention as an outcome (computerized tests) or indirectly measuring attention through performance. Galanis et al. (2022) proposed that investigating the functions of the autonomous nervous system and brain activation would further advance our understanding of self-talk mechanisms. Such an approach could involve further physiological measurements, as research on the psychophysiologal aspects of sport performance has been rapidly developed the last decade. A recent study by Sarig et al. (2017) is among the few that have attempted to explore physiological aspects of the attention induced self-talk effects. Utilizing eye-tracking equipment, the study aimed to measure the quiet eye phenomenon, which is strongly linked to attention, following an intervention of strategic self-talk. The results showed that the self-talk group had higher performance in a golf-putting task which was accompanied by extended periods of quiet eye before the putt.

Autonomic Nervous system

Heart rate variability (HRV) is an important physiological marker that has gained increasing attention in sport psychology research. HRV reflects the dynamic regulation of the autonomic nervous system and can provide insights into an individual's physiological responses to physical and psychological stress. The autonomic nervous system (ANS) is divided into two distinct branches: the parasympathetic nervous system (PNS) and the sympathetic nervous system (SNS). During rest and recovery the PNS is in charge, generally slowing down functions and conserving energy, via the Vagus nerve. The activation of the PNS results in several physiological changes, such as increased HRV, decreased Heart Rate (HR), decreased myocardial contractility, dilated blood vessels, and increased gastrointestinal tract mobility (Stanfield, 2017). In HRV analysis these changes can be detected by changes in several indices including, higher root mean square of successive differences (RMSSD), low-frequency (LF) power, , LF-to-high-frequency (HF) power ratio, and decreased HR (Berntson et al., 2005). During exercise, excitation and stress the SNS takes over, inducing a fight-or-flight response and having the exact opposite physiological effects as PNS (Goldsmith, Bloomfield, & Rosenwinkel, 2000). According to Wheat and Larkin (2010), elevated HRV indicates the ANS's proficiency in regulating physiological arousal in accordance with situational demands, whereas diminished HRV signifies an incapacity to adjust to the situation. Furthermore, heightened HRV has been associated with feelings of relaxation, while decreased HRV has been linked to anxiety and stress. Competition and anxiety inducing conditions have been found to induce a state of sympathetic predominance in athletes (Blasquez et al., 2009). This physiological response is often associated with decreased performance compared to training settings, where athletes typically exhibit their optimal performance levels.

HRV in fine tasks

Concerning aiming tasks, several studies have found that elite athletes exhibited a HR deceleration prior to execution in both golf (Boucher and Zinsser, 1990) and pistol shooting (Tremayne & Barry, 2001). This effect seems to be more prevalent and pronounced in elite athletes and can be correlated with higher performance (Neumann and Thomas, 2009). Performance is also connected with higher LF, and higher values of RMSSD (Ortega & Wang, 2018). According to Lacey and Lacey’s (2017) intake-rejection hypothesis, the HR deceleration may be linked to reduced feedback to the brain, leading to more efficient allocation of attentional resources and ultimately, enhanced performance. This hypothesis could further explain the findings of Hatfield et al. (2004), who reported reduced cerebral cortex activity in elite shooters compared to novices, suggesting greater automaticity in execution.

HRV with psych skills

There is a limited amount of research on the impact of psychological techniques on the autonomic nervous system. Lee et al. (2023) explored the effects of psychological skills training (PST), including Self-talk, Imagery, Relaxation techniques, Goal-setting among others, on RMSSD values. The results showed no statistically-significant changes in RMSSD, probably due to the low number of participants. Nevertheless, interesting tendencies were identified suggesting that the group that had the PST intervention was exhibiting a more relaxed state. In another study, Stojkovic (2017) in a sample of sport science students recorded HRV during and following an endurance task involving cycling to exhaustion. The results showed that there were no statistical differences in the first 12 minutes of cycling, but significant differences were observed thereafter, with differences in RMSSD, LF/HF, HF gradually increasing as participants were nearing exhaustion. In particular, participants of the control group were more depleted with the activation of the SNS becoming dominant. In contrast, participants of the self-talk group were able to mitigate those effects, displaying less SNS activation and more composure. The author argued that that self-talk helped athletes maintain a more relaxed state and keep an effortless performance, providing indications for the the calming physiological effects of self-talk. Extending this line of research and considering the matching hypothesis (Theodorakis et al., 2000), the aim of this study was to explore the effects of a strategic self-talk intervention on the autonomic nervous system, through measures of heart rate variability, as well as performance on a golf-putting task.

Methods

Participants

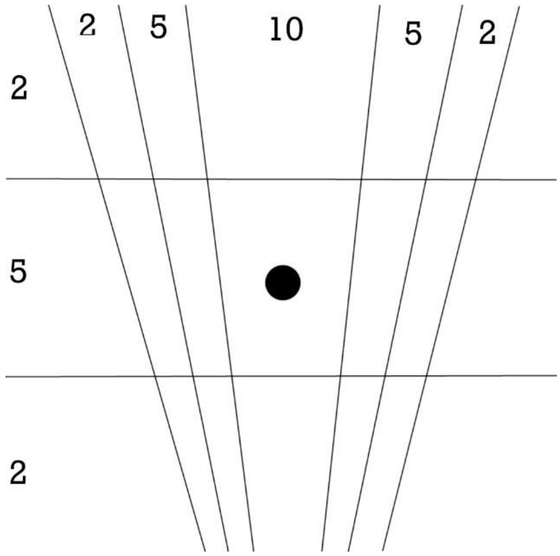
A sample of 40 male sport science students, aged 18 to 23 years participated in this study. The inclusion criteria for the participants were that they were right-handed, due to the equipment available, and that they had no previous significant experience with golf putting. Their participation was voluntary, and participants received in return course credit.

Apparatus and measures

Performance

To evaluate putting performance, a custom-designed point system was established (Picture 1). The objective of this system was to provide a more nuanced and comprehensive assessment of performance, considering not only the number of successful putts but also the precision and force of missed shots and award points accordingly. This approach aimed to provide a more accurate reflection of the participants' putting skill, with emphasis on accuracy and precision, but maintaining an ecological golf perspective. The putting task was conducted using an Amilla Mini-putter, on a specially designed grass strip that features an uphill slope.

Diagram 1. Scoring system used to measure putting performance.



Heart Rate Variability

To measure HRV, a Polar V800 connected to an H9 sensor on a chest strap was utilized. HRV data were transmitted through the PolarFlow app and subsequently analyzed using Kubios (Biosignal Analysis and Medical Imaging Group, Department of Applied Physics, University of Eastern Finland, Finland) to obtain HRV indices, which were RMSSD, LF, HF, LF/HF, SD2.

RMSSD is the most commonly used metric for measuring the short-term variability of heart rate. It is calculated as the square root of the average of the squares of the differences between adjacent normal R-R intervals. RMSSD reflects the influence of the parasympathetic nervous system on heart rate variability. Higher values of RMSSD indicate greater parasympathetic activity, while lower values suggest a decrease in parasympathetic activity.

LF is a frequency-domain measure of heart rate variability. It reflects the combined influence of both the sympathetic and parasympathetic nervous systems on the heart. A higher LF power is often considered an index of increased sympathetic nervous system activity, while lower values indicate a greater influence of the parasympathetic nervous system. HF is another frequency-domain measure of heart rate variability that reflects the influence of the parasympathetic nervous system on the heart. Higher values of HF power indicate greater parasympathetic activity, while lower values suggest decreased parasympathetic activity. LF/HF is a ratio of the low frequency power to high frequency power in the heart rate variability signal. This ratio provides information about the relative balance between the sympathetic and parasympathetic nervous systems. A higher ratio indicates a greater influence of the sympathetic nervous system, while a lower ratio suggests a greater influence of the parasympathetic nervous system.

Finally, SD2 is another measure of heart rate variability that provides information about both the time and frequency domains. The Poincaré plot is a scatter plot of the normal R-R intervals, with each R-R interval plotted against the preceding one. The standard deviation of the plot provides a measure of heart rate variability, with higher values indicating greater variability and lower values lower variability. Combining the aforementioned variables can provide valuable insights in the psychophysiological state of the individual and more specifically in the influence of the sympathetic and parasympathetic nervous system.

Procedure

The study was approved by the institution's ethics committee. Participants were randomly assigned to the control and experimental groups (20 students for each group), they were then contacted and informed about the study, procedures, and expectations. The experiment consisted of a total of four sessions, one baseline measurement, two training sessions, and one final measurement. Prior the measurements, participants were instructed to refrain from consuming alcohol, coffee, or energy drinks for 3 hours as well as avoiding large meals in the last hour before the measurement. A brief questionnaire was administered to verify those requirements and to assess any other behavior that could impact HRV measurements, such as sleep and exercise . In an attempt to minimize the impact of external factors on the autonomous nervous system, the baseline and final measurements were conducted on the same day and hour, one week apart. Based on the response provided on the questionnaire as well as the resting heart rate variability (HRV) measurement, one participant was identified as an outlier due to the presence of bradycardia, which had a substantial impact on his HRV measurements.

In the first session, after signing consent forms and getting fully informed about the study, the participants were introduced to the golf putting technique, given instructions and then were asked to perform 20 putts for familiarization, during which they received feedback and further instructions. Following the familiarization, the polar sensors were fitted and then, the participants were informed that the baseline performance assessment would start and that there will be no feedback for the rest of the session. For the putts in all sessions, the same protocol was followed. Following every putt, one researcher cleared the ball of the course, while the second researcher was placing a new one on the 2,5m mark. Participants were instructed to wait for a sound cue in order for them to proceed with the preparation and execution of the putt. Three sets of 20 shots from 2,5m were performed, with one-minute intervals in-between sets. The whole procedure lasted approximately 60 minutes, with the three performance sets lasting around 8 minutes each.

In the next two sessions, both groups were asked to putt 3 set of 20 shots from different distances (2m, 2.5m, and 3m) in order to reduce the learning effect. Both groups received feedback from the researchers according to their needs and/or mistakes, attempting to simulate golf putt training. For the experimental group, following a brief introduction to self-talk in the first sessions, participants were training with the use of different self-talk instructional cues . During development of self-talk plans, the IMPACT guideline (Hatzigeorgiadis et al., 2014) was followed to increase the effectiveness of the strategic self-talk intervention. More specifically self-talk cues were at first given by the researcher, but gradually participants had input on the selection of cues (as long as the cue was instructional) and following practice with various different cues, they chose the one that they would use in the final measurement. The most commonly used cues were ''Steady'', ''In-line'', and ''Smooth''

In the final measurement, the same procedures with the baseline were applied. Participants performed 20 warm-up shots, during which they received no feedback or instructions and then proceeded to putt 3 set of 20 shots, with a one-minute break in between. Subsequently, manipulation checks were administered to verify that the experimental group employed self-talk prompts.

Results

Baselines measures

Independent samples T-tests were conducted in order to examine whether the two groups differed in baseline measurements in performance. The analysis showed that there were no baseline differences, $t(37)=.602$, $p=.551$. Multivariance analysis of variance was conducted to test for differences in HRV measures in the initial assessment. Results showed that the groups did not differ in performance ($t(37)=.602$, $p=.551$). For the HRV measurements, the results also revealed that there were no significant differences between the two groups for RMSSD ($F(1,37)=.553$, $p=.462$), LF ($F(1,37)=.606$, $p=.441$), HF ($F(1,37)=.610$, $p=.440$), LF/HF ratio ($F(1,37)=.530$, $p=.471$), and SD2 ($F(1,37)=.057$, $p=.082$).

Performance

A repeated-measures ANOVA with one repeated factor (time) and one independent factor (group) was conducted in order to examine the effect of group and time on performance score. The results indicated a significant time by group interaction, $F(1,37)= 5.677$, $p=.022$. From pairwise comparisons, it is revealed that both the control, $F(1,37)= 14.716$, $p<.001$, and experimental group, $F(1,37)=54.012$, $p<.001$, improved significantly from the baseline ($M_{ctr}=660.47$ $SD_{ctr}=24.67$, $M_{exp}=639.75$, $SD_{exp}=24.04$) to the final assessment ($M_{ctr}=787.42$ $SD_{ctr}=28.81$, $M_{exp}=876.80$, $SD_{exp}=28.08$). Nevertheless, in the final measurements, the experimental group had a significantly higher performance compared to the control group $F(1,37)= 4.935$, $p=0.33$. The changes in performance are presented in Figure 1.

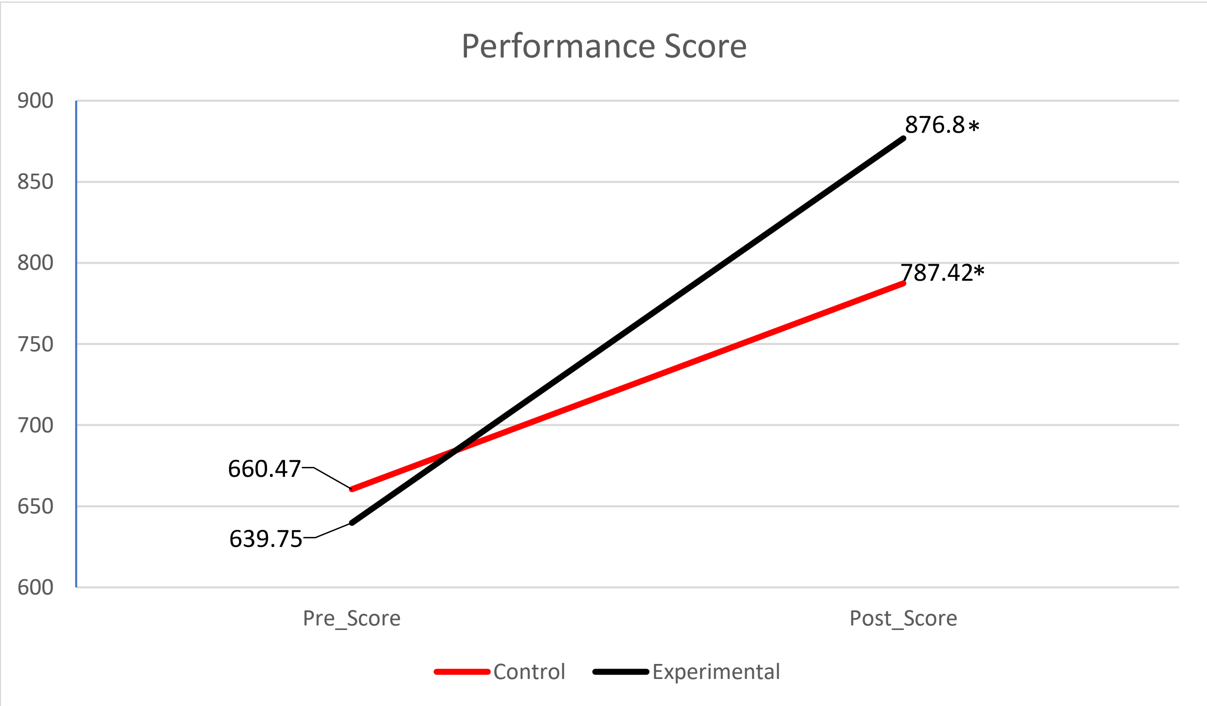


Figure 1. Changes in performance for the two groups from baseline to final assessment.

HRV

A two-way repeated-measures MANOVA with one repeated factor (time) and one independent factor (group) was conducted to examine the interaction of group and time on the HRV variables (RMSSD, LF, HF, LF/HF, SD2). The analysis showed a non-significant multivariate effect, $F(6,32)=1.375$, $p=.255$. Nevertheless, examination of the univariate effects provided some important insights. In particular, for RMSSD the univariate analysis showed a marginal time by group interaction, $F(1,37)= 4.026$, $p=.052$; the examination of the pairwise comparisons showed that the experimental group showed increases in RMSSD ($p= .022$), whereas no differences were recorded for the control group ($p= .586$). Non-significant effects were identified for LF, $F(1,37)=.942$, $p=.338$, HF, $F(1,37)=.334$, $p=.567$, LF/HF ($F(1,37)=.385$, $p=.539$), and SD2, $F(1,37)=2.66$, $p=.111$. The changes in the HRV indices are presented in Figures 2 – Figure 6.

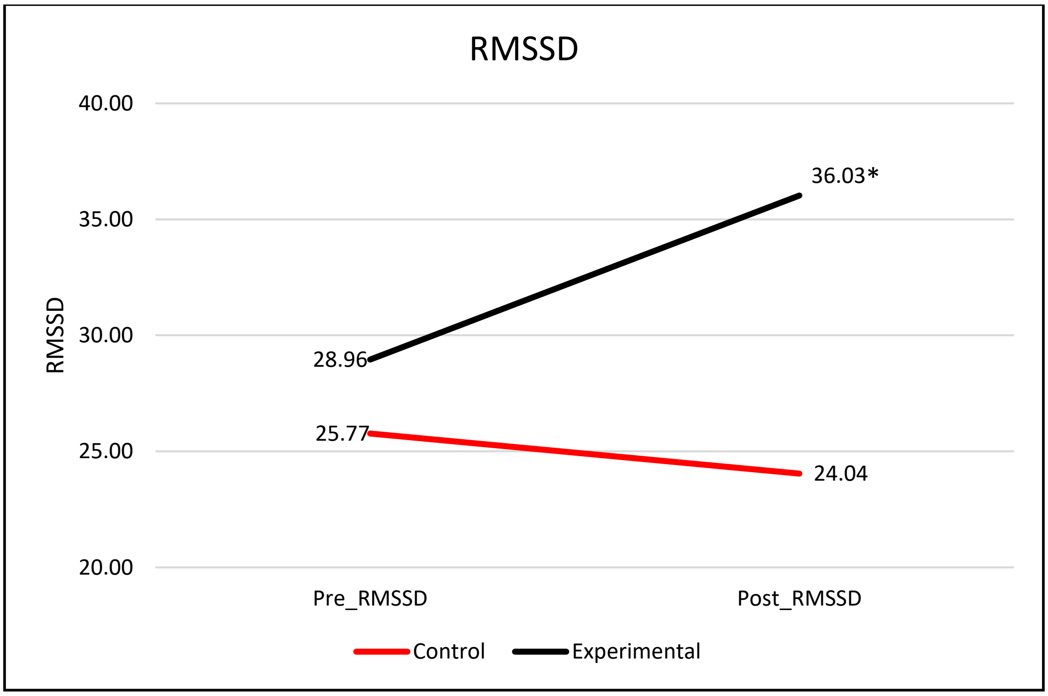


Figure 2. Changes in RMSSD from baseline to final assessment for the two groups.

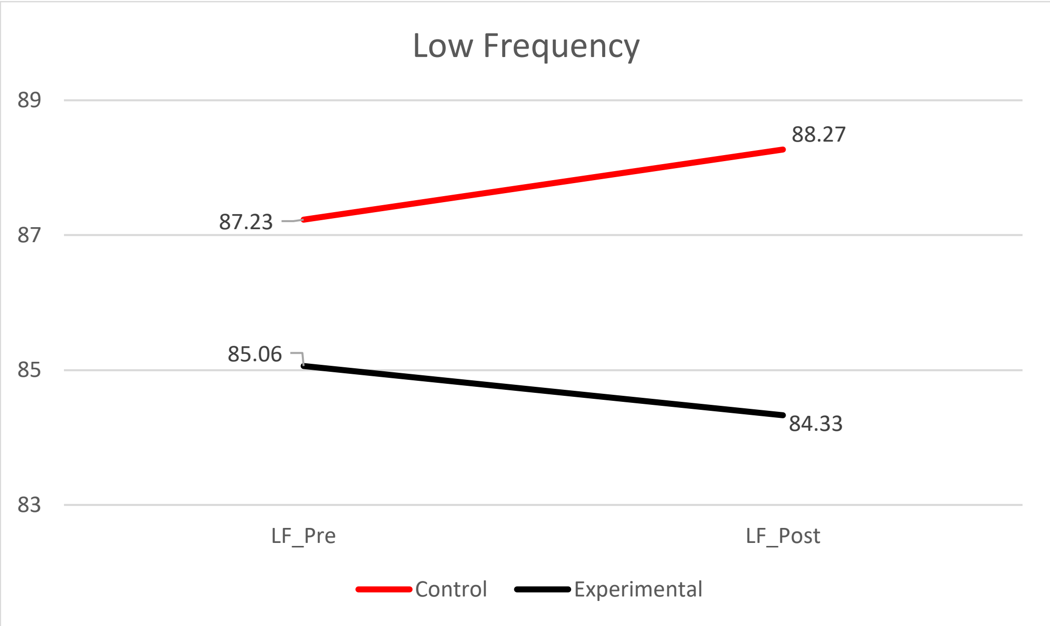


Figure 3. Changes in LF from baseline to final assessment for the two groups.

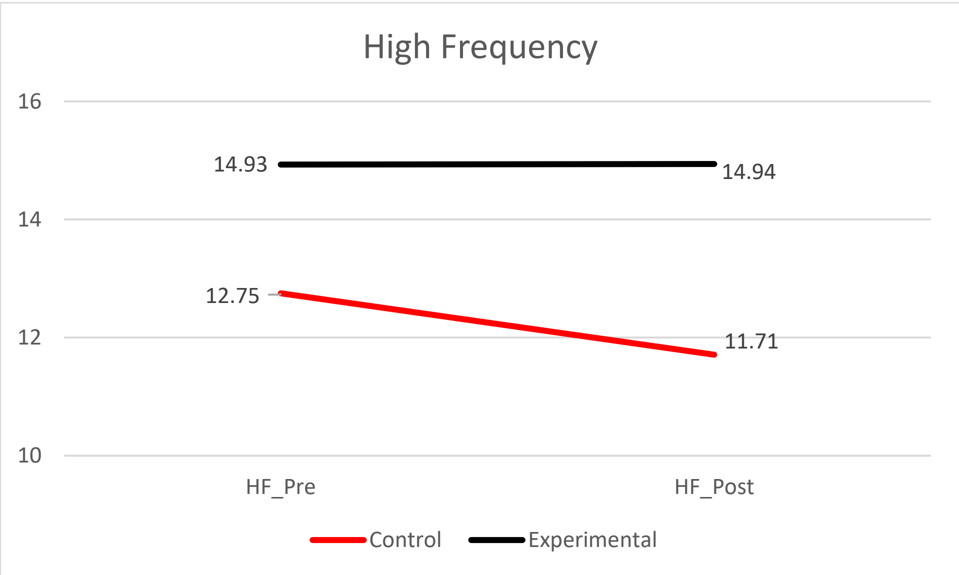


Figure 4. Changes in HF from baseline to final assessment for the two groups.

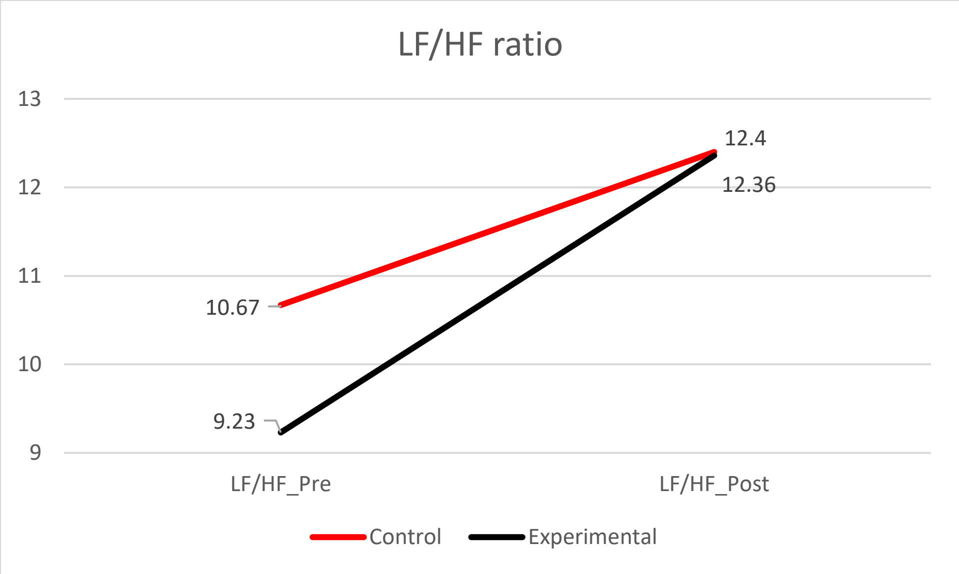


Figure 5. Changes in LF-HF ratio from baseline to final assessment for the two groups.

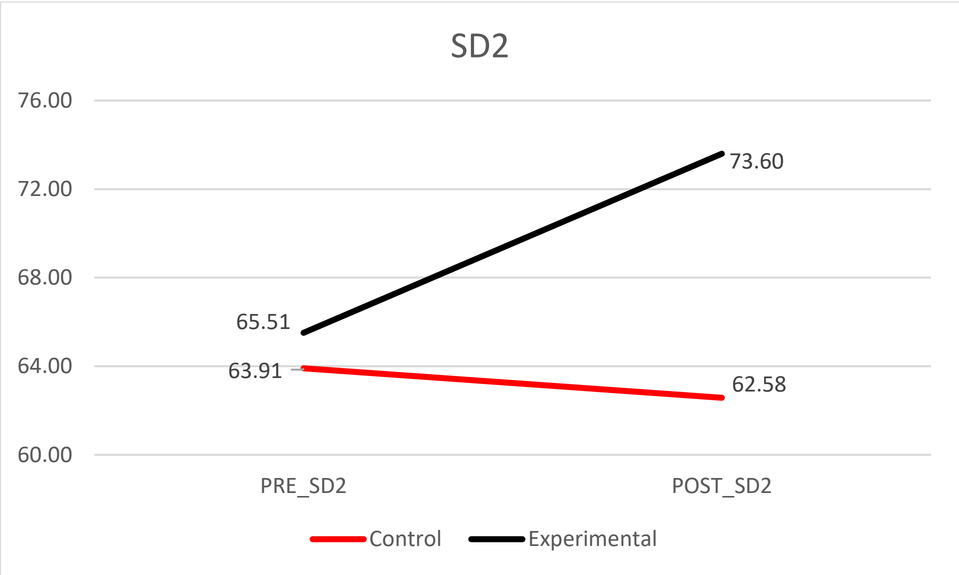


Figure 6. Changes in SD2 from baseline to final assessment for the two groups.

To further explore the effect identified for RMSSD in relation to the length of the experimental task that included three performance sets, a three-way repeated measures ANOVA with two repeated factors (time, set) and one independent factor (group) was conducted. The analysis yielded a marginally non-significant multivariate three-way interaction, $F(2,36)=3.021$, $p=.061$. To further examine this interaction, two-way analyses with two repeated factors, time (pre, post) and putting set (set 1, set 2, set3) were conducted separately for each group. The analysis for the control group did not exhibit a significant multivariate interaction effect, F(2,17)=.076, p=.927, whereas a marginal interaction was identified for the experimental group, F(2,18)=3.476, p=.053. Examination of the pairwise comparisons showed that while for the control group no differences in RMSSD were recorded from set to set within and between the two assessments, for the experimental RMSSD remained stable across sets in the baseline assessment, but increased from set 2 to set 3 in the final assessment. The identified patterns for RMSSD across time and set are presented in Figure 7 for the control group and Figure 8 for the experimental group.

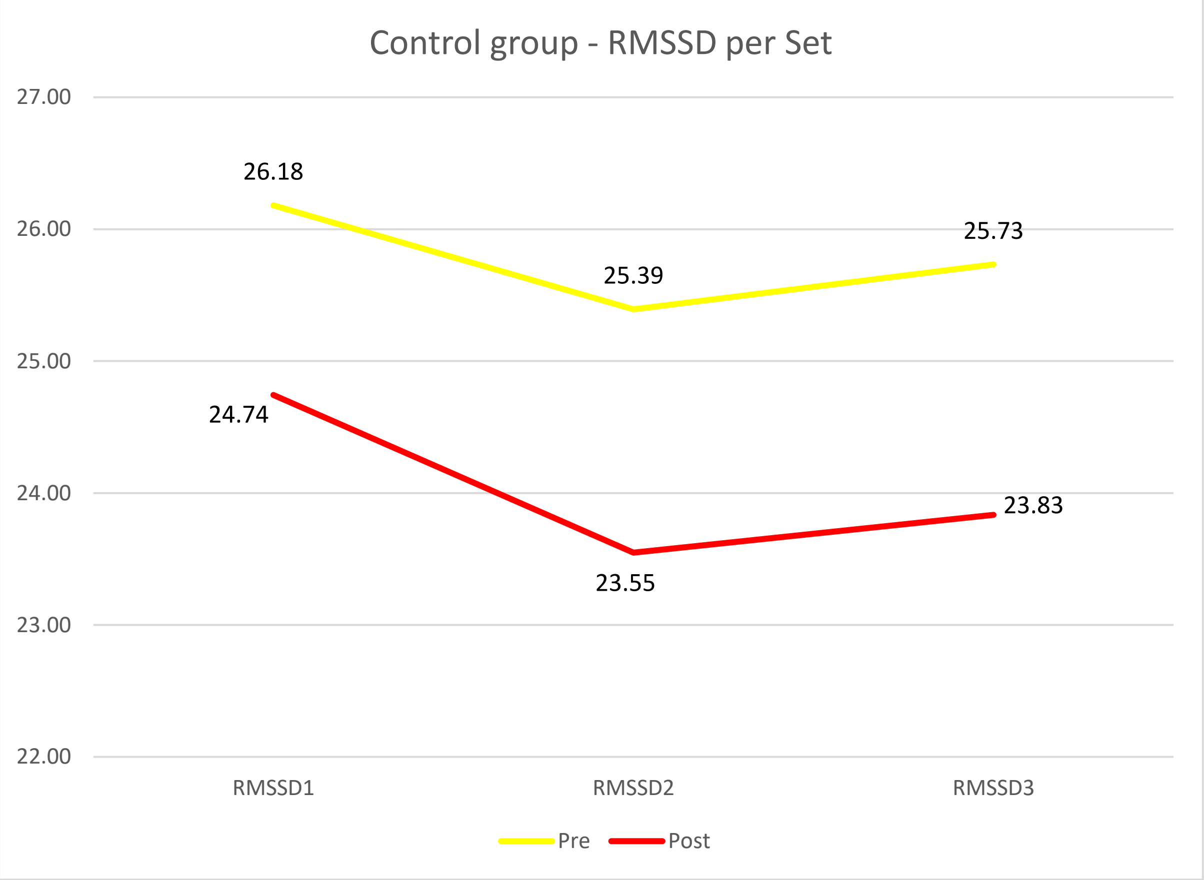


Figure 7. Changes in RMSSD per time per set for the control group.

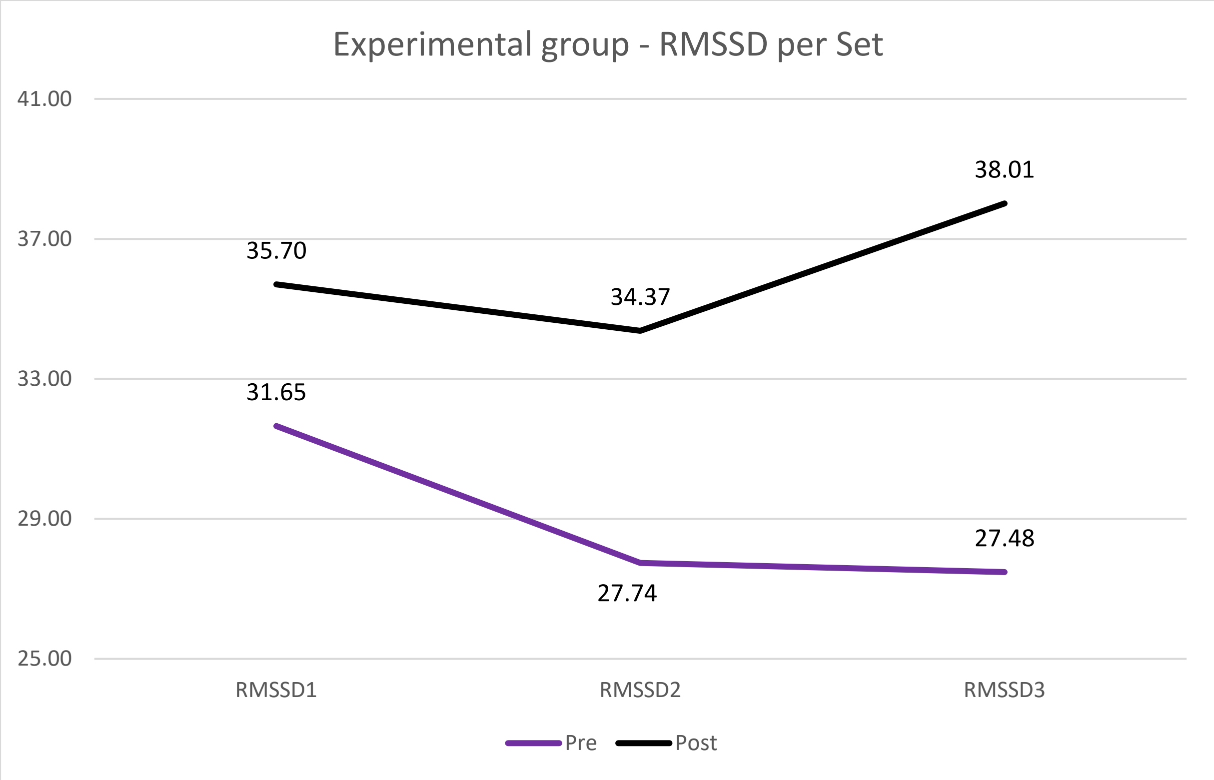


Figure 8. Changes in RMSSD per time per set for the experimental group.

Discussion

The purpose of this study was to examine physiological aspects of the `attentional mechanisms of strategic instructional self-talk on a golf-putting task among individuals with no prior experience. Both performance and heart-rate variability were measured to elucidate the relationship between self-talk and changes in task performance, while recording changes in the autonomic nervous system as a potential . Towards this direction, a strategic, instructional self-talk intervention was implemented. In this intervention, participants were gradually given more input on the self-talk plan with the intention to more accurately replicate self-talk interventions that are implemented in the field by sport psychologists. Consistent with the literature, the self-talk intervention had a considerable effect on performance. Furthermore, the results from the HRV analyses, despite not statistically significant across the indices, provided interesting patters of changes for RMSSD, which suggest a more relaxed physiological state for the experimental group during task execution, and in particular in the latest stages of the task.

As anticipated, both the control and experimental groups had improved performance, owing to the learning effect induced by the two training sessions on a task that was initially unfamiliar to the participants. Nonetheless, upon closer inspection, the experimental group was found to have a significantly superior performance in the final measurements compared to the control group, as well as a more substantial improvement during the training sessions. This adds further evidence to the effectiveness of self-talk interventions on enhancing sports task performance, and particularly to fine tasks.

Our analysis of the HRV variables measured as an average for the duration of the experiment revealed no multivariate effect across all variables. However, further examination through univariate tests revealed a significant difference in RMSSD values between the groups, with the experimental group demonstrating higher values. These results suggest that the self-talk group experienced a more relaxed state and had greater attention compared to the control group. While there is a lack of previous research on fine task self-talk to compare these findings to, they are consistent with existing physiological research on aiming tasks, which have found that higher performance groups exhibit higher RMSSD values.

Following our observation of significant differences in RMSSD values during the overall performance phase, we proceeded to examine the pattern of change within the assessment. The assessment procedure, which involved 3 sets of 20 putts following 20 warm-up shots over a duration of approximately 45-50 minutes, could logically induce ego depletion states, which can be assessed through RMSSD values. Our results indicate that both the experimental and control groups experienced a gradual decrease in RMSSD values during the initial assessment. However, in the final measurement, the experimental group exhibited not only a mitigation of this decrease from the first to the second set, and also demonstrated a spike in RMSSD values during the third and final set, surpassing even their values in their first set. Considering the duration of the task and the mental load that was required to maintain attention and composure for the golf putting task, it is likely that participants reached a state of ego depletion. Accordingly, considering the changes in RMSSD for the last putting set, it could be hypothesized that the use of strategic self-talk seems to have mitigated the depletion effect. This finding is consistent with previous research conducted by Gregersen et al. (2017) on a computerized attention task and Galanis et al. (2022) on a similar golf putting task under divided attention.

Limitations

This study had two primary limitations that warrant consideration. Firstly, due to the difficulty in precisely synchronizing execution with the HRV measurement trigger, we were unable to conduct ultra-short HRV analysis that could have identified patterns in cardiac deceleration as demonstrated in previous studies. Secondly, it is worth noting that our sample only included males. While this enhances the homogeneity of our sample, it is not possible to generalize our findings to the female population. In subsequent investigations into the physiological measurement of fine tasks and self-talk, precise synchronization of execution with HRV data could facilitate enhanced data analysis, by taking into consideration the ultra-short HRV readings. These ultra-short HRV readings have previously indicated cardiac deceleration milliseconds prior to execution, and without synchronization, it is impossible to examine this phenomenon and the potential influence that self-talk may have on it.

Although heart rate variability is a reliable indicator of psychophysiological state, additional physiological measures should be incorporated to deepen our comprehension of self-talk mechanisms during attention. Evaluating brain activity concurrently with HRV would yield more precise data regarding the psychophysiological state, as EEG readings are more directly linked to attention. The utilization of eye-tracking technology may also prove advantageous when measuring psychological influences on aiming tasks, as eye gaze, quiet eye phenomenon, and pupil dilation have all been linked to attention and performance.

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