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# The effect of strategic self-talk on heart rate variability and performance in a shooting task with novices

By
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A Thesis submitted in Partial Fulfillment of the Requirements for the Degree of Master in Psychology of Sport and Exercise at the University of Thessaly

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Trikala, 2025

**Declaration by Student**

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Theodoros Proskinitopoulos

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# Abstract

Strategic self-talk has been forwarded as an important cognitive strategy which can affect sport performance. The exploration of possible underpinning psychophysiological mechanisms which could shed light on why self-talk is effective is sparse. The current study aims on the examination of the effects of strategic self-talk on a pistol shooting task and the changes of psychophysiological variables as possible evidence of increased attention through the assessment of heart rate variability (HRV) indices. Forty-seven sport science students with no prior experience in shooting were randomly assigned in control and experimental groups. The experiment was comprised of the baseline assessment, two training sessions, and the final assessment. Both groups underwent the same training, but the experimental group also received instructional self-talk cues. Both performance and HRV indices were assessed during baseline and final assessment. Analysis of variance revealed greater shooting performance improvement from baseline to final assessment for the experimental group than for the control group. Furthermore, HRV data analysis did not reveal any statistically significant changes. The findings of the present study verify that strategic self-talk can improve shooting task performance and argue that strategic self-talk could be a cost-free strategy if we consider that the experimental group showed a significantly larger improvement and better performance without shifting physiological resources, which could possibly indicate a less effortful performance. The study also provides recommendations for improving psychophysiological assessments with strategic self-talk interventions in the future.

## Introduction

Strategic self-talk effectiveness has been pointedly supported by exploring the efficacy of self-talk interventions on sports performance through a review (Tod et al., 2011) and a meta-analysis (Hatzigeorgiadis et al., 2011). The meta-analysis showed a moderate positive effect size (d=0.48), providing strong evidence of the importance of strategic self-talk interventions. Strategic self-talk interventions involve the planned use of verbal key words (cues) that one addresses to oneself. These interventions aim to enhance performance or achieve performance-related outcomes (Latinjak et al., 2019), and it has received significant attention from the sport psychology research community in recent years (Hatzigeorgiadis et al., 2020). Furthermore, strategic self-talk has been applied in a variety of sport settings and samples (e.g., de Matos et al., 2020), and different tasks and outcome measures have also been used (e.g., Hatzigeorgiadis et al., 2018). Examining these various applications of strategic self-talk interventions reveals that different self-talk cues can have different effects on task performance. This also resulted (although partially supported) by the meta-analysis (Hatzigeorgiadis et al., 2011), in which researchers revealed that instructional self-talk is more effective than motivational self-talk cues for tasks requiring fine motor execution and is more efficient for fine tasks than gross tasks. On this line, strategic self-talk can serve different purposes by stimulating different functions (Hatzigeorgiadis et al., 2007).

Due to the substantial evidence supporting this effectiveness, contemporary self-talk research has increased its focus on exploring self-talk mechanisms by examining the underlying mediators that could influence the relationship between self-talk and sports performance (Galanis & Hatzigeorgiadis, 2020). Initially, four clusters of mechanisms (cognitive, motivational, emotional, behavioural) were proposed by Hardy et al. (2011) through a conceptual framework that explains the effect of self-talk on performance. Furthermore, based on preliminary empirical findings, Galanis et al. (2016) proposed two key clusters of mechanisms which explain those positive effects strategic self-talk can have performance: a motivational cluster and an attentional cluster. In short, the motivational cluster involves the behavioral, affective and cognitive aspects of motivation, such as self-efficacy, anxiety, and effort, while the attentional cluster involves different dimensions of attention, such as the width and direction of attention, distractibility, and mental effort. There is now sufficient evidence supporting attention as a key underlying mechanism explaining the effectiveness of self-talk on performance (for a review, see Galanis & Hatzigeorgiadis, 2020; Hatzigeorgiadis & Galanis, 2017).

It is essential to focus on gaining a deeper understanding of the strategic self-talk attentional functions. A preliminary, indirect study provided valuable evidence and advanced the relevant research conducted by Hatzigeorgiadis et al. (2004), who examined the effects of a strategic self-talk intervention on a power and a precision task in water polo. The results suggested that the facilitative effects of strategic self-talk on task performance were due to reduced interfering thoughts (an attentional interpretation). Similarly, Bell and Hardy (2009) conducted a study through which they examined the effectiveness of strategic self-talk in skilled golfers' performance. The results forwarded that both internal and external strategic self-talk enhances attentional focus.

Further indirect evidence on the attentional mechanisms of strategic self-talk have also been shown under conditions of distractions, ego depletion, and physical exertion. Galanis et al. (2018) examined the effects of a strategic self-talk intervention on task performance under conditions of auditory distraction. This research was conducted in two different settings: in laboratory with a computerized task that required focused attention and in field with a basketball free-throw task. The study was conducted in two settings: a laboratory with a computerized task requiring focused attention and a field with a basketball free-throw task. The results showed that, the strategic self-talk group performed better than the control group under conditions of auditory distraction, in both settings. Similar findings have recently been reported in other studies, supporting the positive effects of strategic self-talk interventions in settings involving ego depletion and physical exertion. In particular, results have forwarded that strategic self-talk improved golf putting (Galanis, Nurke et al., 2022) and forehand drive (Galanis, Makri et al., 2022) performance under conditions of ego depletion, while in physical exertion conditions, participants displayed better performance in a computerized task (Galanis et al., 2023) and basketball free throw shooting task (Galanis, Hatzigeorgiadis, Charachousi et al., 2022).

In addition, Galanis, Hatzigeorgiadis, Comoutos et al. (2022) reported more direct behavioural evidence, through a six-experiment study involving computerized attentional tasks, which provided results that offered consistent proof for the potential of strategic self-talk to trigger and direct participants' attention. Similarly, Tzormpatzakis et al. (2022) explored strategic self-talk and attention-related performance parameters on a pistol shooting task. The results forwarded that participants in the strategic self-talk group displayed greater performance on the shooting task and demonstrated significant improvements in shooting parameters, such as stability of aim and average length of tracing, compared to those of the control group.

Despite the value of the existing literature on the self-talk mechanism, it is important to note that it has largely relied on behavioural and perceptual measures. Complex cognitive processes underlying behaviour cannot be accurately or completely reported by individuals (Nidbett & Wilson, 1977). Furthermore, Ong (2015) identified the overreliance on self-report measures in sport psychology and suggested alternative forms of measurement. Baumeister et al. (2007), on the other hand, argued for assessing inner processes that mediate actions and overt behavioural responses as indicators of cognitive functions.

Towards that direction, and to better understand how strategic self-talk can improve sport performance, psychophysiological approaches should be adopted to provide a more comprehensive assessment and shed light on the mechanisms of body-mind interaction (Di Fronso et al., 2017; Latinjak et al., 2023). An abundance of cognitive functions (namely response selection and selective attention, executive control, etc) have been considered to depend upon working memory (Garavan, 2000). Working memory, which has been shown to involve functions such as online processing, manipulation of information, the active short-term storage, relies its efficient functioning upon inhibitory neural processes (Goldman-Rakic, 1998; Arnsten & Goldman-Rakic, 1998). The basic structure of the neural pathway of working memory is thought to involve a distributed network of structures which incorporates the prefrontal cortex as an important focus (Goldman-Rakic, 1998; Arnsten & Goldman-Rakic, 1998; Garavan, 2000). In addition, the prefrontal cortex has been related with activity in subcortical structures such as the amygdala, inversely (Davidson & Irwin, 1999). The function of the autonomic nervous system (ANS) which is depicted though the heart rate variability (HRV) indices, has also been related to the activity of the prefrontal cortex (Lane et al., 2008). The ANS has two branches called sympathetic nervous system (SNS) and parasympathetic nervous system (PNS). The first is associated with energy mobilization and the second with vegetative and restorative functions, both influencing heart rate (HR) (Tarvainen et al., 2013).

This dynamic function between the prefrontal cortex, the amygdala and the ANS takes place in the central autonomic network (CAN) (Benarroch, 1993; Benarroch, 1997). CAN works as part of an internal system, which is responsible for regulation, through which the brain can control visceromotor, behavioural, and neuroendocrine responses which are critical for functions such as goal-directed behaviour, adaptability, and health. The primary output of the CAN is mediated through preganglionic sympathetic and parasympathetic neurons that innervate the heart via the stellate ganglia and vagus nerve, respectively. The interplay of these inputs to the cardiac sinoatrial node produces complex variability that characterizes the HR time series (Saul, 1990) and is an indicator of cardiac vagal control (Laborde et al., 2018). In addition, organs such as the heart and the immune system provide sensory information to the CAN. As such, cardiac vagal control can also function as an indicator of central-peripheral neural feedback and thus as an indicator of CNS–ANS integration (Thayer et al., 2009) The HRV parameters which are suggested to depict the cardiac vagal activity are referred as vagally-mediated HRV (vmHRV) (Mosley & Laborde, 2022).

In general, HRV is the variance in time interval between consecutive heartbeats in milliseconds. Blood pressure, HR and respiration increase when the SNS is activated, improving this way the body's energy production and ability to perform. On the other hand, when PNS is not supressed, the bodily activity slows down and helps on balance reestablishment (homeostasis) through slowing down HR and respiration and increasing HRV. Normally, these two branches are thought to be in dynamic balance. However, resting cardiac autonomic balance has been shown to favour energy conservation through parasympathetic dominance over sympathetic influences (Thayer & Lane, 2009).

In the sport literature, shooting is a category of sports requiring elevated psychological skills. Early evidence in such sports requiring aiming, such as riffle shooting (Konttinen et al., 1998) or archery (Salazar et al., 1990) have indicated a decrease in HR just prior to execution on both novice and expert shooters, while expert shooters showed a larger deceleration. The authors postulated that this deceleration in HR relates to higher attentional focus. Another study by Ortega and Wang (2017) revealed that advanced shooters were found to have significantly lower average heart rate before shooting when compared with novice and intermediate shooters. More recent evidence confirmed the existence of a relationship between shooting performance and attentional focus (Bahrami et al., 2020). It was revealed that athletes' performance would significantly improve if they managed to limit the effect of distraction through increasing concentration. Given the effect which strategic self-talk has been shown to display on attentional focus, combining these results suggests that strategic self-talk could be an important intervention for sports which incorporate shooting.

Recently steps towards a more complete multi-measure psychophysiological approach of strategic self-talk were made (Bellomo et al., 2020). The effects of strategic self-talk on motor performance were examined through the use of EEG, ECG, EMG, kinematics, and detailed execution parameters. The results regarding the performance and HRV showed that strategic instructional self-talk assisted participants in improving their technique aspects, but not the performance. However, the participants undergoing the use of strategic motivational self-talk indicated increased HR and reduced event-related HRV, revealing an effort-based mechanism underlying strategic motivational self-talk.

The purpose of the present study was to examine the effects of a strategic self-talk intervention on a pistol shooting task and the psychophysiological changes as an indicator of increased attention through the assessment of HRV indices. We hypothesized that the strategic self-talk group would demonstrate elevated concentration and attentional focus during the pistol shooting task, thus showing significantly increased performance compared to the control group. We also speculated that the increased attentional focus of the self-talk group would indicate an increase in the HRV during task execution. We hypothesized as such, because this would reveal an increase in PNS activation, indicating greater vagal control, less body activation and a slower respiration rhythm, aspects important for concentration and for shooting performance efficiency.

## Methods

### *Study design and participants*

The current study was designed based on the ethical principles described in the Declaration of Helsinki and was approved by the institution's ethics committee (Ref: 2553). Forty-seven sport science students (23 females, 24 males; $M_{age}$= 20.68, SD= 1.72) participated in this research. Due to equipment limitations, the participants needed to be right-handed and also no prior experience with pistol shooting should exist. They signed written informed consent and received a course credit upon completion of the study.

Participants were randomly assigned in two groups, a control group (n= 23; 11 females, 12 males) and an experimental group (n= 24; 10 females, 14 males). The independent variables were group (control, experimental) and time (pre-, post-intervention). As for the dependent variables, length of tracing and stability of aim (stability), average score (shooting performance), and root mean square of the successive differences and high frequency power (heart rate variability) were assessed.

### *Apparatus and measures*

A Walther air-pistol was used for shooting in the SCATT shooting system. The SCATT system was utilized to track the performance and the stability outcome. To assess the HRV data, an H10 polar sensor connected on a chest strap was used. HRV data were transmitted through the HRV Logger app. The data were then analysed in the Kubios software in order to filter and obtain the HRV indices.

***Pistol shooting variables:*** Three variables were assessed and utilized for the pistol shooting task; average score (AS), average length of tracing (ALOT), and stability of aim (SOA). Two AS, two ALOT, and two SOA scores were recorded for each participant. The shooting score was the AS of all the shooting sets that the participants performed throughout a session. SOA is the diametrical dispersion of the tracing before shooting. It assesses stability while aiming, in millimetres (mm) and smaller distances indicate greater stability. The ALOT refers to the distance of the tracing covered just the last second before the pulling of the trigger. This is also assessed in millimetres (mm), and smaller distances also indicate greater stability. Together, SOA and ALOT accurately depict overall stability, where SOA depicts the movement of the aim across small intervals within a second and ALOT depicts the distance covered that time.

***Heart rate variability variables:*** Two parameters indicating the vmHRV were assessed: the root mean square of the successive differences (RMSSD) and the absolute power of high frequencies (HFms2). RMSSD is a time-domain matric and the most commonly used one when it comes to assessing short-term variability of heart rate. It represents the average of the squares of the differences between adjacent normal R-R intervals in milliseconds (ms). It can be an indicator of cardiac vagal activity. Higher RMSSD indicates greater cardiac vagal control, while lower values reveal a cardiac vagal control suppression. HFms2 is a frequency-domain metric, and it also represents cardiac vagal activity but for squared milliseconds (ms2). Similar to RMSSD, higher values indicate stronger cardiac vagal control, and lower values represent cardiac vagal control suppression.

### *Procedure*

The study's protocol was designed according to Hatzigeorgiadis et al.'s (2020) recommendations for developing a strategic self-talk intervention. This includes a baseline assessment, training sessions with strategic self-talk and a final assessment. The study was completed after a total of four sessions. Prior the initiation of the first session, the participants were informed to avoid alcohol, coffee, and/or energy drinks consumption for at least three hours before any measurement, while large meal avoidance was also instructed for at least one hour before any measurement. The participants when arranging the timeline of their sessions they were instructed that the baseline and final assessment must take place on the same day and hour, one week apart. This was as such to attempt to minimize the impact of external factors that could affect the autonomic nervous system.

After signing consent forms in the first session, and receiving detailed information about the study, the above requirements were verified through a brief questionnaire along with other behaviours that could influence HRV measurements (e.g., sleep and exercise). Then, the participants after being introduced with the equipment they would use, they received instructions according to the shooting technique. The participants underwent a familiarisation set of 10 shots, at a 10 meters distance from the target. Along this set, feedback was given to the participants. Subsequently, the participants entered the baseline assessment phase after they fitted the polar sensors. Following a calibration procedure, the polar sensors started monitoring the HRV and then the participants performed 4 sets of 10 shots each from a 10 meters distance. Each set was followed by a 1-minute interval. No feedback or technical instructions were provided during this phase. The summary of these 4 sets was the average score of the baseline assessment.

The next two sessions (session 2 and 3) were utilized for shooting training. During these sessions, participants practiced shooting and received feedback. Each session was consisted of 4 sets of 10 shots. However, strategic self-talk was educated and applied by the participants of the experimental group. They practiced shooting with different instructional cues (e.g., "loose trigger", "shooting pin").

Finally, for the fourth and last session, a final assessment was conducted. In this session, after a set of 10 warm-up shots, the exact same procedure with the baseline assessment took place. This time, however, participants in the experimental group were asked to use the self-talk cue they had chosen during training and apply it consistently before each shot. Lastly, the use of strategic self-talk by the experimental group was assessed through manipulation checks.

## Results

### *Shooting task performance (average score)*

A 2 (group: experimental, control) x 2 (time: pre-test, post-test) mixed-design ANOVA was conducted to examine changes in shooting task performance (AS). There was no statistical significant main effect of time, $F(1, 42)= .005$, $p= .94$. However, there was a statistical significant group x time interaction effect, $F(1, 42)= 4.69$, $p= .036$, $\eta^2= .10$. Examination of the pairwise comparisons revealed that for AS both groups improved significantly from pre to post-test ($p< .05$), with the improvement of the experimental group ($M= 249.50$, $SD= 38.66$) being greater than that of the control group ($M= 225.10$, $SD= 41.29$) The changes in the AS are presented in Figure 1.

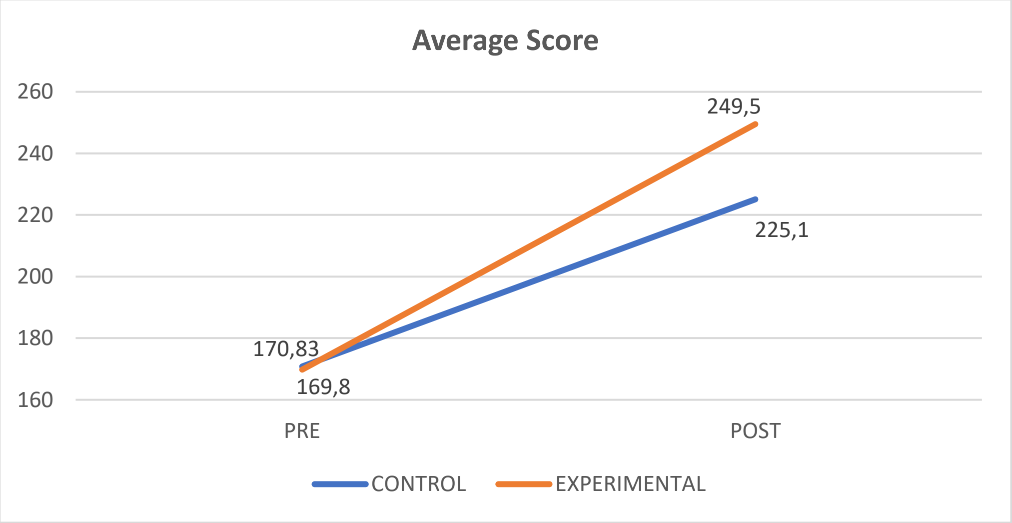


Figure 1: Changes in AS from baseline to final assessment for the two groups.

### *Average length of tracing and stability of aim*

A 2 (group: experimental, control) x 2 (time: pre-test, post-test) mixed-design MANOVA was conducted to examine the effects on average length of tracing (ALOT) and stability of aim (SOA). The analysis showed a non-statistical significant multivariate group x time interaction effect, $F(2, 41)= 1.90$, $p= .16$, $\eta^2 = .08$, indicating no statistical significant differences between the experimental and the control group for the dependent variables; for the control group, the A LOT was 380,81 (*SD*= 71.82), and for the experimental group, the A LOT was 380.26 (*SD*= 98.00); as for the control group, the SOA was 103.31 (*SD*= 26.64), and for the experimental group, the SOA was 93.06 (*SD*= 27.90). Changes in ALOT and SOA are presented in Figures 2-3.

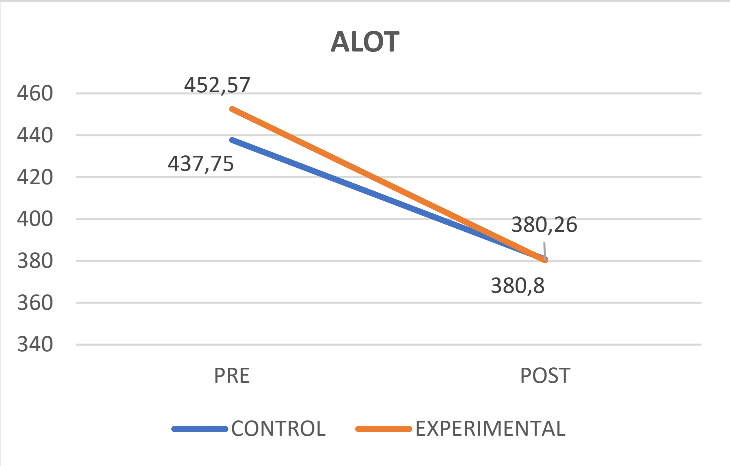


Figure 2: Changes in average length of tracing from baseline to final assessment for the two groups.

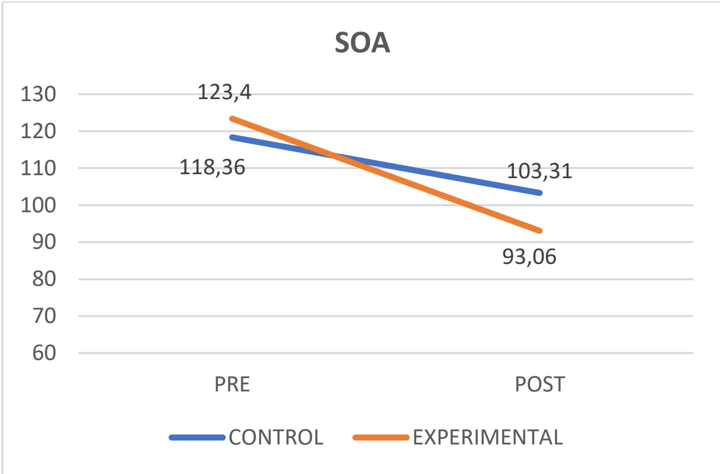


Figure 3: Changes in stability of aim from baseline to final assessment for the two groups.

***Root mean square of the successive differences and high frequency power***

A 2 (group: experimental, control) x 2 (time: pre-test, post-test) mixed-design MANOVA was conducted to examine the effects on root mean square of the successive differences (RMSSD) and high frequency power (HF). The analysis showed a non-statistical significant multivariate group x time interaction effect, $F(2, 39)= .26$, $p= .76$, $\eta^2 = .01$, indicating no statistical significant differences between the experimental and the control group for the dependent variables; for the control group, the RMSSD was 41.07 (*SD*= 26.05), and for the experimental group, the RMSSD was 36.51 (*SD*= 18.05); for the control group, the HF was 6.13 (*SD*= 1.25), and for the experimental group, the HF was 6.07 (*SD*= 0.95). Changes in RMSSD and HF are presented in Figures 4-5.

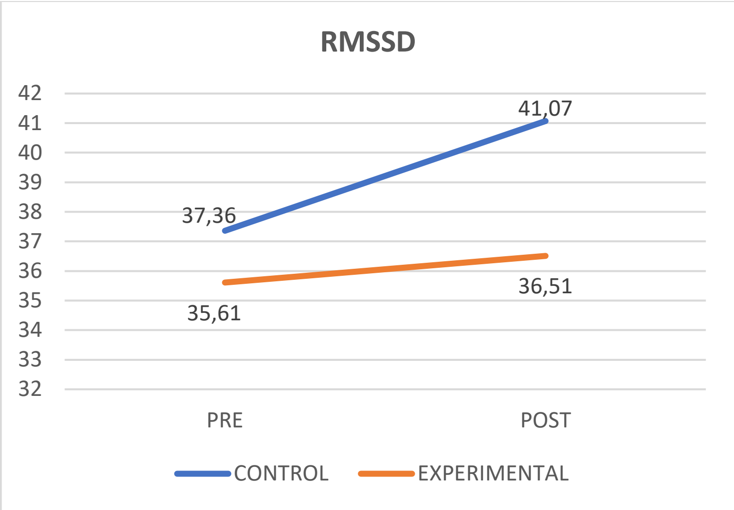


Figure 4: Changes in root mean square of the successive differences from baseline to final assessment for the two groups.

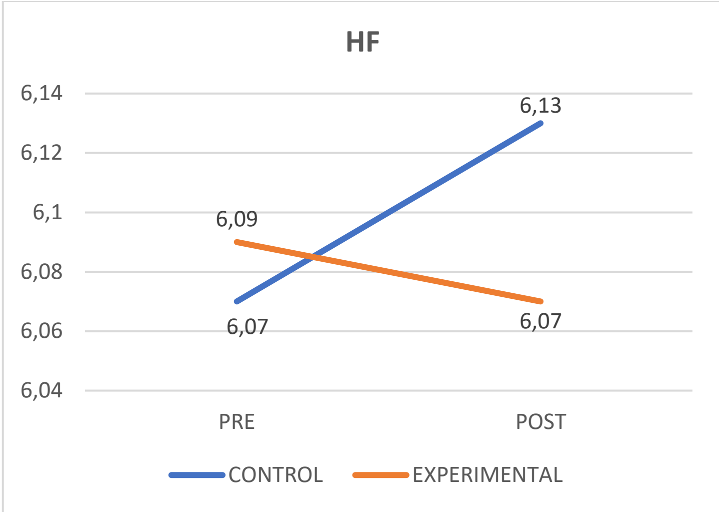


Figure 5: Changes in high frequency power from baseline to final assessment for the two groups.

## Discussion

The purpose of the present study was to examine the effects of a strategic self-talk intervention on a pistol shooting task and the psychophysiological changes as an indicator of increased attention through the assessment of HRV indices. Strategic self-talk plans consisting of instructional cues were implemented as an intervention for the experimental group. The findings were consistent with the first hypothesis and in line with previous literature (e.g., Tzormpatzakis et al., 2022), particularly showing a significant effect on shooting task performance outcomes. Specifically, both groups showed significant improvements in their average shooting scores, likely due to learning from the two training sessions and their novel experience with the task. However, a significant interaction was found, indicating that the group that received the strategic self-talk intervention performed better on the final assessment than the control group. It can be postulated that strategic self-talk improved focus on the execution of the motor task. Despite this performance outcome, neither group showed improvement in the stability variables (ALOT and SOA). This may be due to the fact that only two training sessions took place, whereas Tzormpatzakis et al. (2022) observed significant improvements in these variables for the self-talk group after four training sessions.

Regarding the HRV, none of the indices revealed a statistically significant multivariate effect. This finding does not support the second hypothesis of the present study, which proposed that a shift in cardiac vagal control are an indicator of the underpinning attentional mechanisms. However, it can be assumed that strategic self-talk is a cost-free strategy, as the experimental group showed significantly greater improvement and better performance without allocating additional physiological resources. This could indicate a less effortful performance. On top of that, robust theoretical frameworks are also needed. The vagal-tank theory, proposed by Laborde et al. (2018) as an updated framework combining the polyvagal theory (Porges, 2006) and the neurovisceral integration model (Thayer et al., 2009), could provide a new approach to assessing and analyzing data through the three Rs (resting, reactivity, and recovery). This new approach could reveal the effects that strategic self-talk has on self-regulation and ego depletion.

**Limitations and future recommendations**

Regarding the effects on shooting task performance, the limited number of training sessions could be highlighted. Increases in the training sessions could possibly have affected the outcome of the stability variables. Future research should test the effects of strategic self-talk interventions by adopting a more comprehensive self-talk training protocol.

Regarding the cardiac vagal control indices, several limitations were revealed. Covariates were not assessed to minimize potential confounding factors that could affect the intervention's outcome (Laborde et al., 2018). For example, the menstrual cycles of the female participants were not tracked, which could have affected cardiac function. Additionally, the majority of our sample was athletes, who tend to have higher vagal baroreflex sensitivity (Laborde et al., 2018). There were also limitations in the available equipment. Although the H10 sensor, when placed on a chest strap, can provide data similar to that of a multi-lead ECG (Laborde et al., 2018), it does not provide the ability to perform ultra-short analyses of mvHRV and event-related markers (e.g., the last 500 ms prior to pulling the trigger, during which strategic self-talk cues occur).

Another possible limitation is the absence of tonic and phasic cardiac vagal control aspects in the data assessment. The lack of baseline resting and endline cardiac mvHRV indices restricts the ability to check for reactivity and recovery abilities after the application of the strategic self-talk intervention (Mosley & Laborde, 2022). In addition, the task itself was not challenging enough to cause ego-depletion or/and there was not a high stress situation which requires ego-depletion and self-regulation. This suggests that vagal cardiac control is not a suitable measurement for these kinds of tasks, as it does not affect central autonomic network function. Rather, an assessment of motor cortex function would be more appropriate for a more comprehensive, in-depth investigation of the self-talk mechanisms.

## Conclusions

The present study further advances the existing self-talk literature using psychophysiological indices as markers of attention-related mechanisms. Strategic self-talk may be cost-free, enabling athletes to enhance performance without allocating additional physiological resources and potentially suggesting a less effortful performance. It provides some initial steps and, through these, encourages the use of physiological markers as a way of tracking psychological phenomena and processes, and it also provides future recommendations to help establish psychophysiological assessments with self-talk interventions.

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