A psychophysiological approach to the study of strategic self-talk mechanisms through heart rate variability during a cycling task

Un enfoque psicofisiológico para el estudio de los mecanismos del autohabla estratégico a través de la variabilidad de la frecuencia cardíaca durante una tarea de ciclismo

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Abstract

Introduction: The self-talk literature has stressed the importance of employing multidisciplinary approaches to better understand how strategic self-talk operates.
Objective: The purpose of the present study was to examine the effect of a strategic self-talk intervention on vagal modulation during moderate-intensity aerobic exercise.
Methodology: A randomized control trial was employed. Eighty-three sport science students (36 females) with a mean age of 21.02 (±2.31) years, completed the requirements of the study. Participants were randomly assigned to experimental and control groups. Heart rate variability was monitored during exercise to assess changes in vagal modulation. Participants cycled at 50% of their heart rate reserve for 20 minutes, with the experimental group using strategic instructional self-talk. The heart rate variability measures were averaged to 4-minute time intervals and analyzed using repeated measures analysis of variance.
Results: Analysis of pairwise comparisons showed significant differences between the two groups for RMSSD during the final 8-minute of the task ($p < .05$).
Discussion: These differences reflected less vagal suppression for the self-talk group compared to the control group. The observed differences in vagal modulation may be explained by the self-regulating effects of strategic self-talk during the task, particularly in the later parts, suggesting a less effortful performance.
Conclusions: The present findings provide encouraging evidence to further investigate the strategic self-talk mechanisms through psychophysiological approaches.

Keywords

Applied sport psychology; autonomic nervous system; RMSSD; vagal modulation.

Resumen

Introducción: La literatura sobre el autohabla ha destacado la importancia de emplear enfoques multidisciplinarios para comprender mejor cómo funciona el autohabla estratégico.
Objetivo: El propósito del presente estudio fue examinar el efecto de una intervención de autohabla estratégico sobre la modulación vagal durante el ejercicio aeróbico de intensidad moderada.
Metodología: Se empleó un ensayo controlado aleatorizado. Ochenta y tres estudiantes de ciencias del deporte (36 mujeres), con una edad media de 21.02 (±2.31) años, completaron los requisitos del estudio. Los participantes fueron asignados aleatoriamente a los grupos experimental y de control. Se monitoreó la variabilidad de la frecuencia cardíaca (HRV) durante el ejercicio para evaluar los cambios en la modulación vagal. Los participantes pedalearon al 50% de su reserva de frecuencia cardíaca durante 20 minutos, con el grupo experimental utilizando autohabla estratégico de tipo instruccional. Las medidas de HRV se promediaron en intervalos de 4 minutos y se analizaron mediante un análisis de varianza de medidas repetidas.
Resultados: El análisis de comparaciones por pares mostró diferencias significativas entre los dos grupos en la medida de variabilidad de frecuencia cardíaca (RMSSD) durante los últimos 8 minutos de la tarea ($p < .05$).
Discusión: Estas diferencias reflejaron una menor supresión vagal en el grupo de autohabla en comparación con el grupo de control. Las diferencias observadas en la modulación vagal podrían explicarse por los efectos autorregulatorios del autohabla estratégico durante la tarea, especialmente en las fases finales, lo que sugiere un menor esfuerzo en el rendimiento.
Conclusiones: Los presentes hallazgos proporcionan evidencia alentadora para continuar investigando los mecanismos del autohabla estratégico mediante enfoques psicofisiológicos.

Palabras clave

Psicología del deporte aplicada; sistema nervioso autónomo; RMSSD; modulación vagal.

Introduction

Sports and exercise often expose performers to demanding situations that challenge their cognitive and physical abilities by compromising optimal psychophysiological functioning (Bortoli et al., 2012; Laborde et al., 2017). Empowering performers with cognitive strategies that help to address such situations improves performance in a given context. A key component to achieving optimal psychophysiological functioning is the implementation of cognitive-behavioral strategies; a widely used strategy is self-talk. Research on the impact of strategic self-talk on sport task performance has provided robust meta-analytic evidence for its effectiveness (Hatzigeorgiadis et al., 2011), and has identified parameters that must be considered for developing effective self-talk plans, such as task characteristics, learning stage and experience level, and setting or circumstances. Accordingly, Hardy (2006) suggested that self-talk may be operating through different mechanisms.

Over the past few years, there has been an increasing research interest in understanding the mechanisms that underlie the effectiveness of strategic self-talk for performance, across diverse settings and populations (e.g., Aulia et al., 2025; Cabral et al., 2024; Gregersen et al., 2017; Naderirad et al., 2023; Sarig et al., 2023). Galanis et al. (2016) argued that understanding the potential mechanisms and subsequently targeting specific mechanisms through strategic self-talk, will enable us to develop and implement more effective interventions. Subsequently, they proposed two key clusters of mechanisms accounting for the facilitating effects of strategic self-talk on performance, an attentional and a motivational; preliminary research has explored these mechanisms. Considering the attentional mechanisms, Galanis, Hatzigeorgiadis et al. (2022) investigated the effects of strategic instructional self-talk on different attention functions through a series of experiments involving cognitive tasks. The results showed that self-talk led to faster reaction times on all tested attention domains, supporting the use of self-talk to trigger or direct attention. Similar findings have been also reported in two studies, supporting the positive impact of strategic instructional self-talk on divided attention under conditions of physical exhaustion (Galanis et al., 2023) and ego depletion (Galanis, Nurkse et al., 2022). Considering the motivational mechanism, research with endurance tasks has provided robust results regarding the beneficial effects of strategic self-talk. These effects have been attributed to the regulation of perceptions of exertion, which has been identified as a determinant factor of endurance performance (Marcora et al., 2019). Blanchfield et al. (2014) found that participants using motivational self-talk had endured more in a cycling-to-exhaustion task, while reporting lower perceived exertion (RPE) compared to a control group. Similar findings were also reported by Hatzigeorgiadis et al. (2018) and de Matos et al. (2021) in a cycling time-trial and in a swimming pace test, respectively, where participants using motivational self-talk produced greater power output and higher pace, and reported similar RPE with control participants.

The above research has provided valuable evidence regarding the functioning of self-talk mechanisms; yet, they have been mostly based on behavioural and perceptual measures. Subsequently, basic research and multidisciplinary approaches involving psychophysiological indicators (Bololon et al., 2025) will further enhance our understanding of self-talk mechanism (Latinjak et al., 2019; 2023). Preliminary research towards this direction has explored gaze behaviour and changes in brain activation as a result of strategic self-talk. Sarig et al. (2023) examined whether strategic instructional self-talk could prolong quiet eye duration, which has been associated with better performance, in a golf putting task. The results confirmed that self-talk led to longer quiet eye durations and improved performance. Furthermore, Panoulas et al. (in press) provided preliminary evidence for the effects of strategic instructional self-talk on readiness potential (brain activity prior to movement) during the motor planning phase of a pistol shooting task. The results indicated a reduction in negative amplitude in motor-related brain regions during the last 500ms before shooting, suggesting reduced brain activity, thus a more efficient use of resources.

Another important psychophysiological indicator of human functioning is heart rate variability (HRV). HRV is the variance in time interval between consecutive heartbeats in milliseconds and reflects cardiac vagal tone, which depicts the influence of the parasympathetic nervous systems (PNS) on cardiac regulation (Laborde et al., 2017). Specifically, the activation of PNS slows down bodily activity and helps re-establish balance (homeostasis) after a stressful situation. An increased parasympathetic activity causes the heart rate and respiration to slow down and HRV to increase (Berntson et al., 1997; Thayer & Lane, 2000). Higher vagally mediated HRV indicates a more flexible and adaptive nervous system, because it reflects greater functional capacity (Thayer & Lane, 2000; Wei et al., 2018). Consequently, in accordance with the neurovisceral integration model (Thayer et al., 2009), HRV can function as a biomarker for both self-regulation and environmental adaptation. Bellomo et al. (2020) attempted a multi-measure investigation of psychophysiological effects of strategic self-talk in a golf task. Their results showed a trend for higher heart rates and a significantly less event-related HRV for the motivational self-talk group compared to the instructional self-talk group, suggesting an effort-based mechanism through which the benefits of motivational self-talk can be explained. Extending this line of research and considering the dearth of studies incorporating self-talk and physiological assessment of arousal, the purpose of the present study was to examine the effect of a strategic self-talk intervention on vagal modulation during moderate-intensity aerobic exercise.

Method

A randomized control trial was conducted with one experimental group and one control group. Pre- and post-intervention measures were taken. The study was designed based on the ethical principles described in the Declaration of Helsinki and was approved by the institution's ethics committee (Ref: 1156). The study was not preregistered.

Participants

A power calculation was performed to decide the size of the sample. The meta-analysis regarding the effect of the effect size of strategic self-talk on task performance (Hatzigeorgiadis et al., 2011) has identified a moderate effect size (.47). Considering that in our study performance was not assessed, and that at the time of the study there was no published data regarding the potential effect of strategic self-talk on HRV indices, which was the key dependent variable, a more conservative effect size was employed. The analysis (G-Power) showed that estimating an effect size of .40, to achieve a power of .80 with α-error probability at .05, with five repeated measures for two groups, a sample size of 80 participants was required. Taking into account potential attrition, a sample of 90 individuals was targeted. Ninety healthy, physically active, non-smoking, sport science students volunteered to participate in the experiment and were randomly assigned into experimental and control groups. Among them, 83 (47 males, 36 females), with a mean age of 21.02 (±2.31) years, completed the experimental procedures (44 from the experimental and 39 from the control group). A chi-square test revealed no differences in sex distribution, $\chi2(1)= 8.56$, $p= .38$, whereas t-test revealed no differences in age, $t(81)= 1.24$, $p= .22$, between participants of the two groups.

Aparatus

Participants exercised on a cycloergometer (Monark Ergometic 894-E Peak Bike, Monark, Vansbro, Sweden), where revolutions per minute (RPM), cycling time, power output (WATT) and distance covered were displayed on the screen. HRV was assessed through a chest belt (Polar Electro Oy, Finland) and a wireless receiver (Polar V800, Polar Electro Oy, Finland).

Procedure

Before the onset of the experimental procedures, participants were contacted by phone and instructed to avoid strenuous exercise before their visit to the lab. A systematic protocol was followed for testing the participants. Upon arrival, participants were introduced to the study procedure and equipment, and were asked to sign a consent form. The Polar chest strap was wetted and fastened securely to the participant's chest. Subsequently, the HRV recording was initiated, and participants were taken to a quiet room where their resting heart rate was recorded in a supine position for 10 minutes; based on the resting heart rate, the 50% of heart rate reserve was estimated based on the Karvonen formula (Brooks, 2004).

After returning to the experiment room, the participants warmed up on the cycloergometer at 50 RPM for five minutes. During the warm-up period, the self-talk group received instructions and practiced self-talk cues. One minute before the end of the warm-up period, the participants were left alone to reflect on what the researcher had presented and to ask any questions they had about self-talk. The cue words "steady" and "calm" were proposed to help participants maintain a steady tempo. Participants of the experimental group were instructed to use the cue words whenever they wanted, as well as every two minutes after receiving a reminder (each time the researcher recorded data from the cycloergometer). Participants of the control group were accordingly instructed to maintain a steady tempo. Then, participants cycled for 20 minutes. During the exercise period, the RPM was monitored every two minutes and adjusted if needed, so that the heart rate remained within the desirable heart rate reserve range (50 ± 5%).

Distance covered, heart rate, and power output were recorded every two minutes during exercise and used as control measures. HRV data was recorded throughout the trial. After completing the 20-minute test, participants cooled down for three minutes at 50 RPM. Finally, all participants completed a standard self-talk manipulation check. In particular, participants of the experimental group were asked to report how often they used the self-talk cue words of choice on a scale (from 1, not at all, to 10, all the time), whereas participants of the control group participants were asked to report (a) whether they systematically used any self-talk cues (b) if so, what were these cues, and (c) if so, how often they used them (on a scale from 1 to 10).

HRV indices

Two of the most commonly used indices in research were selected to assess HRV, RMSSD, which is a time-domain variable and HF which is a frequency-domain variable. These two indices depict the vagal modulation (activation or suppression) of the autonomic nervous system to the HRV (Laborde et al., 2017). Higher values in RMSSD and HF indicate vagal activation, whereas lower values indicate vagal suppression and thus withdrawal of the parasympathetic influence of the HRV.

Data analysis

To eliminate erroneous, ectopic, and noisy complexes, at times low to medium, and in a few cases strong to very strong, we used artifact correction in preprocessing, which is common in HRV studies (Laborde et al., 2017). Using Kubios HRV analysis software, five 4-minute chunks were created from the 20-minute exercise period, in accordance with previous research recommendations (Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology, 1996). Time-domain and frequency-domain analyses were performed on the HRV data according to the recommendations of Tarvainen et al. (2014). Mixed measures ANOVA with one repeated factor (time: five 4-minute intervals) and one independent factor (group: experimental, control) were used to test for differences in the control measures and the HRV measures across time as a function of group.

Results

Self-talk manipulation check

Participants of the experimental group reported consistent use of self-talk during the cycling task (M= 7.70, SD= .97). Five participants of the control group reported using self-talk cues during the task. In particular, they reported cues like 'let's go', 'you can do it', 'keep going'; however, they all reported using the cues at low to moderate frequency (ranging from 2 to 5).

Control measures

Three 2-way (5 x 2) mixed measures ANOVAs were calculated to test for differences in heart rate, distance covered, and power output throughout the 20-minute of exercising as a function of group. The analysis revealed no significant group by time interaction in any of the control measures; for heart rate, $F(4, 78)= 0.38$, $p= .81$; for distance covered, $F(4, 78)= 0.58$, $p= .68$; and for power output, $F(5, 10)= 1.30$, $p= .28$. Furthermore, all pairwise group comparisons were non-significant. The mean scores for all control measures are presented in Table 1.

Table 1. Descriptive statistics for all control measures.

	Control			Experimental		
	Heart Rate (bpm)	Distance (miles)	Power (watt)	Heart Rate (bpm)	Distance (miles)	Power (watt)
min 1-4	119.12 ± 17.60	1.85 ± .11	36.60 ± 2.97	119.48 ± 15.23	2.07 ± 1.42	36.91 ± 2.98
min 5-8	127.53 ± 14.05	3.05 ± .24	42.47 ± 7.41	128.68 ± 11.43	3.07 ± .23	43.74 ± 7.04
min 9-12	132.23 ± 10.58	4.37 ± .49	45.50 ± 10.15	133.32 ± 8.75	4.41 ± .46	46.23 ± 8.81
min 13-16	134.35 ± 10.27	5.71 ± .79	46.27 ± 11.18	135.35 ± 8.08	5.75 ± .73	47.11 ± 9.59
min 17-20	136.10 ± 9.41	7.07 ± 1.11	46.67 ± 11.65	136.58 ± 8.02	7.14 ± 1.01	47.20 ± 9.92

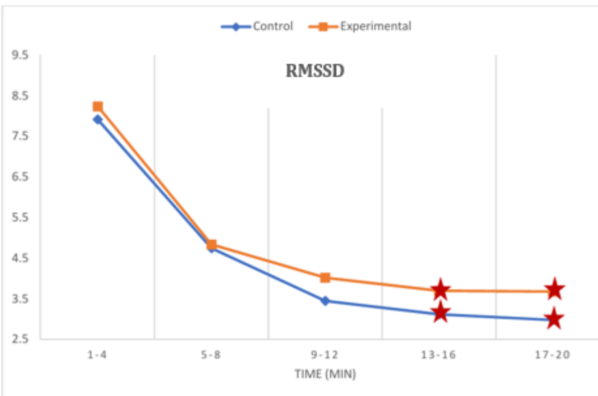
HRV measures

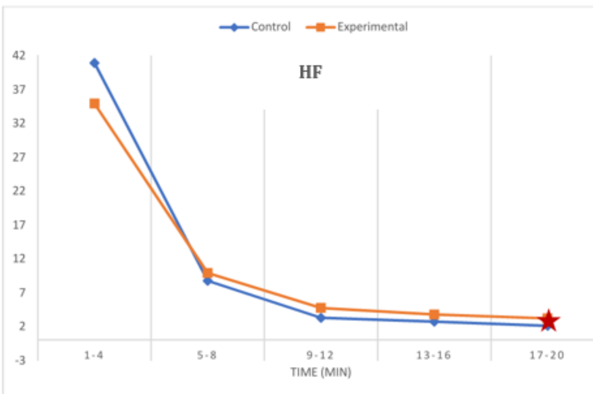
Two 2-way (5 x 2) mixed measures ANOVAs showed no significant multivariate interaction effect for RMSSD, F(4, 80)= 0.80, p= .53 or for HF, F(4, 80)= 0.20, p= .93. The mean scores for the two HRV measures are presented in Table 2. Nevertheless, important trends were identified in the HRV measures and supported by significant pairwise comparisons. In particular, for RMSSD comparisons as a function of group showed that while no significant differences were found between the two groups for minutes 1-4 (p= .79, Mcon= 7.92±6.30, Mexp= 8.24±4.69, d= -0.05), minutes 5-8 (p= .85, Mcon= 4.75±2.44, Mexp= 4.84±1.98, d= -0.04), and minutes 9-12 (p= .10, Mcon= 3.45±1.44, Mexp= 4.02±1.68, d= -0.36), the two groups differed for minutes 13-16 (p= .04, Mcon= 3.12±1.13, Mexp= 3.70±1.32, d= 0.47), and minutes 17-20 (p= .03, Mcon= 2.98±1.06, Mexp= 3.68±1.75, d= -0.48), with the self-talk group displaying higher RMSSD. Additionally, for HF comparisons as a function of group showed that while no significant differences were found between the two groups for minutes 1-4 (p= .64, Mcon= 40.92±75.52, Mexp= 34.95±26.39, d= 0.10), minutes 5-8 (p= .57, Mcon= 8.79±9.63, Mexp= 9.93±8.69, d= -0.12), minutes 9-12 (p= .08, Mcon= 3.33±3.35, Mexp= 4.77±3.94, d= -0.39), and minutes 13-16 (p= .16, Mcon= 2.77±2.69, Mexp= 3.82±3.89, d= -0.31), the two groups differed for minutes 17-20 (p= .04, Mcon= 2.15±1.51, Mexp= 3.25±2.98, Cohen's d= 0.46), with the self-talk group displaying higher HF. These trends are presented in Figures 1.

Table 2. Descriptive statistics for the RMSSD and HF measures.

	RMSSD			HF		
	Control	Experimental	*p*	Control	Experimental	*p*
min 1-4	7.92 ± 6.30	8.24 ± 4.69	.79	40.92 ± 75.52	34.95 ± 36.39	.64
min 5-8	4.75 ± 2.44	4.84 ± 1.98	.85	8.79 ± 9.63	9.93 ± 8.69	.57
min 9-12	3.45 ± 1.44	4.02 ± 1.68	.10	3.33 ± 3.35	4.77 ± 3.94	.08
min 13-16	3.12 ± 1.13	3.70 ± 1.32	.04*	2.77 ± 2.69	3.82 ± 3.89	.16
min 17-20	2.98 ± 1.06	3.68 ± 1.75	.03*	2.15 ± 1.51	3.25 ± 2.98	.04*

Figure 1. RMSSD and HF over time during a 20-minute exercise period for control and experimental groups, showing significant differences with an asterisk (*).





Discussion

The purpose of the present study was to examine the effect of a strategic self-talk intervention on vagal modulation during moderate-intensity aerobic exercise. The findings provided indications that the self-talk group displayed a smaller vagal withdrawal in the latest parts of the cycling task compared to the control group. Laborde et al. (2017) suggested that higher values of RMSSD and HF indicate a more effective cognitive and physiological regulation due to a more efficient use of autonomic resources. The difference in HRV between the two groups became significant after the 13th minute for RMSSD and after the 17th minute for HF, while the shift toward vagal withdrawal began from the onset of the task for both groups. The findings suggest that the effect of the stressful stimulus (exercise) on HRV was stabilized towards the end of the task for the self-talk group, but not for the control group. Accordingly, it can be proposed that the self-talk group exhibited a less effortful performance towards the end of the cycling task.

The present findings appear in line with the body of research, which suggests that self-regulation strategies can shift the nervous system toward a state of vagal pre-dominance (Laborde et al., 2018). In particular, with regard to self-talk, Galanis et al. (2016) postulated that strategic self-talk operates at the cognitive level by affecting motivation and attention in various ways, ultimately influencing task performance. In our study, the effect of strategic self-talk on physiological parameters seems to indicate a shift in nervous system activity, resulting in less effortful task performance. In fact, studies exploring the facilitating effects of strategic self-talk in endurance tasks have forwarded such an interpretation. Blanchfield et al. (2014) in a cycling-to-exhaustion task, Barwood et al. (2015) in a 10-km cycling trial, and Hatzigeorgiadis et al. (2018) in a 30-minute cycling trial under elevated heat conditions, reported through different assessment protocols that the motivational self-talk group displayed superior performance compared to the control group, while reporting similar or lower RPE. These authors interpreted their findings based on the biopsychological model of endurance performance (Marcora, 2010; 2019), which postulates that termination, or disengagement of effort, in endurance tasks is the result of a conscious decision, which reflects motivation and perceptions of exertion. The model further posits that any physiological or psychological factors that may influence these parameters, could have an effect on performance. In the present study, the differences in HRV between the two groups may be associated with reduced RPE in the final stages of the task, an effect which has been also found in the final stages of the 30-minute cycling trial by Hatzigeorgiadis et al. (2018). Our findings suggest that strategic self-talk can play a role in the functioning of the autonomic nervous system, and in particular vagal modulation, thus regulating exertion and facilitating performance.

Some issues should be considered with regard to the interpretation of the findings. First, considering the lack of significant multivariate effects, our interpretation stemming from the results of the pairwise comparisons should be cautious. The lack of multivariate effect could be attributed to the lack of between-group differences in the earlier stages of the task; yet the differences identified in the latest stages of the task are meaningful, because they add to evidence from the self-talk literature suggesting that strategic self-talk can help counter ego-depletion (Galanis, Nurkse et al., 2022). Moreover, the lack of statistical significance may be due to the lack of past evidence for the calculation of power analysis. Subsequently, the present findings can assist in performing more reliable power analysis for the estimation of appropriate sample size. Further limitations of the study include that women participants' menstrual cycle was not taken into account, and the lack of a longer self-talk intervention due to the demanding design and the requirements of the study. Future research should address such limitations and, in addition, involve trained athletes. Moreover, future studies should forward the psychophysiological perspectives of strategic self-talk through the combi-nation of HRV and EEG measures for a more comprehensive understanding of the self-talk mechanisms.

Conclusions

The skill to self-regulate one's body and mind is of particular importance in sport and exercise. Strategic self-talk has proven a valuable tool for facilitating learning and enhancing performance due to its self-regulatory functions. Adding to the evidence regarding the cognitive mechanisms of self-talk, such as attentional efficacy and perceptions of exertion, the present study provided indications for the regulation of physiological functions related to the activation of the autonomic nervous system. The deceleration of the vagal suppression for the self-talk group towards the end of the task, while maintaining similar physical load and performance with the control group, suggests an optimization of physical performance, using fewer resources more efficiently, thus leading to a less effortful performance. The findings, despite the acknowledged limitations, provide valuable preliminary evidence for the self-talk mechanism and further encourage the exploitation of psychophysiological perspectives in self-talk research.

From an applied perspective, considering that self-regulation is an integral part of behaviour and performance, the findings provide valuable preliminary directions for instructors and coaches. The potential of self-talk to improve the regulation of physiological parameters can be crucial for optimizing the efficiency of the resources used by individuals towards the achievement of their cognitive, affective, and performance goals. Accordingly, person-tailored self-talk plans addressing individual needs can be developed, trained, and implemented in training, practice, or competition to enhance individuals' experiences and the attainment of personal goals.

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