Exploring self-talk mechanisms: A psychophysiological approach

by

Zoran Stojković
BSc, University of Victoria, 2015

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Dr. Antonis Hatzigeorgiadis, Associate Professor, Supervisor

Dr. Nikos Comoutos, Assistant Professor, Advisor

Dr. Athanasios Papaioannou, Professor, Advisor

Abstract

The purpose of the present study was to examine whether self-regulated calming self-talk cues may affect autonomic nervous system functioning during moderate intensity aerobic exercise. An experimental design was adopted and heart rate variability was monitored during exercise to to assess changes in the functioning of the sympathetic and the vagal system. Participants were 83 healthy, physically active, non-smoking sport science students (males=47, females=36) with a mean age of 21.02 (± 2.31), who were randomly assigned to experimental (n=44) and control (n=39) groups. Participants cycled at 50% of heart rate reserve for 20 minutes with the experimental group using self-talk following respective instructions. Heart rate variability was recorded during the whole procedure (Polar V800). Heart rate variability measures were averaged to 4 minute intervals and analyzed using repeated measures analysis of variance. The analysis showed non-significant multivariate effects; however, univariate analyses showed significant group by time interactions for RMSSD, HF, LF/HF ratio, and Poincare SD1, during the final 8min of exercising ($p < .05$). These differences reflected greater vagal activation for the experimental group, compared to the control group. The differences observed in the vagal direction may be explained through the calming effects self-talk may have had during exercise, and in particular during the later parts, suggesting a more composed or effortless performance. The present findings should be cautiously interpreted; however, they provide encouraging evidence to further investigate psychophysiological measures for the understating of self-talk effectiveness.

Keywords*: self-talk mechanisms*, heart rate variability, sympathetic, parasympathetic, vagal, autonomic nervous system, RMSSD.

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Declaration by Author

This thesis is composed of my original work, and contains no material previously published or written by another person except where due reference has been made in the text. I have clearly stated the contribution by others to jointly-authored works that I have included in my thesis.

I have clearly stated the contribution of others to my thesis as a whole, including statistical assistance, survey design, data analysis, significant technical procedures, professional editorial advice, and any other original research work used or reported in my thesis. The content of my thesis is the result of work I have carried out since the commencement of my research higher degree candidature and does not include a substantial part of work that has been submitted to qualify for the award of any other degree or diploma in any university or other tertiary institution. I have clearly stated which parts of my thesis, if any, have been submitted to qualify for another award.

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No jointly-authored works.

Statement of Contributions by Others to the Thesis as a Whole

The author of this thesis had a great amount of help from Dr. Antonis Hatzigeorgiadis.

Statement of Parts of the Thesis Submitted to Qualify for the Award of Another Degree

None.

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Dedication

First and foremost, I dedicate this thesis to my grandfather, Marjan Moki Mojsić, who passed away during its writing. We spent a lot of time together in my early childhood while I was figuring out how the world worked and discovering its many beauties and intricacies. Through play filled with patience, curiosity, and passion my grandfather taught me how to think creatively, gave me the courage to strive for my dreams, and modeled what it means to be a loving human being who lives with integrity, honesty and trust. As I grew older, through our many discussions and interactions, he guided me with practical advice and profound life lessons, packaged in a way that would make sense to me. Always calm, patient and selfless, this man will always be a role model to me, as he was a great father and the best grandfather. I am grateful to have had such a positive figure in my life.

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I appreciate you.

Exploring self-talk mechanisms: A psychophysiological approach

Self-talk strategies in sport

Humans use self-talk in everyday life situations, talking and thinking to themselves. The competitive environment is no different. In sport and exercise settings, performers often face high-pressure situations that test their cognitive and physical abilities. Rapid decision-making is needed, and optimal psychophysiological states enhance the performer's psychophysiological functioning. Being equipped with strategies that target these situations enhances performance in the given context. Coaches and sport psychologists teach performers cognitive-behavioral strategies to enhance sport and exercise performance through psychological skills training; a widely used and effective strategy is self-talk (ST), a crucial psychological skill for improving performance (Chang, Ho, et al. 2014; Hatzigeorgiadis, Galanis, Zourbanos, & Theodorakis, 2014; Shannon, Gentner, Patel, & Muccia, 2012).

Hatzigeorgiadis, Zourbanos, Latinjak and Theodorakis (2014) defined ST as "what people say to themselves either silently or aloud, inherently or strategically, to stimulate, direct, react and evaluate events and actions." ST can refer to the past, present or future, can be thought or said aloud, and can be strategic, used with purpose, to focus the performer's attention on a relevant goal in that moment. Galanis and colleagues (2016) explained that strategic cue words at the right moments can get us to focus on a specific strategy, pump us up, or calm us down. With that in mind, the performer must be aware of what is important at that moment, and whether he or she is in the optimal arousal state (too relaxed, just right, too anxious), so that ST cues can be tailored to the performer, context and task to achieve the desired effect (e.g. calm down, focus, get motivated).

Effectiveness of self-talk strategies

Self-talk literature has developed initially within the sport context using motor and sport tasks, and current research trends have shifted towards evaluating the usefulness of self-talk strategies in the exercise domain. Self-talk interventions have been studied as a performance-enhancement tool, and specific characteristics that influence the intervention have been identified. Hatzigeorgiadis, Zourbanos, Galanis and Theodorakis (2011) explored which factors affect the effectiveness of ST, and found the following as important: (1) task characteristics—motor demands (gross, fine), novelty (novel, well-learned), (2) participant characteristics—students, and athletes of varying levels, (3) self-talk characteristics—content (instructional, motivational), selection (assigned, self-selected), overtness (internal, external), and (4) intervention characteristics—length (sessions, time), training (ST only, mental training package), exposure (none, practice, competition).

Various self-talk training programs and interventions have been tested in previous studies. Theodorakis, Hatzigeorgiadis, and Zourbanos (2012) classified self-talk interventions into four levels with regard to the performance context and task characteristics. Interventions tested (1) effectiveness of self-talk on fundamental motor tasks in the field or lab settings, (2) effectiveness of self-talk on performance in different sport skills, (3) self-talk strategies on performance in non-competitive sporting contexts, and (4) effectiveness of self-talk strategies on competitive sport performance. Besides classifying the ST interventions, Theodorakis and colleagues also suggested the matching hypothesis as a way of tailoring ST systematically and strategically which has been supported in the literature (Edwards, Tod, & McGuigan, 2008; Kolovelonis, Goudas, & Dermitzaki, 2011; Tod, Thatcher, McGuigan, & Thatcher, 2008). Through empirical studies, researchers have found that self-talk enhances motor skill and sport performances in various domains (Koloverlonis, Goudas, & Dermitzaki, 2011; Weinberg, Miller, & Horn, 2012). Instructional self-talk strategies have become increasingly common in sport psychology in the last three decades, enhancing performance and aiding learning by stimulating the appropriate responses in the performer (Hatzigeorgiadis, Zourbanos, Galanis, & Theodorakis, 2011; Hatzigeorgiadis, Zourbanos, Galanis, & Theodorakis, 2014).

Self-talk strategies seem to be effective in enhancing learning and boosting performance. These strategies can be used in teaching and training environment, and in competitive contexts. In a systematic review, Tod, Hardy, and Oliver (2011) revealed that (a) positive, instructional, and motivational ST enhance performance, and that (b) cognitive-behavioral elements have the most stable relationship with ST. A meta-analysis of 32 studies revealed a moderate positive effect size (d = 0.48) of ST interventions on performance, with strong evidence supporting the notion that ST interventions are valuable and helpful in performance (Hatzigeorgiadis, Zourbanos, Galanis, & Theodorakis, 2011). The researchers also found that ST works better for fine and novel tasks, then for gross and learned tasks, and that practicing self-talk before using it in competition is crucial. Agreeing with a previous study by Theodorakis and colleagues (2000), Hatzigeorgiadis also discovered that instructional ST cues worked better for fine tasks, motivational cues for gross motor tasks, and that instructional ST was more effective for fine than gross tasks. Further research in the area revealed that instructional ST was better for novel tasks and novice performers, while motivational was more effective for automated, well-learned tasks (Theodorakis, Hatzigeorgiadis, & Zourbanos, 2012). A further suggestion was made by Zourbanos and colleagues (2013) that instructional ST be used in practice settings, and motivational in competitive settings. Effective ST interventions should be tailored to the activity being performed, the context, and personal characteristics (Hatzigeorgiadis, Galanis, Zourbanos,

& Theodorakis 2014; Thomas & Fogarty, 1997; Van Raalte, Vincent, & Brewer, 2016).

Exploring mechanisms behind effectiveness of self-talk interventions

Research, discussion, and exploration of motivational self-talk is prevalent (Hatzigeorgiadis, Zourbanos, Galansis, & Theodorakis, 2011). It would be interesting to see whether calming self-talk works, but by using objective measures alongside the traditional questionnaires. Relationships between self-talk and behavior, cognitions, and affect exist, but research on why self-talk is effective and how it works has been neglected in recent years (Galanis, Hatzigeorgiadis, Zourbanos and Theodorakis, 2016). Past studies evaluating effectiveness and mechanisms of ST interventions (Hardy, Gammage, & Hall, 2001; Hamilton, Scott, & MacDougall, 2007; Galanis, Hatzigeorgiadis, Zourbanos, & Theodorakis, 2016; Van Raalte, Vincent, & Brewer, 2016) lacked physiological and perceptual measures, so the mechanisms behind enhanced work output were unclear. Blanchfield and colleagues (2014) have suggested that cardiorespiratory and musculoenergetic mechanisms have no effect on perception of effort, yet they left our crucial physiological variables such as gaze behavior and heart rate analysis from their study. While self-talk strategies have been found to be effective in enhancing performance, learning and endurance, the mechanisms behind why these strategies work are still being understood, and further exploration in this direction is needed.

In the past 10 years, a wealth of self-talk studies have been conducted and researchers have begun integrating models. Hardy, Oliver and Tod (2009) presented a framework for studying self-talk and applying it within sport. The framework borrows aspects of other psychological theories and models such as Bandura’s self-efficacy theory (1977). From the self-efficacy theory, Hardy and colleagues (2009) integrated context, behavior and performer characteristics into their framework for self-talk study. While the framework gives concrete guidelines and supposed cause and effect relationship direction, it is difficult to evaluate in research and use in practice. Furthermore, Hardy and colleagues created the framework using a comprehensive review of research to date. They suggested that with a need for more empirical research, researchers should examine a range of variables using a range of measurement techniques.

A recent model for evaluating self-talk effectiveness and mechanisms was proposed by Galanis and colleagues (2016). The model views self-talk through the lenses of major psychological theories: cognitive-behavioral therapy (Meichenbaum, 1977), rational-emotive therapy (Ellis, 1976), social-cognitive therapy (Bandura, 1986), and self-regulated learning theory (Schunk, & Zimmerman, 2003). The model postulates a unique view on self-talk mechanisms which includes two groups that mediate effects of self-talk on performance. The first group explains how attention facilitates effects of self-talk, and consists of attentional dimensions (intensity-vigilance, special-orienting, and selectivity-executive) and constructs linked to the examination of self-talk mechanisms (distractibility, width and direction of attention, and mental effort). The second group explains how motivation enhances effects of self-talk, and consists of motivational aspects (cognitive, affective and behavioral) and constructs linked to the study of self-talk mechanisms (self-efficacy, self-confidence and anxiety, and effort and persistence). The researchers suggest that this brand-new model of self-talk mechanisms is still being developed, and will be adapting to incorporate newer research findings in the area.

Investigating psychological and neurophysiological factors will enhance understanding of self-talk effectiveness

Galanis and colleagues (2016) suggested that a multidisciplinary approach involving psychological and neurophysiological variables will greatly enhance our understanding and expand the field. The researchers suggested using heart rate variability measures as a tool to match self-talk responses to autonomic nervous system control, and even to motivational and affective states.

Recently, research incorporating physiological measures into psychological inquiry on self-talk has been used to create a model for further exploration in the area. The psychobiological model of endurance performance, suggests that exhaustion in endurance exercise happens because a conscious decision is made to do so, not because of muscle fatigue as has been previously suggested (Marcora, Staiano, & Manning, 2009; Marcora, & Staiano, 2010). The conscious decision to terminate activity is driven by potential motivation (amount of effort required versus amount of effort allotted), perception of ability to achieve maximum effort, and mental fatigue endured before the exercise task (Blanchfield, Hardy, de Morree, Staiano & Marcora, 2014). The brain plays a huge role in regulating endurance performance and brain function can limit short term endurance performance (Marcora, Staiano, & Manning, 2009). Physical and mental tasks seem to share common neurocognitive resources and doing cognitively draining tasks before endurance exercise seem to make exhaustion occur faster than being well rested mentally (Marcora, Staiano, & Manning, 2009).

Physiological strategies to enhance endurance performance have been examined. Blanchfield and colleagues (2014) conducted a study examining the effects of motivational ST on endurance performance. They found that the ST intervention made participants last longer in endurance exercise, reduced RPE and enhanced endurance performance. The findings from this study support the psychobiological model of endurance performance, and ST interventions tailored to target perception of effort are beneficial to endurance performance. The interesting thing about this study is that the researchers used facial EMG to measure perception of effort, a psychophysiological measure which has been validated in a previous experiment (de Morree & Marcora, 2012). In a recent experimental study, Wallace and colleagues (2016) proposed that motivational ST can change the internal psychophysiological control of exercise, which suggests that ST may be a cognitive-behavioral strategy that can enhance performance. Researchers have begun to incorporate neurophysiological measurements in ST studies, and researchers must create multidisciplinary studies to delve further into understanding ST mechanisms.

Autonomic nervous system activation and how to measure it

Since the genesis of medicine and physiology, heart rate was thought to be controlled involuntarily, through the medulla oblongata, and it is most of the time (Porges, 2001). Porges's research on the Polyvagal Theory was one of the early proponents suggesting that we can control our heart rate voluntarily through our breathing. The realization that there may be cognitive-behavioral strategies that can control our physiology attracted researchers to delve deeper into the topic . It was taught that perhaps identifying cognitive-behavioral strategies may enhance performance by regulating the psychophysiology of the performer.

The autonomic nervous system (ANS) is a branch of the central nervous system, and includes the brain and spinal cord (Stanfield, 2017). The ANS consists of the parasympathetic (PNS; referred to as vagal from now on) and sympathetic (SNS) nervous systems which innervate smooth and cardiac muscle, glands, visceral organs and adipose tissue. The PNS is primarily controlled involuntarily via the vagal nerve, while the SNS is controlled by direct hormonal influence. The vagal nerve and neurotransmitter release is initiated by the executive decision of the central executive in the medulla oblongata, a brain center responsible for regulating vital life functions (Lehrer, 2007; Stanfield, 2017).

The intricate relationship between the dichotomous portions of the ANS launches and maintains a flexible homeostasis despite constantly changing surroundings (Stanfield, 2017). Submaximal endurance exercise training seems to make the PNS more active (higher vagal tone) and the SNS less active (lower sympathetic tone), as evidenced by the different autonomic profiles in trained and untrained performers (Goldsmith, Bloomfield, & Rosenwinkel, 2000). Studies have found cardioprotective changes of baseline vagal activation in patients with heart problems with regular, 20-30-minute endurance training (Coats, Adamopoulos, Radaelli, McCance, Meyer, Bernardi, et al., 1992; Killavuori, Roivonen, Naveri, & Leinonen, 1995; Malfatto, Facchini, Sala, Branzi, Bragato, & Leonetti, 1998). The 8 to 12-week exercise interventions found shifts of nervous system activation from sympathetic towards vagal. This finding agrees with the postulation that trained individuals have more vagally dominant baseline nervous system activation as a result of endurance training (Goldsmith, Bloomfield, & Rosenwinkel, 2000).

The interplay between the PNS and SNS influences the performer as the two systems are on a vagal-sympathetic continuum, adjusting and adapting activation depending on a plethora of psychophysiological factors. During rest and recovery, the PNS is in charge, releasing acetylcholine, and via the Vagus nerve, the following changes occur: increased HRV, decreased HR, decreased myocardial contractility, dilated blood vessels, increased gastrointestinal tract motility, and relaxed the sphincters (Aubert, Sept, & Beckers, 2003; Goldsmith, Bloomfield, & Rosenwinkel, 2000; Stanfield, 2017). The SNS takes over during periods of activity, excitation and stress, inducing the fight-or-flight response. With epinephrine and norepinephrine released into the blood stream, the following changes happen in the heart, lungs, and gastrointestinal tract: decreased HRV, increased HR, increased myocardial contractility, constricted blood vessels, decreased gastrointestinal tract motility, and constricted sphincters (Corrales, Blanca de la Cruz

Torres, Esquivel, Salazar, & Orellana, 2012; Pumprla, Howorka, Groves, Chester, & Nolan, 2002; Goldsmith, Bloomfield, & Rosenwinkel, 2000).

Measuring ANS activity with valid and reliable tools is crucial for both researchers and practitioners. Heart rate variability (HRV) analysis is a valid and reliable way to assess ANS functioning and how the SNS and PNS influence HR (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014). The R complex is part of the QRS wave which every heart beat has, and is detected by an electrocardiogram. The time from one R complex to the next one is called the RR interval (RRI), and in HRV analysis represents one heartbeat. HRV explains how much the RR interval, or time between successive heart beats varies (Kazan, 2013; Niskanen, Tarvainen, Ranta-Aho, & Karjalainen, 2004; Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology [Task Force], 1996). Research is quite certain that HRV analysis shows how the ANS is controlling the heart beat rhythm by analyzing RRI changes between beats, how much the RRI changes and when it stops changing (Khazan, 2013).

Respiratory sinus arrhythmia (RSA) is the most obvious periodic constituent of HRV, and is divided into low-frequency (LF; 0.04-0.15 Hz) and high frequency (HF; 0.15-0.4 Hz) ranges. Although there has been debate over what these two HRV indices represent, researchers have mostly agreed that the HF component is controlled by PNS input only, while LF is controlled by PNS and SNS activity (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014).

There are multiple factors that have been found to influence HRV, and discussion of these factors is beyond the scope of this paper. The factors most prevalent during exercise are: heredity (size of left ventricle and predisposition for the sport activity; Aubert, Sept, & Beckers, 2003), fitness level (Hainsworth, 1998; Natelson, 1985; Ramaekers, 1999; Akselrod, Gordon, Ubel, Shannon, Berger, & Cohen, 1981; Eckberg & Fritsch, 1991; Beckers, Ramaekers & Aubert, 1999), exercise mode (static training or endurance; Aubert, Sept, & Beckers, 2003), body posture, (Mangin, Kobeissi, Lelouche, d' Herouville, Mansier, et al., 2001), hormonal status (McCole, Brown, Moore, Zmuda, Cwynar, & Hagberg, 2000), stimulants (Nishijama, Ikeda, Takamatsu, Kiso, Shibata, Fushiki, & Moritani, 2002), and eating habits (Aubert, Sept, & Beckers, 2003).

Empirical research seems to be going towards multidisciplinary exploration. Following this trend, Galanis and colleagues (2016) suggested that future studies of self-talk should employ a multidisciplinary approach with physiological and neurophysiological variables which would advance our understanding of self-talk mechanisms and help develop effective interventions. Furthermore, the researchers recommended that HRV analysis could be used to evaluate whether self-talk is linked with ANS activation and motivational and affective states. Thus, the idea to use HRV analysis to measure ANS activation and the purpose of the present study arose from Galanis's suggestions.

Purpose

Self-talk has received considerable attention in the last two decades with studies demonstrating its effectiveness in enhancing focus, performance, and motivation (Hardy, Tod, & Oliver, 2009; Hatzigeorgiadis et al, 2014; Van Raalte, Vincent, & Brewer, 2016). However, there is a lack of research incorporating self-talk and physiological measures of arousal. During exercise, performers may be under- or over-aroused, both of which negatively impact performance (Stanfield, 2017). Having specific strategies to optimize ANS functioning would be valuable because then performers would be in a state allowing optimal performance levels.

Galanis and colleagues (2016) suggested that future self-talk research inquiry incorporate physiological and neurophysiological variables, which would expand the field by advancing knowledge of mechanisms behind effectiveness of self-talk and help create more effective interventions. The purpose of this experimental study was to examine whether self-regulated calming self-talk cues affect autonomic nervous system activation during submaximal aerobic exercise. Autonomic nervous system functioning was measured with heart rate variability analysis. It was hypothesized that during exercise self-talk would improve vagal activation.

Method

Participants

Participants were 83 (47 males, 36 females) healthy (no heart problems or medication), physically active, non-smoking, Sport Science students, with a mean age of 21.02 (± 2.31) years. Participants were randomly assigned to experimental (n = 44) and control (n = 39) groups. A Chi-square test revealed no differences in sex distribution, $\chi^2(1) = 8.56$, $p = .38$, whereas t-test revealed no differences in age, $t\ (81) = 1.24$, $p = .22$.

Apparatus

Monark Ergomedic Peak Bike

Participants exercised on a Monark Ergomedic Peak Bike (Monark Ergometic 894-E Peak Bike, Monark, Vansbro, Sweden). The cyclo-ergometer showed pedal-turns per minute/pedal frequency/rotations per minute (RPM), cycling time in minutes and seconds, power output (watts) and distance covered.

Polar V800

Autonomic nervous system function was measured using heart rate variability analysis, a method which is valid and reliable (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014). Heart rate variability was measured using a chest belt (model H7, Polar Electro Oy, Finland) and a wireless receiver (Polar V800, Polar Electro Oy, Finland). Both devices have been validated for measuring HRV in previous studies (Giles, Draper & Neil, 2016; Hernández-Vicente, Santos-Lozano, De Cocker & Garatachea, 2016). After the HRV data was collected onto the Polar V700, it was transmitted to a computer and analyzed using into Kubios HRV analysis software (Version 3.0).

Procedures

The study was approved by the institution’s ethics committee (Ref: 1156, 7 /12/ 2017). Prior to coming into the lab, participants were instructed to avoid strenuous exercise. A systematic protocol was followed in testing the participants. Upon arrival, participants were introduced to the study procedure and equipment, signed consent forms. The Polar chest strap was wetted and fastened securely to the participant’s chest following the manufacturer’s guidelines. HRV recording was initiated and the participant was taken to a quiet room where their resting heart rate was recorded in a supine position for 10 minutes. Resting heart rate was recorded and subsequently the 50th% of heart rate reserve was estimated based on the Karvonen formula (Brooks, 2004).

After being brought back into the experiment room, the participant warmed up on the cyclo-ergometer at 50 RPM for 5 minutes. At this point, the self-talk group during the 5min of the warm up, received instructions and practiced self-talk cues, which were posted on a paper placed in front of them. One minute before the end of the warm up, participants were left alone to think of what the researcher has presented to them and ask for anything they would like concerning self-talk. The cue words “steady and calm” were chosen so participants keep their tempo, and cycle in a more effortless state. Participants of the experimental group were instructed to use the cue words whenever they liked, but also every 2min following a reminder. The participants cycled for 20 min. During the exercise period RPM were adjusted so that heart rate was maintained within the desirable heart rate reserve range (50 ± 5 %).

Distance covered, RPM, and power output (WATT) were recorded every 2 minutes during exercise. Heart rate variability data was recorded throughout the trial. After completing the 20-minute test, participants cooled down for 3 minutes at 50 rpm. Finally, all participants completed a standard self-talk manipulation check (Hatzigeorgiadis et al., 2014). In particular, participants of the experimental group were asked: (a) how often they uses the self-talk cue word of choice (b) whether they used any other self-talk cue words (c) if so, what self-talk cues they used, and (d) if so, how often (on a scale of 1-10). Participants of the control group participants were asked: (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 of 1-10).

HRV indices

In our data analysis and processing we considered a wealth of HRV indices provided by Kubios HRV. We chose to focus on four of the most commonly used indices in research, with a mixture of computational methods which each have their own analysis parameters: time-domain (RMSSD), frequency-domain (HF and LF/HF ratio), and nonlinear (Poincare SD1). After some debate, to our knowledge, studies have agreed on the interpretation of the indices. The four indices reveal where the participant's ANS activation lies on the vagal-sympathetic continuum. For example, vagal activation has been suggested in the following instances: higher RMSSD, HF and Poincare SD1; lower LF/HF ratio. Sympathetic predominance is measured by the opposite findings: lower RMSSD, HF and Poincare SD1; higher LF/HF ratio (Berntson, Lozano, & Chen, 2005; Kim, Park, & Shin, 2010; Corrales, Blanca de la Cruz Torres, Esquivel, Salazar, & Orellana, 2012).

Data screening and analysis

To eliminate erroneous, ectopic and noisy complexes, at times low to medium, and in a few cases strong to very strong artifact correction was used in preprocessing, which is common in HRV studies (Tarvainen, Niskanen, Lipponen, Ranta-Aho, & Karjalainen, 2014). In Kubios

HRV, five 4-minute chunks were created from the 20-minute exercise period following the suggestions of previous research (Task Force, 1996). Time-domain, frequency-domain, and non-linear analysis were used to analyze the HRV data based on recommendations by Tarvainen and colleagues (2014).

Mixed measures ANOVA with one repeated factor (time: four 5min intervals) and one independent factor (group: experimental, control) were used to test for differences in HRV measures across time as a function of group.

Results

Manipulation check

Participants of the experimental group reported consistent use of self-talk during the experimental 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 with one repeated factor (time: five 4-min intervals) and one independent factor (group: experimental, control) were calculated to test for differences in HR, distance covered, and output (Watt) throughout the 30 min of exercising as a function of group. The analysis revealed no significant group by time interaction in any of the control measures; for HR, F (4, 78) = 0.38, p = .81; for distance covered, F (4, 78) = 0.58, p = .68; and for 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 Figures 1-3 below.

Figure 1. Distance covered (miles) over time during a 20-minute exercise period for control and experimental groups, showing no significant differences.

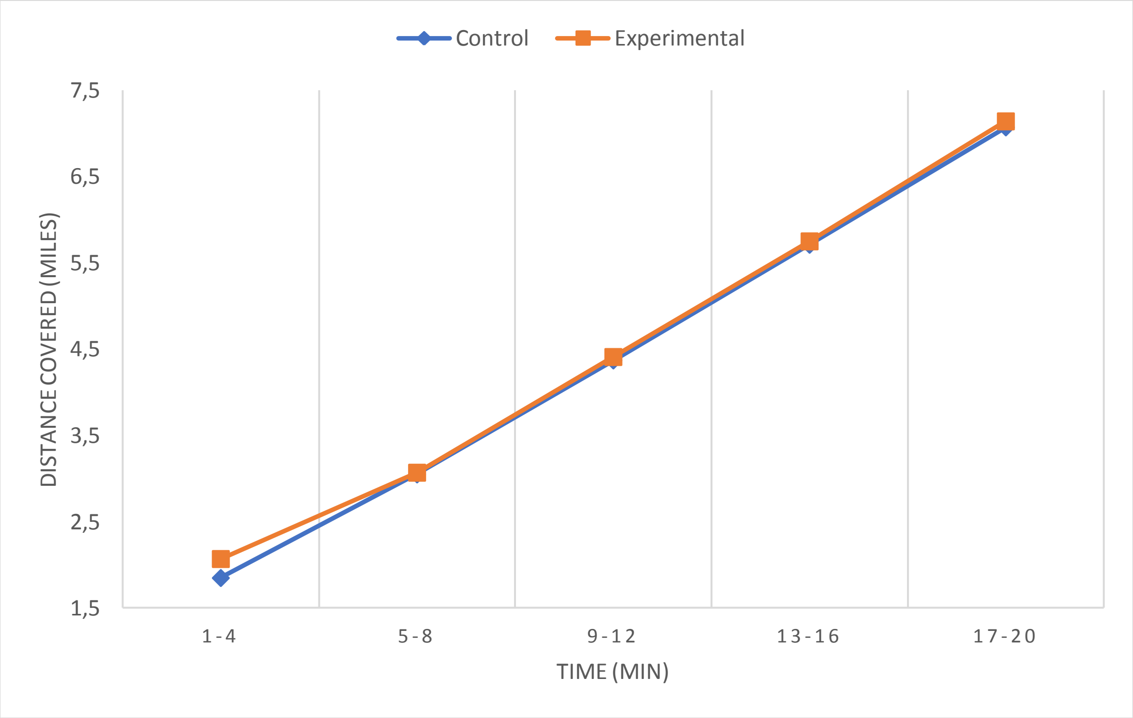


Figure 2. Heart rate (bpm) over time during a 20-minute exercise period for control and experimental groups, showing no significant differences.

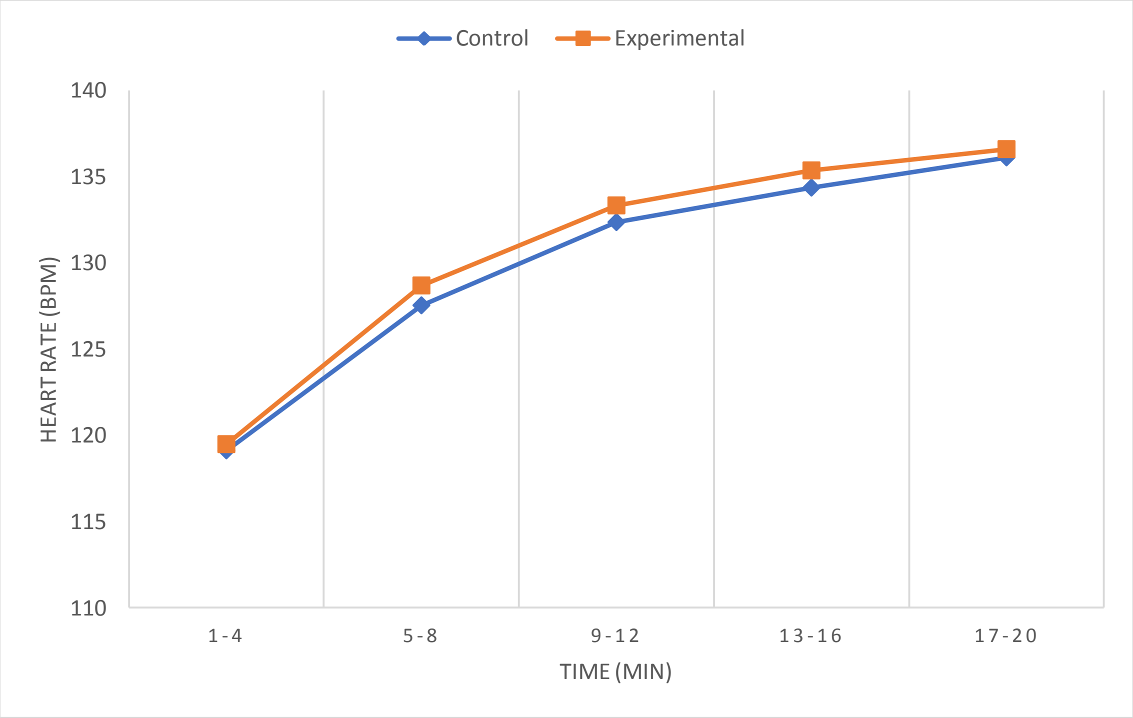
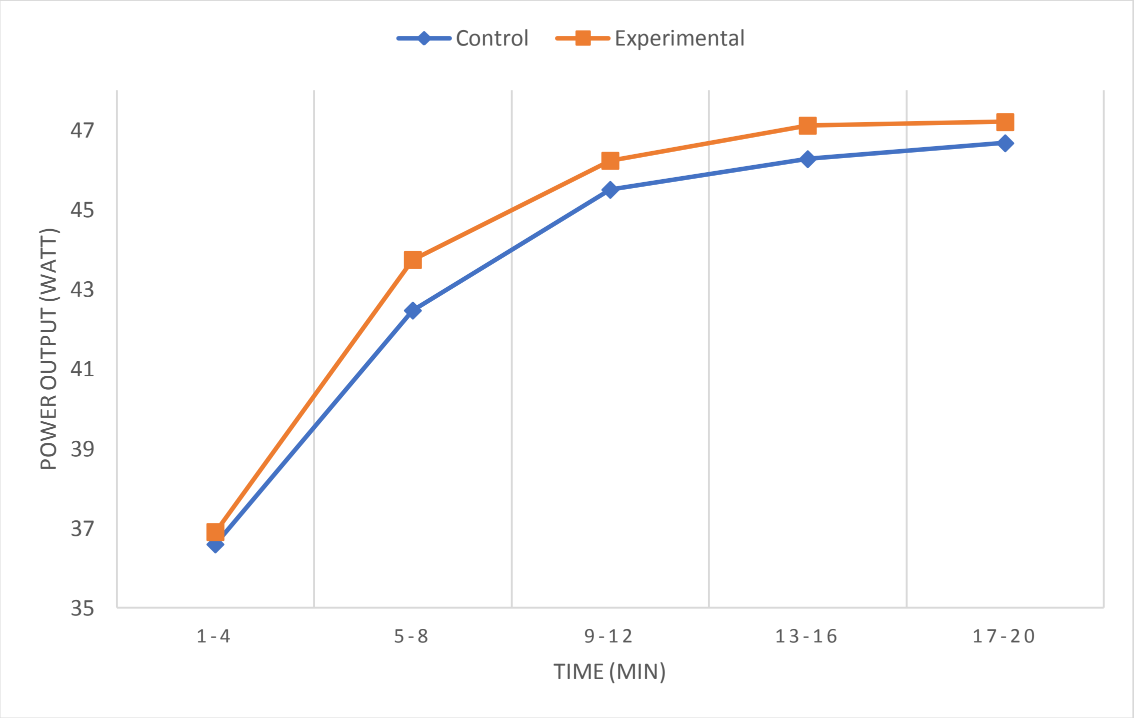


Figure 3. Power output (watt) over time during a 20-minute exercise period for control and experimental groups, showing no significant differences.



HRV measures

Eleven 2-way (5 x 2) mixed measures ANOVAs with one repeated factor (time: five 4-min intervals) and one independent factor (group: experimental, control) were calculated to test for differences in HRV measures. The analyses showed no significant multivariate interaction effect; for Mean RR, *F* (4, 78) = 0.66, *p* = .63; for SDNN, *F* (4, 78) = 0.41, *p* = .80; for mean HR, *F* (4, 78) = 0.67, *p* = .62; for STD HR, *F* (4, 78) = 0.39, *p* = .82; for RMSSD, *F* (4, 80) = 0.80, *p* = .53; for pNN50, *F* (4, 78) = 1.20, *p* = .32; for LF, *F* (4, 78) = 0.57, *p* = .69, for HF, *F* (4, 80) = 0.20, *p* = .93, for LF/HF ratio, *F* (4, 78) = 0.85, *p* = .50; for Poincare SD1, *F* (4, 78) = 0.80, *p* = .53; for Poincare SD2, *F* (4, 78) = 0.32, *p* = .86. The mean scores for all measures are presented in Table 2 in the Appendix.

Nevertheless, some important trends were identified in certain HRV measures, supported through 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 min1-4 (p = .79), min5-8 (p = .85), and min9-12 (p = .10), the two groups differed for min13-16 (p < .05), and min17-20 (p < .05), with the self-talk group displaying higher RMSSD. For HF comparisons as a function of group showed that while no significant differences were found between the two groups for min1-4 (p = .64), min5-8 (p = .57), min9-12 (p = .08), and min13-16 (p = .16), the two groups differed for min17-20 (p < .05), with the self-talk group displaying higher HF. For LF_HF ratio comparisons as a function of group showed that while no significant differences were found between the two groups for min1-4 (p = .37), min5-8 (p = .30), and min.13-16 (p = .06), the two groups differed for min9-12 (p < .05), and min17-20 (p < .05), with the self-talk group displaying lower LF/HF ratio. Finally, for Poincare SD1, comparisons as a function of group showed that while no significant differences were found between the two groups for min1-4 (p = .79), min5-8 (p = .85), and min9-12 (p = .10), the two groups differed for min13-16 (p < .05), and min17-20 (p < .05), with the self-talk group displaying higher Poincare SD1. These trends are presented in Figures 4 through 7.

Figure 4. RMSSD over time during a 20-minute exercise period for control and experimental groups, showing significant differences with an asterisk (*).

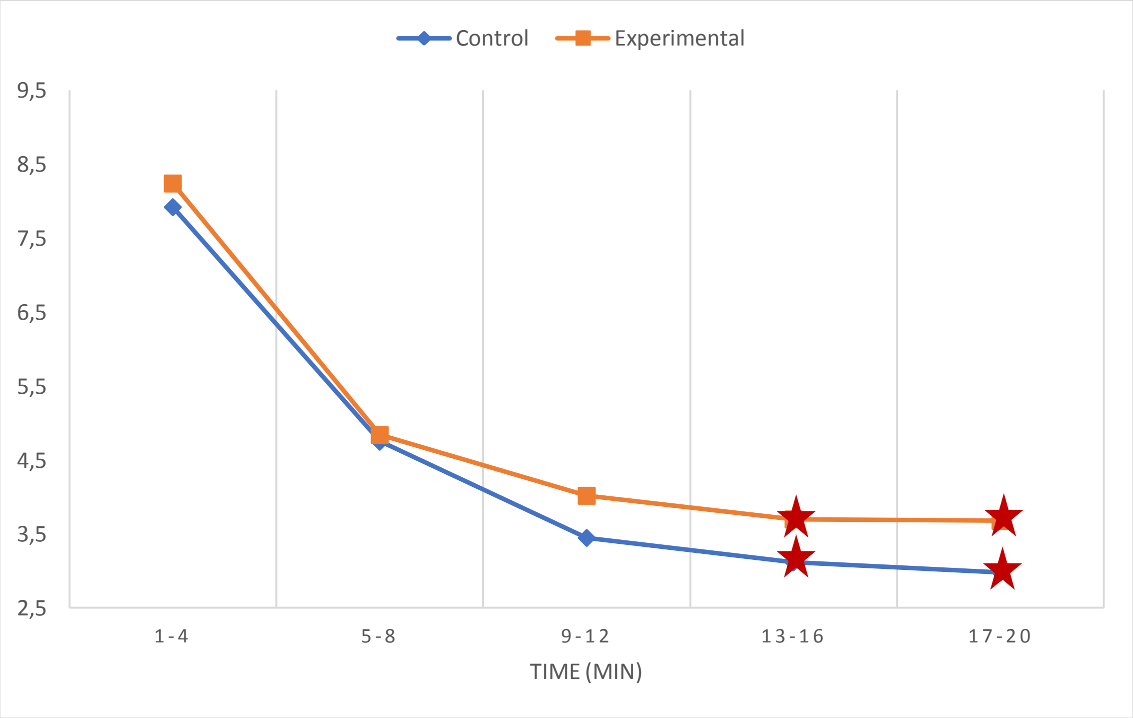


Figure 5. LF/HF ratio over time during a 20-minute exercise period for control and experimental groups, showing significant differences with an asterisk (*).

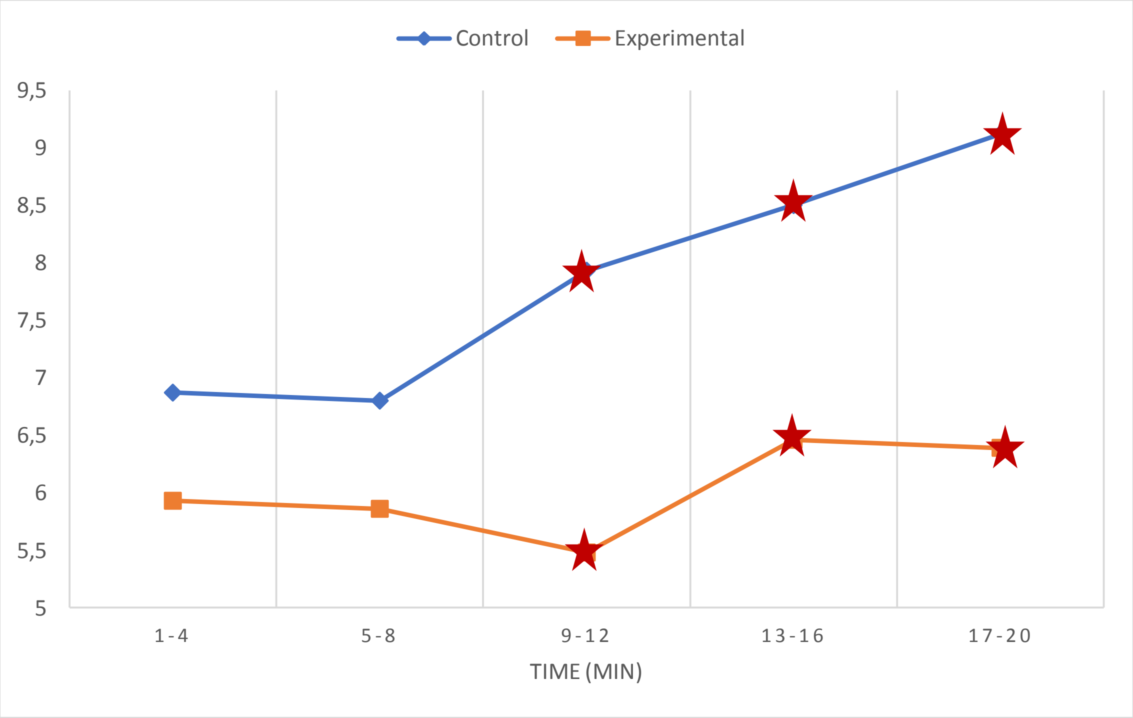


Figure 6. HF over time during a 20-minute exercise period for control and experimental groups, showing significant differences with an asterisk (*).

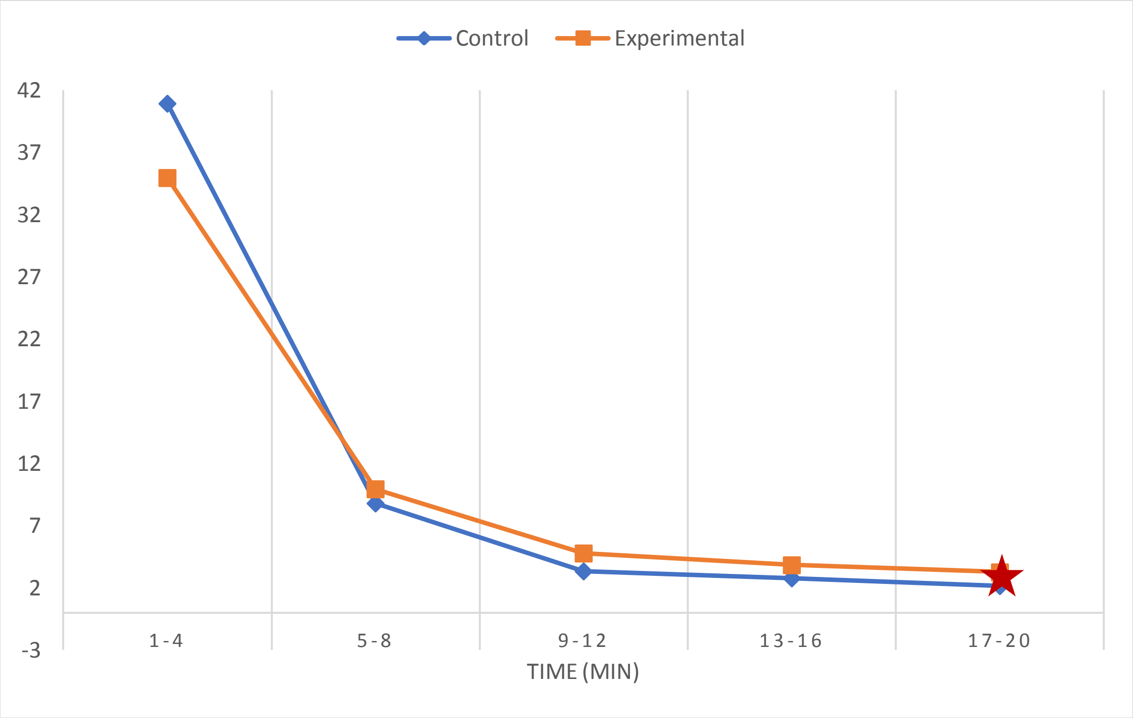
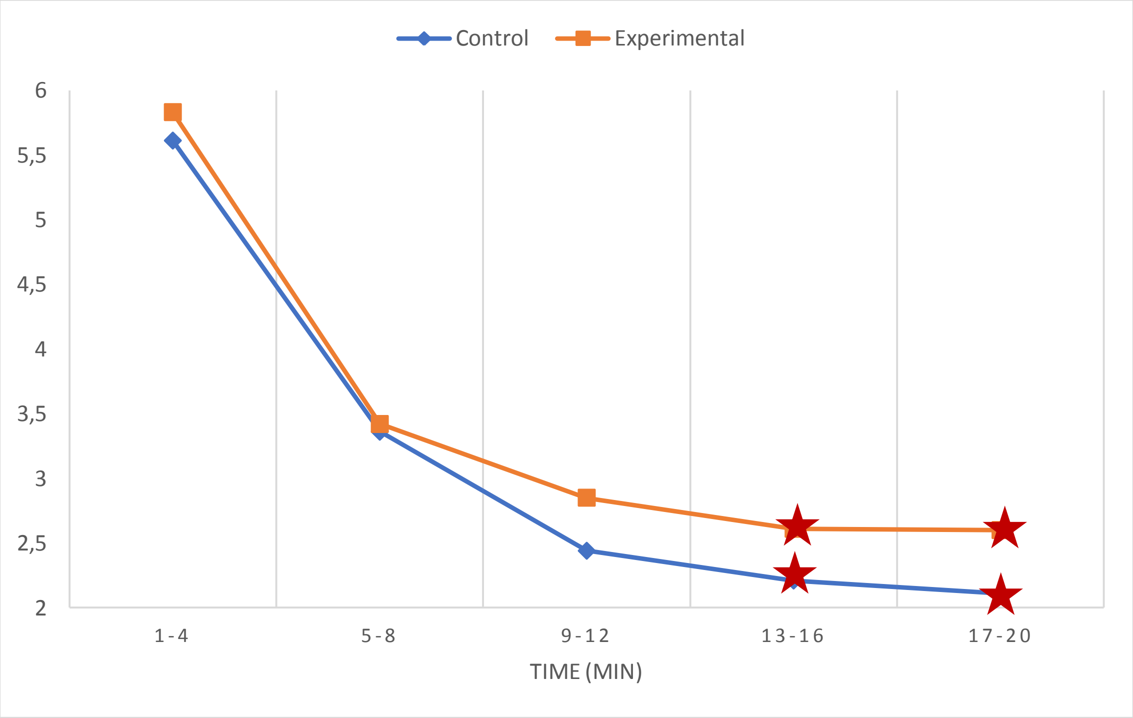


Figure 7. Poincare SD1 over time during a 20-minute exercise period for control and experimental groups, showing significant differences with an asterisk (*).



Discussion

The purpose of the present study was to explore the effectiveness of self-talk on regulating the nervous system during exercise. We decided to examine whether self-talk is a cognitive-behavioral strategy that can influence the autonomic nervous system, and found that it seems to be effective in shifting autonomic nervous system activation towards vagal on the vagal-sympathetic continuum. We evaluated ANS functioning through interpreting HRV data collected with a heart rate detection device. The most commonly used variables in HRV research are the LF/HF ratio, and RMSSD, both indicators of ANS activation. Higher RMSSD values and a lower LF/HF ratio are associated with greater vagal activation, while the opposite findings suggest greater sympathetic involvement (Berntson, Lozano, & Chen, 2005; Kim, Park, & Shin, 2010; Task Force, 1996, Penttilä, Helminen, Jartti, Kuusela, Huikuri, Tulppo, Coffeng, & Scheinin, 2001). For optimal sport performance, higher values in HF, LF/HF ratio, and SD1 and lower RMSSD scores are better because these results indicate vagal predominance. Vagal prevalence suggests that internal physiological conditions allow the performer to experience a more relaxed and effortless performance.

We have found that the control measures (heart rate, distance covered, and power output) showed not significant differences. Higher values of RMSSD and a lower LF/HF ratio occurred from minute 8 for the LF/HF ratio and minute 16 for RMSSD, and grew larger until the end. At these times, the difference between the two groups became significant, while the move towards vagal predominance started earlier for both groups (see figures 1 and 2). A key finding from our study is that effects of the stressful stimulus (exercise) seemed to smoothen at the end for the ST group, and not for the control group. This suggests that the ST group experienced a more relaxed effort during performance, as evidenced by the RMSSD stabilization after minute 8, and LF/HF ratio plateau after minute 16. While the univariate effects were significant and there was a consistent trend, the results should be interpreted with caution as the multivariate effects were non-significant.

Past studies support our finding that self-regulation strategies can shift the nervous system balance towards vagal predominance (Malfatto, Facchini, Sala, Branzi, Bragato, & Leonetti, 1998; Goldsmith, Bloomfield, & Rosenwinkel, 2000). Self-talk has been found to enhance task performance, and more recent studies have found that self-talk assists exercise endurance performance (Blanchfield, Hardy, de Morree, Staiano, & Marcora, 2014). Furthermore, Blanchfield and colleagues found that endurance performance is influenced by exertion, some of which is actual physical exertion, and some which is exertion perceived by the participant (2014). The same researchers linked exertion with vagal activity in performers doing endurance tasks. It seems then, that self-talk may benefit endurance performance through the effective regulation of vagal activity.

Our study is one of the first to delve into self-talk intervention effectiveness research and integrate psychological and neurophysiological approaches in doing so followed the suggestions of Galanis and colleagues (2016). Our findings suggest that self-talk works on the physiological levels, affecting ANS activation of the participants receiving the treatment. Galanis and colleagues (2016) presented a framework based on previous research that suggest that ST works on a cognitive level by affecting motivation and attention through various ways, which ultimately influences task performance. Self-talk seems to affect the physiology of the performer by shifting nervous system activation to produce more effortless exercise performance. The finding that calming self-talk cues influence the performer’s physiology does not seem to fit well into the model of self-talk research proposed by Galanis and colleagues. The researchers explained that their model is a dynamic model, and in future explorations of self-talk mechanisms, they should consider incorporating, besides attention and motivation, other potential effects of self-talk. The findings from the present study suggest that appropriate self-talk can play a role in regulating the autonomic nervous system, and in particular vagal functioning, thus facilitating exertion and continued exercise. Our findings suggest that coaches and sport psychologists should consider tailoring self-talk strategies and experiment with biofeedback devices in training. The most effective self-talk strategies are those that are tailored to the task, the context, and to the performer (Theodorakis, Hatzigeorgiadis, Zourbanos, & 2012). Coaches and sport psychologists should be aware of the aforementioned factors in creating self-talk programs. For example, endurance cycling athletes who are trained will already have optimal nervous system activation during exercise. However, during a competition, they may face distractions, and lose motivation for one reason or another. In these moments, using specific practiced self-talk cues can keep them going or help them focus. Find the activation level range for each performer. Some may need to use self-talk that calms them down, others to pump them up, and some may be at the right levels in which case they should use instructional or goal-directed ST. Using biofeedback training alongside self-talk training can helps practitioners evaluate, monitor, and develop effective intervention strategies of arousal regulation. Understanding the nervous system and how to manipulate its activation has potential to enhance performance and lead towards effortless performance during competition. In addition, considering the intensity of the exercise task, developing and using self-talk plans would be also valuable for recreational exercisers.

Limitations

There are a few limitations that we believe are important to consider. ST training in our study was shorter than has been done in previous studies which could have further enhanced the effects observed and helped identify statistically stronger evidence. In addition it should be mentioned that participants came to the lab at different times of the day, which may have influenced their state of rest. However, that no significant differences of baseline HRV were found between the participants possibly attenuate such external validity factors. Assessing $VO2_{max}$ in coordination with HRV and self-talk would have been ideal and it would have increased the power of our study. However, the proposed suggestions were not possible considering the sample size, but can be done with smaller samples of elite level athletes in combination with extended ST training.

Future research directions

As per the suggestions of Galanis and colleagues (2016) research should incorporate psychological and neurophysiological measures in gauging the effectiveness of self-talk interventions and to further explore and understand the mechanisms. In addition, future studies should replicate our experiment and create a methodology which considers our limitations and suggestions: have an extended ST training program, measure more physiological variables (e.g. $VO2_{max}$), and evaluate only trained athletes. An interesting direction would be to explore how to best identify an optimal nervous system activation range for each individual performer, and how individualized self-talk strategies can be best delivered to bring performers into that range.

Conclusion

The present findings contribute to understanding how calming self-talk affects physiological variables during performance. Competitive contexts require performers to not only understand their body, the performance context, and their task, but also have specific, tailored strategies to use in certain situations, with the overarching goal being performance-enhancement. Our findings suggest that self-talk can calm the performer down on a physiological level, and with little training as evidenced by heart rate variability that pervious research has associated with autonomic nervous system activation. The calming self-talk cues seemed to produce effortless performance in a short time during exercise. Self-talk is a cognitive-behavioral strategy that can be tailored to these specific situations and have a desired effect on the performer's psychophysiological state. To our knowledge, our study is one of the first studies to use objective physiological measures of nervous system activation to evaluate effectiveness of self-talk.

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Table 1. Mean scores for control measures during exercise

	Control	**Experimental**
Heart rate (bpm)		
min 1-4	119.12 ± 17.60	119.48 ± 15.23
min 5-8	127.53 ± 14.05	128.68 ± 11.43
min 9-12	132.23 ± 10.58	133.32 ± 8.75
min 13-16	134.35 ± 10.27	135.35 ± 8.08
min 17-20	136.10 ± 9.41	136.58 ± 8.02
Distance (miles)		
min 1-4	1.85 ± 0.11	2.07 ± 1.42
min 5-8	3.05 ± 0.24	3.07 ± 0.23
min 9-12	4.37 ± 0.49	4.41 ± 0.46
min 13-16	5.71 ± 0.79	5.75 ± 0.73
min 17-20	7.07 ± 1.11	7.14 ± 1.01
Power output (watt)		
min 1-4	36.60 ± 2.97	36.91 ± 2.98
min 5-8	42.47 ± 7.41	43.74 ± 7.04
min 9-12	45.50 ± 10.15	46.23 ± 8.81
min 13-16	46.27 ± 11.18	47.11 ± 9.59
min 17-20	46.67 ± 11.65	47.20 ± 9.92

Table 2. Mean scores for all HRV measures

	Control	**Experimental**	**p**
Mean RRI			
min 1-4	521.50 ± 79.95	519.27 ± 66.50	.89
min 5-8	482.37 ± 57.43	476.52 ± 44.64	.60
min 9-12	458.73 ± 39.62	455.07 ± 31.94	.64
min 13-16	450.18 ± 34.33	447.35 ± 27.63	.68
min 17-20	444.42 ± 31.71	441.97 ± 26.12	.70
SDNN			
min 1-4	12.33 ± 7.64	12.96 ± 6.47	.69
min 5-8	8.01 ± 4.40	7.78 ± 2.77	.78
min 9-12	5.78 ± 2.08	5.77 ± 1.63	.98
min 13-16	5.55 ± 2.38	5.39 ± 1.70	.73
min 17-20	5.12 ± 1.97	5.15 ± 1.61	.94
Mean HR			
min 1-4	117.86 ± 17.62	117.67 ± 15.00	.95
min 5-8	126.19 ± 14.33	127.15 ± 11.81	.74
min 9-12	131.81 ± 11.07	132.55 ± 9.16	.74
min 13-16	134.10 ± 10.04	134.69 ± 8.21	.77
min 17-20	135.73 ± 9.55	136.28 ± 7.98	.78
STD HR			
min 1-4	2.79 ± 1.07	3.05 ± 1.45	.36
min 5-8	2.25 ± 0.83	2.28 ± 0.52	.80
min 9-12	1.87 ± 0.41	1.90 ± 0.42	.71
min 13-16	1.88 ± 0.59	1.88 ± 0.45	.96
min 17-20	1.77 ± 0.45	1.84 ± 0.57	.58

Table 2 (continued). Mean scores for all HRV measures

	Control	Experimental	p
RMSSD			
min 1-4	7.92 ± 6.30	8.24 ± 4.69	.79
min 5-8	4.75 ± 2.44	4.84 ± 1.98	.85
min 9-12	3.45 ± 1.44	4.02 ± 1.68	.10
min 13-16	3.12 ± 1.13	3.70 ± 1.32	.04
min 17-20	2.98 ± 1.06	2.98 ± 1.75	.03
pNN50			
min 1-4	0.29 ± 0.64	0.37 ± 1.16	.69
min 5-8	0.02 ± 0.08	0.00 ± 0.03	.20
min 9-12	0.01 ± 0.06	0.02 ± 0.10	.48
min 13-16	0.00 ± 0.00	0.02 ± 0.10	.16
min 17-20	0.00 ± 0.00	0.03 ± 0.16	.27
LF			
min 1-4	128.33 ± 149.84	146.41 ± 148.695	.58
min 5-8	51.54 ± 73.38	46.09 ± 39.74	.67
min 9-12	22.87 ± 19.93	21.43 ± 15.04	.71
min 13-16	20.51 ± 15.64	19.07 ± 17.82	.70
min 17-20	17.15 ± 13.77	16.98 ± 13.96	.95
HF			
min 1-4	40.92 ± 75.52	34.95 ± 36.39	.64
min 5-8	8.79 ± 9.63	9.93 ± 8.69	.57
min 9-12	3.33 ± 3.35	4.77 ± 3.94	.08
min 13-16	2.77 ± 2.69	3.82 ± 3.89	.16
min 17-20	2.15 ± 1.51	3.25 ± 2.98	.04

Table 2 (continued). Mean scores for all HRV measures

	Control	Experimental	p
LF/HF ratio			
min 1-4	6.87 ± 5.31	5.93 ± 4.15	.37
min 5-8	6.80 ± 4.40	5.86 ± 3.84	.30
min 9-12	7.93 ± 5.69	5.48 ± 2.93	.01
min 13-16	8.50 ± 5.67	6.46 ± 4.15	.06
min 17-20	9.12 ± 6.81	6.39 ± 4.27	.03
Poincare SD1			
min 1-4	5.61 ± 4.46	5.83 ± 3.32	.79
min 5-8	3.36 ± 1.73	3.42 ± 1.40	.85
min 9-12	2.44 ± 1.02	2.85 ± 1.19	.10
min 13-16	2.21 ± 0.80	2.62 ± 0.93	.04
min 17-20	2.11 ± 0.75	2.60 ± 1.24	.03
Poincare SD2			
min 1-4	16.42 ± 9.99	17.27 ± 8.76	.68
min 5-8	10.74 ± 6.09	10.42 ± 3.76	.77
min 9-12	7.76 ± 2.86	7.59 ± 2.19	.75
min 13-16	7.49 ± 3.36	7.11 ± 2.36	.55
min 17-20	6.88 ± 2.78	6.73 ± 2.17	.77