

Exploring self-talk mechanisms: A psychophysiological approach

by

Zoran Stojković

BSc, University of Victoria, 2015

A Thesis Submitted in Partial Fulfillment  
of the Requirements for the Degree of

MASTER OF SCIENCE

in the Department of Physical Education, and Sport Sciences

© Zoran Stojković, 2017

University of Thessaly

All rights reserved. This thesis may not be reproduced in whole or in part, by photocopy or other means, without the permission of the author.

## **Supervisory Committee**

Exploring self-talk mechanisms: A psychophysiological approach

by

Zoran Stojković

BSc, University of Victoria, 2015

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 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 ( $\pm$  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.

## Table of Contents

Supervisory Committee .....	ii
Abstract .....	iii
Declaration by Author .....	vi
List of Tables .....	vii
List of Figures .....	viii
Acknowledgments .....	ix
Dedication .....	x
Exploring self-talk mechanisms: A psychophysiological approach .....	1
Self-talk strategies in sport .....	1
Effectiveness of self-talk strategies .....	2
Exploring mechanisms behind effectiveness of self-talk interventions .....	4
Investigating psychological and neurophysiological factors will enhance understanding of self-talk effectiveness .....	5
Autonomic nervous system activation and how to measure it .....	7
Purpose .....	10
Method .....	12
Participants .....	12
Apparatus .....	12
Procedures .....	13
HRV indices .....	14
Data screening and analysis .....	14

Results .....	16
Manipulation check .....	16
Control measures .....	16
HRV measures.....	18
Discussion.....	22
Limitations .....	25
Future research directions .....	25
Conclusion .....	25
References .....	27

## **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.

I acknowledge that electronic and hard copies of my thesis must be lodged with the University Library.

I acknowledge that copyright of all material contained in my thesis resides with the copyright holder(s) of that material.

### ***Statement of Contributions to Jointly Authored Works Contained in the Thesis***

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.

## List of Tables

Table 1. Mean scores for control measures during exercise .....	31
Table 2. Mean scores for all HRV measures .....	32

## List of Figures

Figure 1. Distance covered (miles) over time during a 20-minute exercise period for control and experimental groups, showing no significant differences. ....	17
Figure 2. Heart rate (bpm) over time during a 20-minute exercise period for control and experimental groups, showing no significant differences. ....	17
Figure 3. Power output (watt) over time during a 20-minute exercise period for control and experimental groups, showing no significant differences. ....	18
Figure 4. RMSSD over time during a 20-minute exercise period for control and experimental groups, showing significant differences with an asterisk (*). ....	20
Figure 5. LF/HF ratio over time during a 20-minute exercise period for control and experimental groups, showing significant differences with an asterisk (*). ....	20
Figure 6. HF over time during a 20-minute exercise period for control and experimental groups, showing significant differences with an asterisk (*). ....	21
Figure 7. Poincare SD1 over time during a 20-minute exercise period for control and experimental groups, showing significant differences with an asterisk (*). ....	21



## Acknowledgments

It would not have been possible to write this thesis without the extraordinary people around me. Foremost, I would like to express my sincere gratitude to the members of my committee—Dr. Antonis Hatzigeorgiadis, Dr. Nikos Comoutos and Dr. Athanasios Papaioannou—for their continued support of my academic pursuit. I would like to express my sincere gratitude to my supervisor, Dr. Antonis Hatzigeorgiadis for the continuous support on this Master's Thesis, for his guidance, support, and patience, advice, motivation, and immense knowledge in the research area. His supervision and friendship have been invaluable to me both on an academic and personal level, for which I am extremely grateful.

I owe my deepest gratitude to Stella Katarachia for her collaboration in carrying out this experiment to completion. I also wish to thank Nadia Filippou for her assistance in making the experiment run smoothly despite setbacks and challenges. I am appreciative of the ideas and suggestions from Evangellos Galanis and Dr. Andreas Flouris throughout the development and completion of this thesis. For their assistance with the experiment in the lab, I wish to thank Jelle Kooijman, Joshua Jenkins, and Laur Nurkse and wish them all the best in your final year of the EMSEP program. The academic support of the University of Thessaly and University of Jyväskylä and their staff, the library facilities and the computer facilities has been paramount. I am thankful for having had the chance to pursue an education at these two institutions in a topic that inspire and moves me.

Finally, I would like to thank my fellow EMSEP students Jochen Abrams, Kanyali Ilako, and Nollaig Ni Charthaigh for their support, counsel, friendship, and adventures throughout our moments in Greece and Finland. I will always remember and cherish our time together.

## 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.

Second, I dedicate this manuscript to my family, Andjela, Milan, and Sladjana, who have been there with me through the whole degree, supporting my progress, giving me strength in challenging times, and providing me with faith in myself when I needed it most.

Third, I dedicate this paper my fiancée, Josipa Miličević, who spent with me hours and hours discussing thesis ideas (even when they were boring), comments, thoughts, and patiently, gave me strength, support, and motivation to endure the workload and overcome the challenges.

Fourth, I dedicate this thesis to Mike Best—my mentor, coach, friend—without whom I would not have even thought of coming to Europe to do a Master’s Degree and whose belief and personal investment in me have shaped my life forever.

Thank you all for your presence, support, and belief in me from start to finish.

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, Galanis, & 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 out 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, excitement 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 ( $\pm$  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 Ergometric 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 50<sup>th</sup>% 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 ( $50 \pm 5 \%$ ).

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

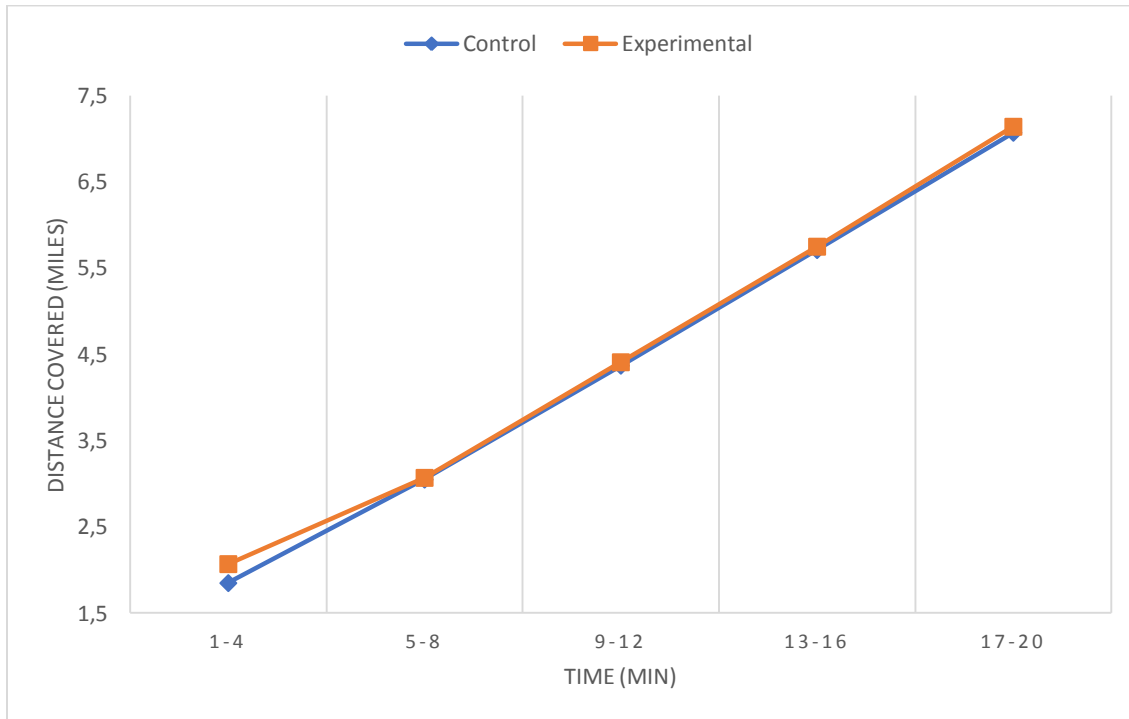
### Manipulation check

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).

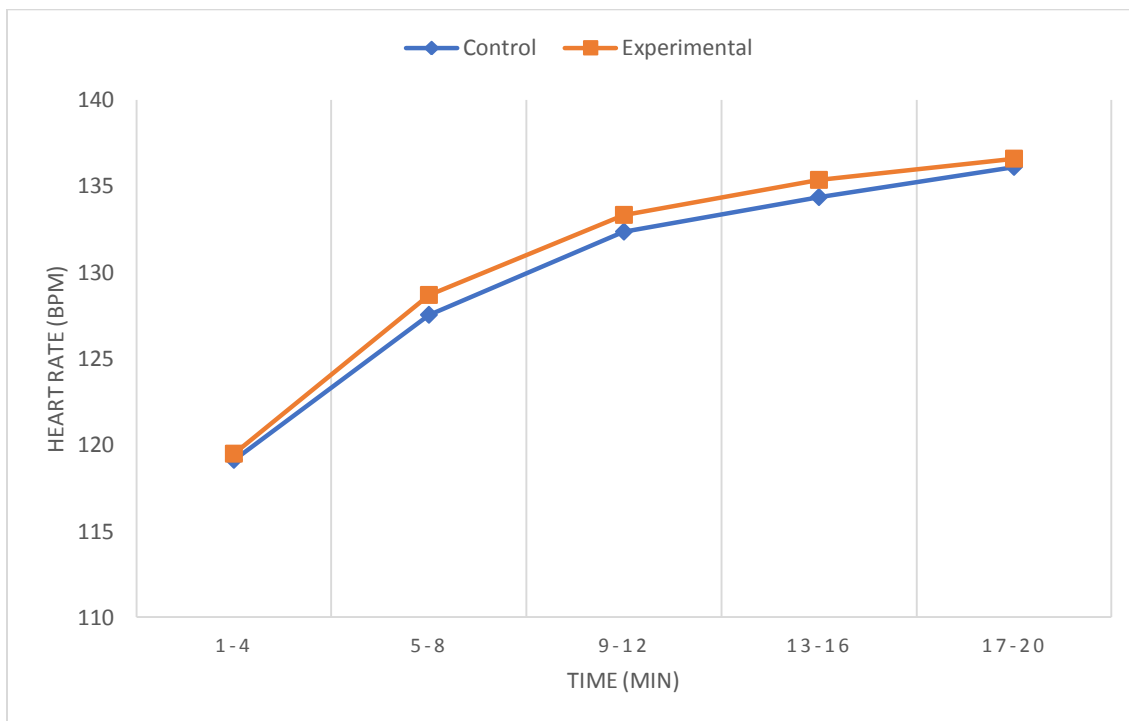
### Control measures

Three 2-way ( $5 \times 2$ ) 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.

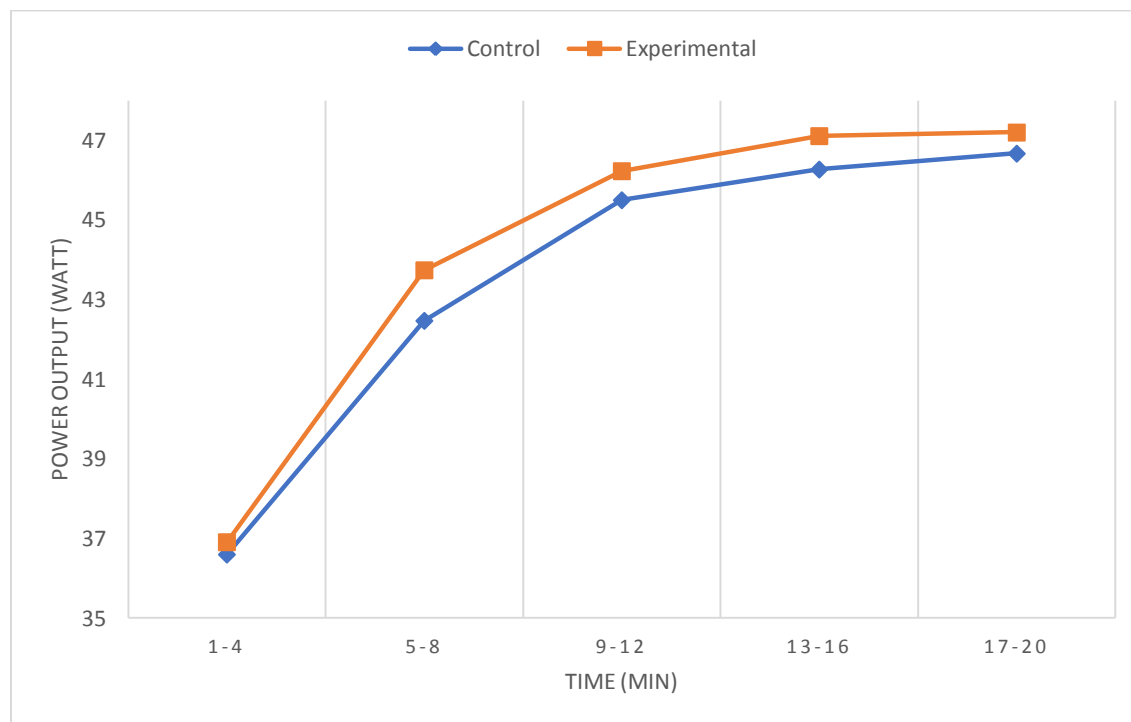
**Figure 1. Distance covered (miles) over time during a 20-minute exercise period for control and experimental groups, showing no significant differences.**



**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.**



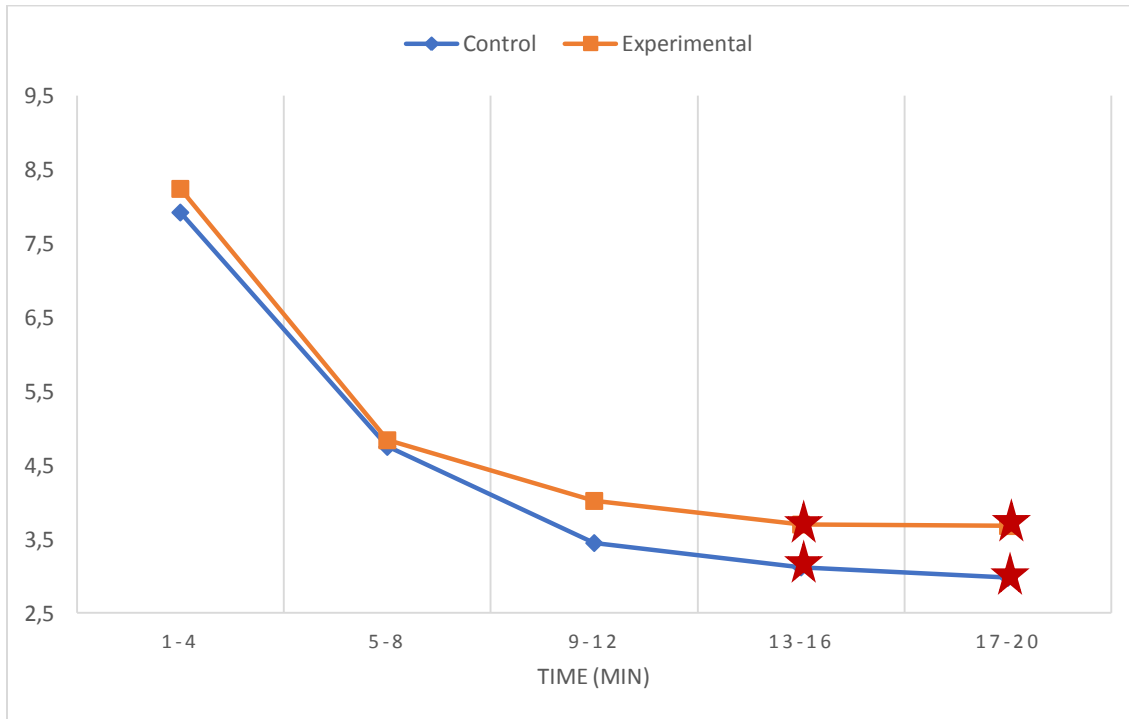
### HRV measures

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.

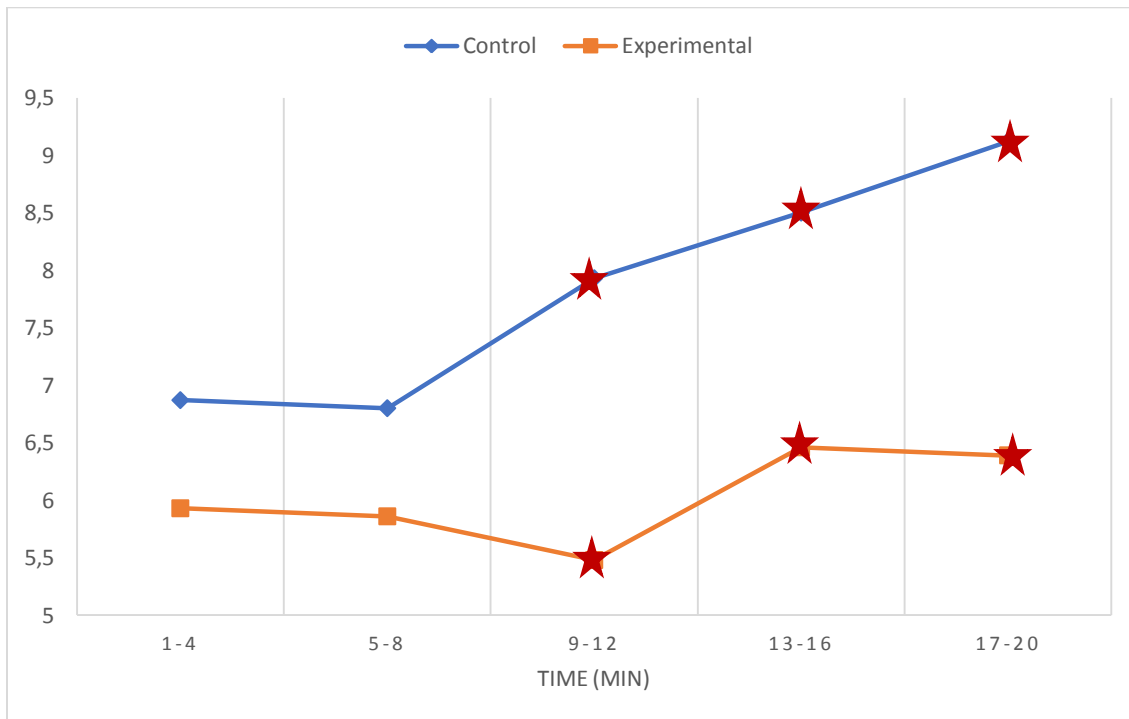
Nevertheless, some important trends were identified in certain HRV measures, supported through significant pairwise comparisons. In particular, for RMSSD comparisons as a function of

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.

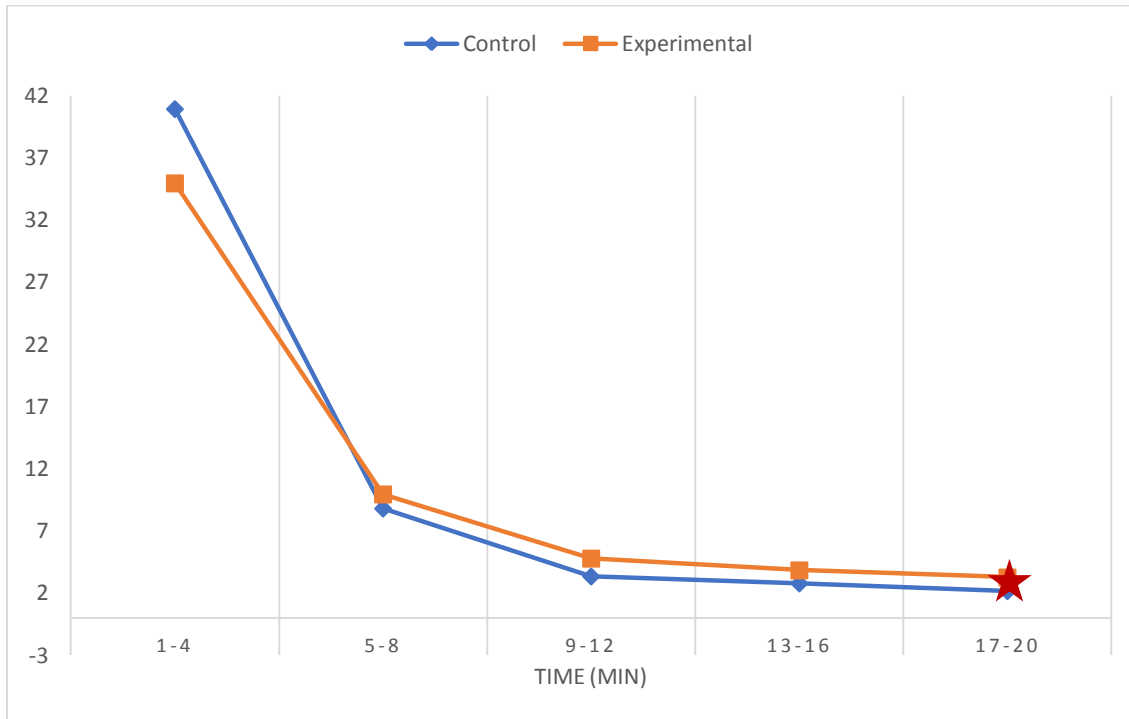
**Figure 4. RMSSD over time during a 20-minute exercise period for control and experimental groups, showing significant differences with an asterisk (\*).**



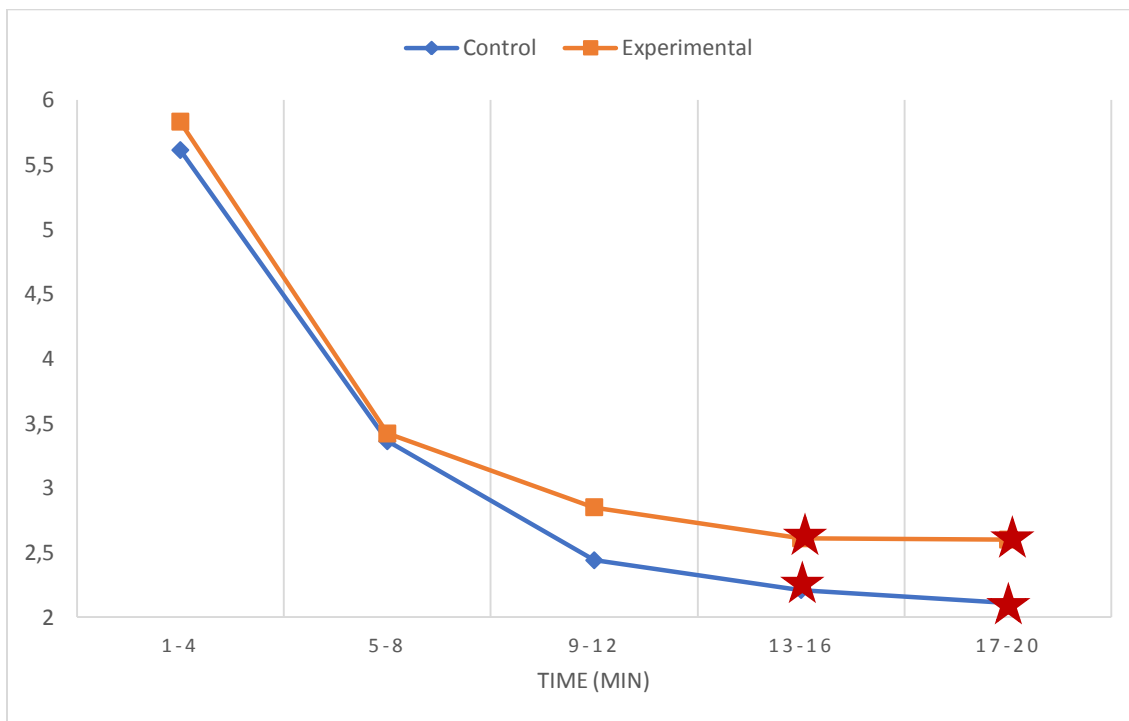
**Figure 5. LF/HF ratio over time during a 20-minute exercise period for control and experimental groups, showing significant differences with an asterisk (\*).**



**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 help 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  $VO_{2max}$  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.  $VO_{2max}$ ), 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 previous 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.

## References

- Akselrod, S., Gordon, D., Ubel, F.A., Shannon, D.C., Berger, A.C., & Cohen, R.J. (1981). Power spectrum analysis of heart rate fluctuation: A quantitative probe of beat-to-beat cardiovascular control. *Science*, *213*, 220–222.
- Aubert, A.E., Seps, B., & Beckers, F. (2003). Heart rate variability in athletes. *Sports Medicine*, *33*, 889-919.
- Bandura, A. (1977). Self-efficacy: toward a unifying theory of behavioral change. *Psychological review*, *84*(2), 191.
- Bandura, A. (1986). *Social foundation of thought and action: A social-cognitive view*. Englewood Cliffs, NJ: Prentice Hall
- Berntson, G. G., Lozano, D. L., & Chen, Y. J. (2005). Filter properties of root mean square successive difference (RMSSD) for heart rate. *Psychophysiology*, *42*(2), 246-252.
- Blanchfield, A. W., Hardy, J., De Morree, H. M., Staiano, W., & Marcora, S. M. (2014). Talking yourself out of exhaustion: the effects of self-talk on endurance performance. *Medicine & Science in Sports & Exercise*, *46*(5), 998-1007.
- Brooks, D. (2004). *The complete book of personal training*. Champaign: Human Kinetics.
- Coats, A. J., Adamopoulos, S., Radaelli, A., McCance, A., Meyer, T. E., Bernardi, L., Solda, P. L., Davey, P., Ormerod, O., & Forfar, C. (1992). Controlled trial of physical training in chronic heart failure. Exercise performance, hemodynamics, ventilation, and autonomic function. *Circulation*, *85*(6), 2119-2131.
- Corrales, M. M., de la Cruz Torres, B., Esquivel, A. G., Salazar, M. A. G., & Orellana, J. N. (2012). Normal values of heart rate variability at rest in a young, healthy and active Mexican population. *Health*, *4*(07), 377.

- de Morree, H. M., & Marcora, S. M. (2012). Frowning muscle activity and perception of effort during constant-workload cycling. *European Journal of Applied Physiology*, *112*(5), 1967-1972.
- Goldsmith, R. L., Bloomfield, D. M., & Rosenwinkel, E. T. (2000). Exercise and autonomic function. *Coronary Artery Disease*, *11*(2), 129-135.
- Giles, D., Draper, N., & Neil, W. (2016). Validity of the Polar V800 heart rate monitor to measure RR intervals at rest. *European Journal of Applied Physiology*, *116*(3), 563-571.
- Hamilton, R. A., Scott, D., & MacDougall, M. P. (2007). Assessing the effectiveness of self-talk interventions on endurance performance. *Journal of Applied Sport Psychology*, *19*(2), 226-239.
- Hardy, J., Gammage, K., & Hall, C. (2001). A descriptive study of athlete self-talk. *The Sport Psychologist*, *15*(3), 306-318.
- Hernández-Vicente, A., Santos-Lozano, A., De Cocker, K., & Garatachea, N. (2016). Validation study of Polar V800 accelerometer. *Annals of Translational Medicine*, *4*(15).
- Khazan, I. Z. (2013). Heart Rate Variability. In I. Z. Khazan (Ed.), *The Clinical Handbook of Biofeedback*, 97-117. West Sussex, UK: John Wiley and Sons.
- Killavuori, K., Toivonen, L., Näveri, H., & Leinonen, H. (1995). Reversal of autonomic derangements by physical training in chronic heart failure assessed by heart rate variability. *European Heart Journal*, *16*(4), 490-495.
- Kim, T., Park, C., & Shin, T. (2010). Comparison of The Changes of HRV Parameters During Incremental Exercise: 2195: Board# 74 June 3 2: 00 PM-3: 30 PM. *Medicine & Science in Sports & Exercise*, *42*(5), 541-542.]

- Lehrer, P.M. (2007). Biofeedback training to increase heart rate variability. In P.M. Lehrer, R.L. Woolfolk, and W.E. Sime (Eds.), *Principles and Practice of Stress Management* (3<sup>rd</sup> ed., pp. 227–248). New York: Guilford Press.
- Malfatto, G., Facchini, M., Sala, L., Branzi, G., Bragato, R., & Leonetti, G. (1998). Effects of cardiac rehabilitation and beta-blocker therapy on heart rate variability after first acute myocardial infarction. *The American Journal of Cardiology*, *81*(7), 834-840.
- Mangin, L., Kobeissi, A., Lelouche, D., d'Herouville, Y., Mansier, P., Swynghedauw, B., & Macquin- Mavier, I. (2001). Simultaneous Analysis of Heart Rate Variability and Myocardial Contractility During Head- Up Tilt in Patients with Vasovagal Syncope. *Journal of Cardiovascular Electrophysiology*, *12*(6), 639-644.
- McCole, S. D., Brown, M. D., Moore, G. E., Zmuda, J. M., Cwynar, J. D., & Hagberg, J. M. (2000). Enhanced cardiovascular hemodynamics in endurance-trained postmenopausal women athletes. *Medicine & Science in Sports & Exercise*, *32*(6), 1073-1079.
- Nishijima, Y., Ikeda, T., Takamatsu, M., Kiso, Y., Shibata, H., Fushiki, T., & Moritani, T. (2002). Influence of caffeine ingestion on autonomic nervous activity during endurance exercise in humans. *European Journal of Applied Physiology*, *87*(6), 475-480.
- Niskanen, J. P., Tarvainen, M. P., Ranta-Aho, P. O., & Karjalainen, P. A. (2004). Software for advanced HRV analysis. *Computer Methods and Programs in Biomedicine*, *76*(1), 73-81.
- Penttilä, J., Helminen, A., Jartti, T., Kuusela, T., Huikuri, H. V., Tulppo, M. P., Coffeng, R., & Scheinin, H. (2001). Time domain, geometrical and frequency domain analysis of cardiac vagal outflow: effects of various respiratory patterns. *Clinical Physiology and Functional Imaging*, *21*(3), 365-376.

- Porges, S. W. (2001). The polyvagal theory: phylogenetic substrates of a social nervous system. *International Journal of Psychophysiology*, 42(2), 123-146.
- Pumprla, J., Howorka, K., Groves, D., Chester, M., & Nolan, J. (2002). Functional assessment of heart rate variability: physiological basis and practical applications. *International Journal of Cardiology*, 84(1), 1-14.
- Schunk, D. H., & Zimmerman, B. J. (2003). Self-regulation and learning. In W. M. Reynolds, & G. E. Miller (Eds.), *Handbook of psychology: Educational Psychology* (pp. 59–78). Hoboken, NJ: Wiley.
- Stanfield, C. L. (2017). *Principles of human physiology* (6<sup>th</sup> ed.). Boston, MA: Pearson.
- Tarvainen, M. P., Niskanen, J. P., Lipponen, J. A., Ranta-Aho, P. O., & Karjalainen, P. A. (2014). Kubios HRV—heart rate variability analysis software. *Computer Methods and Programs in Biomedicine*, 113(1), 210-220.
- Task Force of the European Society of Cardiology and the North American Society of Pacing and Electrophysiology. (1996). Heart rate variability: Standards of measurement, physiological interpretation and clinical use. *Circulation*, 93(5), 1043-1065.
- Theodorakis, Y., Hatzigeorgiadis, A., & Zourbanos, N. (2012). Cognitions: Self-Talk and Performance. In S. Murphy (Ed.), *The Oxford Handbook of Sport and Performance Psychology* (pp. 191-212). Oxford, New York: Oxford University Press.
- Tod, D., Hardy, J., & Oliver, E. (2011). Effects of self-talk: A systematic review. *Journal of Sport and Exercise Psychology*, 33(5), 666-687.
- Wallace, P. J., Mckinlay, B. J., Coletta, N. A., Vlaar, J. I., Taber, M. J., Wilson, P. M., & Cheung, S. S. (2016). Effects of Motivational Self-Talk on Endurance and Cognitive Performance in the Heat. *Medicine & Science in Sports & Exercise*, 49(1), 191-199.



**Table 1. Mean scores for control measures during exercise**

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

**Table 2. Mean scores for all HRV measures**

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

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

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

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

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