Talking Yourself out of Exhaustion:  
The Effects of Self-talk on Endurance Performance

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ABSTRACT

Purpose: The psychobiological model of endurance performance proposes that perception of effort is the ultimate determinant of endurance performance. Therefore, any physiological or psychological factor affecting perception of effort will affect endurance performance. Accordingly this novel study investigated the effects of a frequently used psychological strategy, motivational self-talk (ST), on rating of perceived exertion (RPE) and endurance performance.

Methods: In a randomized between groups pre-test – post-test design, 24 participants (mean ± SD age 24.6 ± 7.5 years; V\textsubscript{O}	extsubscript{2max} 52.3 ± 8.7 ml·kg\textsuperscript{-1}·min\textsuperscript{-1}) performed two constant-load (80% peak power output) cycling time to exhaustion tests (TTE), punctuated by a two week ST intervention or a control phase.

Results: Group (ST vs. Control) x test (Pre-test vs. Post-test) mixed model ANOVA’s revealed that ST significantly enhanced TTE from pre-test to post-test (637 ± 210 s vs. 750 ± 295 s, \(p < 0.05\)) with no change in the control group (486 ± 157 s vs. 474 ± 169 s). Moreover, a group x test x iso-time (0%, 50%, 100%) mixed model ANOVA revealed a significant interaction for RPE, with follow-up tests showing that motivational self-talk significantly reduced RPE at 50% iso-time (7.3 ± 0.6 vs. 6.4 ± 0.8, \(p < 0.05\)), with no significant difference in the control group (6.9 ± 1.9 vs. 7.0 ± 1.7).

Conclusion: This study is the first to demonstrate that ST significantly reduces RPE and enhances endurance performance. The findings support the psychobiological model of endurance performance and illustrate that psychobiological interventions designed to specifically target favorable changes in perception of effort are beneficial to endurance performance. Consequently this psychobiological model offers an important and novel perspective for future research investigations.

Keywords: Perception of effort, psychobiological model, isotime, psychological strategy
The increased popularity of endurance sports in recent decades has coincided with a substantial growth in the number of individuals taking part in endurance based events. As such, the use of performance enhancing strategies is relevant for many competitors when training or taking part in these events. A key aspect of performance in most endurance sports is the ability to sustain aerobic exercise over prolonged periods. The upper limit to this ability, commonly referred to as exhaustion, is traditionally thought to represent the culmination of progressive muscle fatigue (1, 2, 24). Consequently, strategies designed to enhance the performance of endurance competitors frequently target the musculo-energetic and cardio-vascular elements of endurance (24).

Alternatively, the psychobiological model of endurance performance (29, 30, 31), based on motivational intensity theory (7) posits that exhaustion is caused by the conscious decision to terminate endurance exercise, as opposed to muscle fatigue (30). As such, an individual will terminate endurance exercise either when the effort required by the task exceeds the greatest amount of effort that the individual is willing to exert during the task (potential motivation), or when maximal effort is considered to have occurred and continuation of the task is perceived as impossible (29, 30, 31).

According to this psychobiological model, the ultimate determinant of endurance performance in highly motivated subjects is perception of effort; defined as the conscious sensation of how hard, heavy and strenuous exercise is (32). Therefore, it is predicted that any physiological or psychological factor affecting perception of effort will affect endurance performance (29, 30). In support of this perspective, interventions such as sleep deprivation (33), naloxone administration (40) and mental fatigue (30) have been shown to elevate rating of perceived exertion (RPE) and hinder endurance performance, whereas interventions such as physical training (13), nutritional intake (5) and psycho-stimulant manipulations (12, 22) have been shown to reduce RPE and enhance endurance performance. The enhancement of endurance
performance through strategies that specifically target a reduction in perception of effort is therefore appealing. To date however, the scope of strategies that are designed for this purpose remains narrow. Moreover, other than the effects of music (25) and associative/dissociative attentional techniques (28), the exploration of psychological strategies within this context seems minimal. The identification of psychological strategies that are able to reduce RPE and enhance endurance performance therefore warrants further investigation.

One widely used psychological strategy that has been postulated to favor effort based tasks is self-talk (18). Self-talk has been defined as a multidimensional phenomenon concerned with athletes’ self-addressed verbalizations that can serve both instructional and motivational functions (14). This definition is based on the results of qualitative data analyses revealing that self-talk can be broadly categorized as instructional or motivational (18). Moreover, motivational self-talk employed during exercise can be further divided into the auxiliary components of arousal, mastery, and drive (14).

It has been noted that the effort oriented motivational drive function represents the most frequently reported reason for the use of self-talk during exercise, most prevalently towards the end of the workout when the desire to terminate exercise is at its strongest (14). As such, it has been proposed that motivational self-talk should be effective at not only enhancing motivation but at regulating effort (18). Corresponding to the psychobiological model of endurance performance, this suggests that motivational self-talk might be an effective psychological strategy for the enhancement of endurance performance. To date however, many studies that have investigated the use of self-talk during endurance performance have done so within the framework of psychological skills packages (4, 43). As acknowledged by these investigations, this makes the precise benefit of individual components such as self-talk difficult to evaluate.
Despite this, the completion of post-experimental questionnaires has indicated that participants find self-talk to be an effective psychological strategy (4). Even so, very few studies have explored the effects of self-talk upon endurance performance in isolation. Furthermore, no investigation has examined the effects of motivational self-talk upon RPE during endurance exercise. For example, it has been found that assisted positive self-talk, self-regulated positive self-talk, and assisted negative self-talk each enhanced work output during 20-min cycling exercise (16). Nonetheless, the multiple baseline single-subject design provided no indication of statistical analysis thus making the findings difficult to interpret and generalize. Furthermore, physiological and perceptual measures were lacking, making it difficult to determine the mechanisms behind the enhanced work output. Similarly, the effect of self-addressed verbalizations upon performance has been investigated at specific race points during a marathon (38). However, despite finding that self-addressed verbalizations correlated with improved performance, once more physiological and perceptual measures were lacking. Moreover, the non-experimental nature of this study makes it difficult to establish a causal relationship between the use of self-talk and improved endurance performance.

The primary aim of the present study was to investigate experimentally the effect of self-talk on endurance performance during high-intensity cycling exercise. A time to exhaustion test was selected as this test has been shown to be a sensitive measure of endurance performance (3). Furthermore, we measured perception of effort using RPE and a recently developed psychophysiological measure based on the facial expression of effort (10). We hypothesized that motivational self-talk would reduce RPE during high-intensity cycling exercise and that this would increase time to exhaustion.
METHOD

Participant Characteristics and Ethics. Twenty four recreationally trained individuals (15 male and 9 female); [mean ± SD, age 24.6 ± 7.5 years; height 176 ± 7 cm; weight 72.7 ± 10.1 kg; peak power output (PPO) 313 ± 69 W; maximum oxygen uptake (\(\dot{V}O_{2}\max\)) 52.3 ± 8.7 ml·kg\(^{-1}\)·min\(^{-1}\)] volunteered to take part in the study. All participants were healthy, free from injury, and recreationally engaged in a range of individual or team based aerobic sports on a minimum of two occasions per week with an average session duration of 83.3 ± 29.3 minutes. Prior to taking part, all participants completed a standard medical questionnaire to confirm their present state of health along with an informed consent form which was approved by the ethics committee of the School of Sport, Health and Exercise Sciences (SSHES), Bangor University, UK. Participants were provided with a detailed overview of all procedures and requirements of the study prior to its commencement but remained naive to the aims and hypotheses. In addition, upon the cessation of the study, participants were debriefed as to its nature and were requested not to discuss the study with other participants.

Study Design and Procedures. The study consisted of a controlled, pre-test – post-test design in which participants visited the laboratory on three separate occasions and were randomized into two independent groups (\(N = 12\)) after the second visit. The control group contained 7 males and 5 females while the self-talk group contained 8 males and 4 females. All exercise tests were conducted in the same location on the same electromagnetically braked cycle ergometer (Excalibur Sport, Lode, Groningen, the Netherlands), with saddle and handlebar specifications adjusted to suit the preference of each subject and maintained for each visit. During visit one each participant first completed an informed consent questionnaire and an instruction checklist,
after which anthropometric measurements were recorded. An incremental test was then carried out to establish PPO and $\dot{V}O_{2\text{max}}$. The incremental test began with a two minute rest after which power output was increased by 50 W every two minutes until volitional exhaustion. Exhaustion was operationally defined as a reduction in cadence below 60 revolutions per minute (RPM) for 5 consecutive seconds despite strong verbal encouragement. For the incremental test, the cycle ergometer was set in hyperbolic mode, which allows the power output to be set independently of cadence over a range of 30-120 RPM, and the participant was instructed to remain in the saddle at all times. $\dot{V}O_{2\text{max}}$ was measured breath by breath via a computerized metabolic gas analysis system (Metalyzer 3B, Cortex Biophysik, Leipzig, Germany) connected to an oro-(mouth) mask (7600 series, Hans Rudolph, Kansas City, MO). The device was calibrated before each incremental test using a known concentration of gases and a 3.0 liter calibration syringe (Series 5530, Hans Rudolph). PPO was calculated according to the equation of Kuipers, Verstappen, Keizer, Geurten, & van Kranenburg (26). Resting heart rate was recorded 15 seconds from the end of the two minute rest using wireless chest strap radio telemetry (S610, Polar Electro, Kempele, Finland) and was then measured every minute during the incremental test thereafter. RPE was also recorded every minute during the incremental test using the CR10 scale (see “Perceptual and psychophysiological measures of effort” section for details).

During visit two, participants first completed an instruction checklist followed by separate mood and motivation questionnaires (see “Psychological questionnaires” section for details). Following this, participants completed a time to exhaustion test. For the time to exhaustion test, subjects were positioned on the cycle ergometer (set to hyperbolic mode) and instructed to remain in the saddle at all times. The time to exhaustion test commenced with a three minute warm up at 40% of the participants PPO. After three minutes, the power output was
automatically increased to a power output corresponding to 80% PPO. Cadence was freely chosen between 60 – 100 RPM and was recorded every minute during the task. RPE was also recorded at one minute intervals using the CR10 scale along with heart rate (see “Additional physiological measures” section for details). Bipolar single differential surface electromyography (EMG) was recorded from the corrugator supercilii throughout (see “Perceptual and psychophysiological measures of effort” section for details). Time to exhaustion was defined as the time accrued from the onset of the 80% PPO until the point at which cadence had fallen below 60 RPM for five consecutive seconds. No verbal encouragement was provided at any point during the time to exhaustion test so as to eliminate the superimposition of any extraneous verbal statements. A fan was placed approximately 60 cm in front of the cycle ergometer. Participants were provided with the option of being tested with or without the use of the fan and completed the subsequent time to exhaustion test under identical conditions. To avoid bias from mimicry and audience effects upon facial EMG measurements, the experimenter stood behind participants at all times (41). Three minutes after exhaustion, participants provided a blood sample for lactate concentration analysis (see “Additional physiological measures” section for details). Random allocation took place at this point (www.randomization.com) with participants allocated to the self-talk group carrying out a two-stage intervention over the ensuing two weeks (see “Motivational self-talk intervention” section for more details) while participants allocated to the control group received no intervention. Both groups were instructed to continue with their usual aerobic exercise regimen during this two week period.

All testing procedures carried out during visit two were replicated during visit three; participants in the self-talk group were reminded to make use of their four self-talk statements during the time to exhaustion test. At the end of visit three, all participants completed a
A manipulation check questionnaire (see “Manipulation checks” section for details) and remained naive to their cycling times during visits two and three until the debriefing that followed the manipulation checks.

Visits one and two were separated by a minimum of 72 hours, while visits two and three were punctuated by a minimum of 14 days, during which the motivational self-talk intervention (self-talk group) or usual exercise without the self-talk intervention (control group) took place. All participants visited the laboratory at a similar time of day for each of their visits. As instructed before each visit, participants maintained similar dietary patterns during the preceding 24 hours while consuming an amount of water equivalent to at least 35 ml·kg\(^{-1}\) body weight and attaining at least 7 hours of sleep the night before. Participants also avoided any heavy exercise in the 24 hours prior to testing and refrained from the consumption of caffeine and nicotine in the 3 hour period leading up to each test. Finally, participants voided before each test and performed during all visits in similar clothing.

**Motivational Self-talk Intervention.** Analogous to Thelwell and Greenlees (43) the motivational self-talk intervention was administered in two stages and involved the use of a workbook. Stage one occurred after the first time to exhaustion test (pre-test), and comprised of a 30 minute introduction to self-talk along with the identification and development of four motivational self-talk statements. Stage two consisted of the practical use of these statements during their customary aerobic exercise sessions throughout the two week intervention. This format was used to facilitate the personalized and practised use of each statement.
During stage one, participants were introduced to the concept of self-talk and provided with a workbook in which they highlighted any self-talk statements that they had used in the preceding time to exhaustion test. From this pool of self-statements, participants identified up to five that were deemed to be motivational and compared them to a set of 12 pre-listed motivational statements (e.g., “drive forward”, “you’re doing well”) generated from the existent self-talk literature. From these two lists participants were requested to select four statements that would optimize their performance during a time to exhaustion test identical to the one previously carried out. It was instructed that two of these statements should be relevant to the early-mid stage of such test (e.g., “feeling good”) with the remaining two being more applicable to the last stage of the test near exhaustion (e.g., “push through this”). This approach was chosen so as to identify the contextual influence of verbal statements (27) upon specific stages of the time to exhaustion test.

Stage two was a familiarization phase in which participants were instructed to continue with their own training whilst using their selected statements, during a minimum of three aerobic exercise sessions over the two week period. After each aerobic exercise session, participants completed a workbook protocol to assist them in assessing the use and efficacy of each of their four chosen statements during the session. Effective statements were noted and employed in the subsequent aerobic exercise sessions; whereas ineffective statements were either re-phrased or replaced with a more suitable statement (as deemed by the participants). This process was designed to ensure that participants were comfortable with the use of their four motivational self-statements when they performed the second time to exhaustion test (post-test).
**Manipulation Checks.** Following the second time to exhaustion test (post-test), each participant completed a questionnaire based manipulation check. For both groups, this manipulation check assessed adherence to their respective manipulation instructions on an 11-point Likert type scale (0 = not at all, 10 = greatly). The remainder of the manipulation check questionnaire was specific to each group. The manipulation check for the self-talk group was designed to measure the extent of self-talk usage during the time to exhaustion test. The manipulation check for the control group was designed to disclose any use of self-talk during the time to exhaustion test. If participants in the control group used some form of self-talk, space was allocated to reveal each statement used along with its extent of use, measured on an 11-point Likert type scale (0 = rarely, 10 = very often). For the self-talk group, space was allocated to highlight each motivational self-talk statement that they had used during the time to exhaustion test, both designated and undesignated. Again the extent of use for each statement was also indicated.

**Perceptual and Psychophysiological Measures of Effort.** RPE was measured using the 11-point CR10 scale developed by Borg (6). Low (0.5 “very, very light”) and high (10 “maximal”) anchors were established using standard procedures (36). Participants were also free to rate a value above 10 if they perceived their state of effort as higher than any previous maximal effort experienced. Standardized instructions for perceived exertion were provided to all participants prior to each test with the emphasis that each rating should be based upon the effort required to perform the time to exhaustion test as opposed to any leg muscle pain occurring during high-intensity cycling exercise.
Facial EMG has been shown to be a valid psychophysiological measure of perceived effort during a time to exhaustion test of similar exercise intensity (11). Therefore bipolar single differential surface facial EMG amplitude was recorded from the left and right corrugator supercilii muscles throughout the time to exhaustion test. Prior to electrode placement the site above the brows was cleaned with an alcohol swab and the skin carefully dried with a tissue. On each side of the face, one pre-gelled Ag/AgCl electrode (Neuroline 720-00-S, Ambu inc. Ølstykke, Denmark; recording area: ø 11 mm) was attached lateral to the glabellar midline. An additional electrode was attached immediately lateral to each of these placements just superior to the medial border of the eyebrow with a 40 mm inter-electrode distance (10). A ground strap was then placed around the wrist of the participant. The EMG signals were amplified by a multichannel EMG amplifier (EMG 16, OT Bioelettronica, Torino, Italy; Bandwidth: 10-500 Hz, 4th order Bessel low pass filter), fed into a 12-bit acquisition board (DAQCard-6024E, National Instruments Corporation, Austin, TX) at a sampling rate of 2048 Hz, displayed on a PC, and recorded for later offline analysis. Participants were unaware of the real purpose of the facial electrodes and were told that they were used to measure brain activity. EMG data were analyzed offline using Matlab version 7.12. The data were filtered with a zero-lag, bandpass, 4th order Butterworth filter (cutoff frequencies 20 and 400 Hz). The root mean square (RMS) of the facial EMG data was calculated over 1-min periods.

Additional Physiological Measures. Heart rate was recorded throughout the time to exhaustion test using wireless chest strap radio telemetry (S610, Polar Electro, Kempele, Finland). Before testing, the chest strap was wetted and securely fastened to the participant’s chest according to the manufacturer’s guidelines. Lactate concentration was measured by collecting 5 μl of whole
fresh blood from the earlobe three minutes after the time to exhaustion test. Each blood sample was immediately analyzed using a calibrated device (Lactate Pro LT-1710, Arkray, Shiga, Japan).

**Psychological Questionnaires.** The Brunel Mood Scale (BRUMS) was used to assess mood before each time to exhaustion test. This abbreviated 24-item profile of mood states has been validated for use with adult populations (42). This mood questionnaire includes six subscales (anger, confusion, depression, fatigue, tension, and vigor) with four items per subscale. Items were answered on a 5-point Likert type scale (0 = not at all, 1 = a little, 2 = moderately, 3 = quite a bit, 4 = extremely).

Motivation was measured via the success motivation and intrinsic motivation scales developed and validated by Mathews, Campbell, and Falconer (34). Each subscale consists of seven items on a 5-point Likert type scale with identical anchors to those described above.

**Statistical Analyses.** Unless otherwise noted, data are shown as mean ± SD. Age, \( \dot{V}O_{2\text{max}} \) and PPO were assessed for between group differences using independent \( t \)-tests. Manipulation checks were also assessed using independent \( t \)-tests to check for group differences in adherence to task instructions, number of self-talk statements used during the second time to exhaustion test (post-test), and also their mean extent of use. After checking relevant parametric assumptions, group x test ANOVAs assessed for the effects of motivational self-talk on mood and motivation, time to exhaustion, mean cadence and various measures at exhaustion (RPE, facial EMG amplitude, heart rate, and blood lactate concentration). If assumptions of sphericity were violated the Greenhouse-Geisser correction was used while Tukeys HSD post hoc tests were calculated.
where appropriate. Group x test x time ANOVAs were used to test the effects of motivational self-talk on RPE, facial EMG amplitude, heart rate, and cadence at 0% (first minute), 50%, and 100% (final full minute completed) of time to exhaustion. These variables were measured at the selected time-points to allow the within-group comparison of temporal changes that may arise during the time to exhaustion test. In order to obtain this iso-time data, the value of each parameter at 100% iso-time was established by identifying the shortest time to exhaustion accomplished by each individual over their two tests. The value for each variable attained during the final full minute of the shortest time to exhaustion test was then compared to the value attained during the equivalent minute of the longer time to exhaustion test. The minute identified as 100% iso-time was divided by two and rounded up where necessary to attain the value corresponding to 50% iso-time. Iso-time values for 0% were attained by comparing values for the first full minute of each time to exhaustion test. Cohen’s $d$ (9) values are provided as an estimate of effect size where relevant. Thresholds for trivial, small, moderate, or large effect sizes were set at $< 0.2$, $0.2$, $0.5$, and $0.8$ respectively (9). Statistical significance was set at $p < 0.05$ (two-tailed) for all analyses and all data analysis was conducted using the statistical package for social sciences (SPSS version 14).

RESULTS

Group Characteristics and Manipulation Checks. Age, $V_{O2max}$ and PPO were not statistically different between groups (see Table 1), while the manipulation check questionnaire revealed that both groups adhered equally to their task instructions, $t(21) = -1.01, p = 0.32$. Given the nature of self-talk it is unsurprising that ten of the twelve participants in the control group reported limited use of self-talk. However, compared to the self-talk group, self-talk within the control group was
used infrequently. The self-talk group used significantly more self-talk statements than the control group, $t(22) = -3.9$, $p = 0.001$ (4.1 ± 1.5 vs. 1.8 ± 1.4) and to a significantly greater extent, $t(15.48) = -2.16$, $p = 0.047$ (6.9 ± 1.4 vs. 4.9 ± 2.9). Motivational self-talk was therefore used differently and more extensively in the self-talk group compared to the control group.

**Insert Table 1 here**

**Effects of Self-talk on Mood and Motivation Before the Time to Exhaustion Test.**

Participants commenced the time to exhaustion test during each visit in similar mood, as indicated by the fact that no group x test interactions or main effects of test were present for ratings on all BRUMS subscales (see Table 2). Also, no group x test interactions or main effects of test were present for success motivation and intrinsic motivation with mean ratings for each of these scales signifying that participants in both groups were highly motivated to participate and perform well in the time to exhaustion test on both occasions (see Table 2).

**Insert Table 2 here**

**Effect of Self-talk on Time to Exhaustion.** As predicted, motivational self-talk had a significant effect on time to exhaustion, (group x test interaction, $F(1,22) = 8.01$, $p = 0.01$, $d = 0.69$). Follow up tests revealed that time to exhaustion increased significantly from pre-test (637 ± 210 seconds) to post-test (751 ± 295 seconds) in the self-talk group ($p < 0.05$). Moreover, all but two of the participants randomized to the motivational self-talk intervention improved their time to exhaustion. In comparison, time to exhaustion in the control group did not change significantly.
across tests (pre-test 487 ± 157 seconds, post-test 475 ± 169 seconds) (see Figure 1). Pre-test
time to exhaustion was significantly different between groups however. Consequently, further
analysis was carried out using ANCOVA whereby baseline TTE was controlled as the covariate.
Accordingly, the effect of motivational self-talk upon TTE remained significant, $F(1,21) = 4.49,$
$p = 0.046$.

**Insert Figure 1 here**

**Effects of Self-talk on RPE, Facial EMG Amplitude, Heart rate, and Blood Lactate Concentration at Exhaustion.** No significant group x test interaction or main effect of test were present for RPE at exhaustion. Importantly, RPE values at exhaustion indicated that participants in both groups disengaged from the time to exhaustion test upon reaching maximal effort during both the pre-test and post-test visits (see Table 3 and Figure 2). Similarly no group x test interactions and main effects of test were evident for facial EMG amplitude throughout the last full minute prior to exhaustion, heart rate at exhaustion, and blood lactate concentration sampled 3 min after exhaustion (see Table 3).

**Insert Table 3 here**

**Effects of Self-talk on Cadence, Heart Rate, Facial EMG Amplitude, and RPE at Iso-time During the Time to Exhaustion Test.** Mean calculated iso-times were greater for the self-talk group at both 50% and 100% with mean 50% iso-time occurring at $315 ± 109$ s for the self-talk group in comparison to $230 ± 80$ s for the control group and mean 100% iso-time occurring at
624 ± 228 s for the self-talk group and 430 ± 163 s for the control group. Iso-time data for cadence, heart rate, facial EMG amplitude and RPE are reported in Table 4.

Motivational self-talk had a significant effect on cadence at iso-time (group x test x iso-time interaction $F(2,40) = 8.34, p = 0.01$. Follow up tests revealed no significant effect of motivational self-talk at 0% iso-time and 50% iso-time. A significant group x test interaction was present at 100% iso-time ($F(1,20) = 11.46, p = 0.003, d = 2.2$). Further follow-up tests revealed that cadence was significantly greater in the self-talk group at 100% iso-time during post-test compared to pre-test visit ($p < 0.05$). No significant difference between pre-test and post-test was found for cadence at 100% iso-time in the control group.

Motivational self-talk did not affect heart rate and facial EMG amplitude, with no significant group x test x iso-time interactions present for these variables. However, as expected, both heart rate (main effect of iso-time $F(1.41,29.57) = 203.62, p < 0.001$) and facial EMG amplitude (main effect of iso-time $F(2,44) = 10.43, p < 0.01$) increased significantly over iso-time regardless of treatment or visit.

As hypothesized, motivational self-talk had a significant effect on RPE at iso-time (group x test x iso-time interaction $F(2,49) = 3.85, p = 0.029$) (see Figure 2). Follow up tests revealed no significant effect of motivational self-talk on RPE at 0% iso-time, demonstrating that RPE was equal between groups at the onset of the time to exhaustion test (control: pre-test 4.3 ± 1.6, post-test 3.8 ± 1.6; self-talk: pre-test 4.0 ± 1.0, post-test 3.5 ± 0.7). The effects of motivational self-talk upon RPE were however demonstrated by a significant group x test interaction at 50% iso-time ($F(1,22) = 6.7, p = 0.017, d = 0.80$) with a significant reduction in RPE at post-test (6.4 ± 0.8) compared to pre-test (7.3 ± 0.6) in the self-talk group ($p < 0.05$) and no statistical difference
between pre-test (6.9 ± 1.9) and post-test (7.0 ± 1.7) in the control group. A comparable, but non-significant, trend was present for motivational self-talk at 100% iso-time (group x test $F(1,22) = 2.99, p = 0.098, d = 0.91$). RPE was lower at post-test (9.0 ± 0.8) compared to pre-test (9.8 ± 0.5) in the self-talk group despite a similar RPE in the control group (pre-test 9.1 ± 1.7, post-test 9.3 ± 2.4).

**Insert Table 4 here**

**Insert Figure 2 here**

**DISCUSSION**

This study investigated the effects of motivational self-talk upon perception of effort and endurance performance within the framework of the psychobiological model of endurance performance (29, 30, 31). As hypothesized, motivational self-talk reduced RPE and increased time to exhaustion during high-intensity cycling exercise. Specifically, motivational self-talk reduced RPE at 50% iso-time during the time to exhaustion test with a similar, but non-significant trend at 100% iso-time. The present study is therefore unique as it is the first to experimentally demonstrate that motivational self-talk reduces perception of effort, and provides empirical support for previous suggestions that self-talk enhances endurance performance (16, 38). This is an important finding given the absence of experimental support for the asserted effects of motivational self-talk upon effort (18) and task termination (14).

The present findings are supported by the established effects of other endurance based psychological interventions. For instance, although using a different type of test, a psychological
skills package containing self-talk has previously been found to enhance running distance in the heat by 8% (4). The 18% improvement in time to exhaustion in our study depicts the utility of motivational self-talk as a performance-enhancing strategy during endurance exercise and is contextualized by its comparability to the potent performance enhancing impact of psycho-stimulant drugs (27%; 22). Crucially, that this improvement was associated with a reduction in RPE exemplifies the degree to which psychological factors may independently affect endurance performance. This reinforces the proposal that perception of effort acts as the ultimate determinant of endurance performance (29, 30, 31).

Attentional and informational processing frameworks have previously been suggested to account for the performance-enhancing effects of self-talk (17). However, the fact that motivational self-talk instigated a reduction in RPE during the time to exhaustion test provides a novel theoretical framework to explain how this strategy can enhance endurance performance: the psychobiological model proposed by Marcora and colleagues (29, 30, 31). The psychobiological model of endurance performance, based on motivational intensity theory (7), suggests that an individual will terminate endurance exercise either when the effort required by the task exceeds his/her potential motivation, or when a true maximal effort is considered to have occurred and continuation of the task is perceived as impossible (29, 30, 31). In the present study we observed a drop of almost 1.0 point in RPE at 50% and 100% iso-time when using motivational self-talk during the time to exhaustion test. This perceptual effect of motivational self-talk delayed the point at which our highly-motivated subjects perceived very high effort and consciously decided to terminate the time to exhaustion test. Importantly however, RPE at exhaustion was near maximal for all subjects and was not statistically different between groups. Popular strategies such as aerobic training (13), nutritional intervention (5), inspiratory muscle
training (15) and psycho-stimulant administration (22) have already demonstrated that a reduction in RPE enhances endurance performance. That a psychological strategy such as motivational self-talk is able to achieve similar benefits supports our contention that any physiological or psychological factor affecting RPE and/or potential motivation will affect endurance performance (29, 30, 31). As RPE is sensitive to both psychological and physiological factors, the framework offered by the psychobiological model provides a unifying explanation for the positive effects of both psychological and physiological strategies on endurance performance. Accordingly, strategies targeting beneficial changes in RPE through this psychobiological framework may offer a new paradigm for endurance performance enhancement.

The present study was not designed to identify how motivational self-talk might cause a reduction in perception of effort. However, it is possible that the use of motivational self-talk during the time exhaustion test increased the perceived ability of our participants to maintain the required power output for longer. Correspondingly it is this cognitive effect of motivational self-talk that may have reduced RPE and delayed the point at which a maximal effort was believed to have occurred. In support of this hypothetical cognitive mechanism, the performance benefits that are derived from motivational self-talk have previously been associated with enhanced self-efficacy (18, 19). While a different mode and intensity of exercise to that of the present study, self-efficacy has also been reported to predict 14% of the variance in RPE during 30 minutes of moderate intensity running (37). Additionally, psychophysiological investigations of motivational intensity theory have demonstrated that perceived ability can modify effortful behavior. For example, participants with high perceived ability are more willing to exert effort at greater task difficulties whereas individuals with low perceived ability withhold effort and
disengage from a task more readily as difficulty increases (44, 45). Moreover, individuals with low perceived ability appear to experience greater effort than those with high perceived ability at a given level of task difficulty when task difficulty is relatively low (44). From this perspective, participants in the control group would not be expected to alter their perceived ability thus perception of effort and endurance performance would remain similar, as was the case. By extension, it is noteworthy that no statistical difference in RPE was evident between groups at 0% iso-time. Furthermore, mood and motivation were also not statistically different between groups before the time to exhaustion test. This suggests that it was the effect of motivational self-talk during the task rather than an enhanced sense of perceived ability, mood or motivation upon entering the test that led to the 18% improvement in time to exhaustion.

We also recorded heart rate and facial EMG amplitude during high-intensity cycling exercise, along with blood lactate concentration 3 minutes after exhaustion. Heart rate and blood lactate at exhaustion were not significantly different between groups. Similarly, self-talk did not have a significant effect on heart rate at iso-time. While it would be inappropriate to declare that all unmeasured physiological parameters were also similar between groups, these data limit the possibility that the increase in time to exhaustion we observed in the self-talk group can be explained by traditional musculo-energetic and cardio-vascular mechanisms (1, 24). In addition, models of pacing such as the afferent feedback model (2) and the central governor model (35) have been recently proposed to determine the basis of endurance performance. These models are specifically founded on the premise that the brain limits performance according to the physiological condition of the body. However, a purely psychological strategy such as self-talk is unlikely to modify afferent feedback from the locomotor muscles (2), or alter any threat to
physiological homeostasis (35). Therefore these models are also unable to fully account for why our psychological intervention was able to reduce RPE and enhance endurance performance.

Previously, facial EMG amplitude has been shown to correlate with RPE during weightlifting (10), and to differentiate between two different exercise intensities during cycling to exhaustion (11). In our study, facial EMG amplitude, like RPE, increased significantly in both groups during the time to exhaustion test. Interestingly however, facial EMG amplitude at iso-time was not significantly affected by motivational self-talk, despite its significant effect on RPE. A possible explanation for this discrepancy is that the increase in facial EMG amplitude that occurs during high-intensity cycling exercise reflects motor irradiation (11). Under these circumstances the spreading of activation in cortical and subcortical regions stimulates not only the muscles involved in the task but also task-irrelevant muscles (21), such as the facial muscles (10). Alterations in facial EMG activity may therefore not be expected to occur when differences in perception of effort result from cognitive factors such as motivational self-talk. This is supported by the fact that cognitive effort and facial EMG amplitude are not consistently associated in the psychophysiology literature (8, 39), and explains why facial EMG differences were not discernible between groups despite the clear change in RPE in the self-talk group.

In order to contextualize our findings, potentially limiting aspects of the study should also be acknowledged. For example, a time to exhaustion test is suggested to be less ecologically valid than, for example, a time-trial, because it excludes pacing. However, given that the present study aimed to establish the effects of motivational self-talk upon perception of effort and task termination, as opposed to pacing, the influence of a self-paced power output such as that during a time-trial would have made it difficult to clearly establish the effect of the intervention on our dependent measures. The constant power output during a time to exhaustion test therefore
permitted a more stable milieu from which preliminary conclusions about our measures could be made. Moreover, some authors think that the large variability in time to exhaustion tests can make it difficult to detect real changes in performance (23). However, it has been demonstrated that time to exhaustion tests and time-trial tests have similar sensitivity to changes in endurance (3). This is because despite the variability in these tests, performance enhancement also tends to be much greater (20), thus compensating for this variability. Put another way, the signal to noise ratio remains similar to that of a time-trial. The present study also did not include a familiarization visit. It is acknowledged that this could have led to practice effects across visits two and three. Nonetheless, the lack of an increase in performance in our control group during visit three somewhat argues against this.

During the manipulation check ten of the twelve participants in the control group reported employing some self-talk during their time to exhaustion test. This however corresponds to previous findings (14) whereby 95% of a sample of 164 exercisers reported the use of self-talk during their workout. In this regard, given the prevalent nature of self-talk, an inherent issue associated with control groups is whether it is realistic to eliminate self-talk entirely. Moreover, alternative approaches for the control group are not without their own issues; for example, the introduction of potential confounds via distracter type tasks. Nevertheless, as performance was only enhanced in the self-talk group this signifies that it may be practiced and specifically structured motivational self-talk (18) that provides the key to endurance performance enhancement as opposed to the use of self-talk per se. Practically, this suggests that individuals who take part in endurance exercise should be trained in the use of structured and personalized motivational self-talk.
Due to the problematic nature of control groups in self-talk research, the possibility that our findings could be attributable to a placebo effect cannot be entirely eliminated. However, a placebo driven 18% improvement in time to exhaustion might be regarded as substantial. This is supported by a notably lesser change in performance of approximately 6.5% in the placebo group of a placebo controlled study utilizing a comparable mode, intensity, and sample population as ours (15). Similarly, it is possible that the additional thirty minutes that the self-talk group spent with the experimenter during stage one of the self-talk workbook procedure could have provoked either experimenter effects or experimenter bias. Once more however, an 18% improvement in response to either of these would appear extremely large.

In light of our findings, it is important that future research examines the effects of motivational self-talk upon perception of effort and time-trial performance so as these findings can be extended more specifically to competition. In addition, to make these findings more pertinent to individuals of a superior training standard to our participants, similar investigations should be performed on elite and sub-elite athletic cohorts if possible. Moreover, owing to our proposed link with perceived ability, the interplay between motivational self-talk, perception of effort, and perceived ability should be empirically clarified. Likewise, it would be interesting to determine whether the novel theoretical framework provided by the psychobiological model of endurance performance extends to other psychological strategies such as imagery and goal setting. Finally, in recognition of the psychobiological link between motivational self-talk and endurance performance, it is important that the neural structures that are activated by motivational self-talk are identified. This would provide a greater understanding of the psychobiological connections between motivational self-talk, perception of effort and endurance performance.
In summary, our theoretically grounded findings are the first to experimentally demonstrate that the isolated use of motivational self-talk is an effective strategy for endurance performance enhancement. Additionally, this is the first study to reveal that this enhancement is associated with a significant reduction in perception of effort. The latter finding has several implications. First, this strongly supports the psychobiological model of endurance performance which proposes that the point recognized as exhaustion is determined by the conscious decision to terminate endurance exercise. Second, this supports the perspective that any intervention that affects perception of effort will affect endurance performance. Finally, this illustrates that psychobiological interventions designed to specifically target favorable changes in perception of effort are of benefit to endurance performance and should be extensively investigated in the context of competitive preparation for endurance athletes.

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Legends

Table 1. Mean ± SD of participant characteristics for control group and self-talk group.

Table 2. Mean ± SD of ratings for all BRUMS subscales and success and intrinsic motivation scales

Table 3. Mean ± SD of physiological and perceptual measures at exhaustion

Table 4. Mean ± SD of cadence, heart rate and facial EMG amplitude at 0%, 50% and 100% iso-time during the time to exhaustion tests.

Figure 1. Mean (± SEM) pre-intervention to post-intervention changes in time to exhaustion for control group and self-talk group (Black lines) and individual values for pre-intervention to post-intervention changes within each group (Grey lines). * indicates significant difference between pre-intervention and post-intervention. # indicates significant difference between groups during corresponding visit.

Figure 2. Mean (± SEM) RPE at iso-times of 0%, 50% and 100% and at exhaustion for the control group (left) and self-talk group (right). *indicates significant difference between pre-intervention and post-intervention at a given iso-time.
Table 1

<table>
<thead>
<tr>
<th></th>
<th>Age (years)</th>
<th>VO$_{2\text{max}}$ (ml·kg·min$^{-1}$)</th>
<th>PPO (W)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Control (n = 12)</strong></td>
<td>25.0 ± 9.2</td>
<td>52.7 ± 8.7</td>
<td>306.2 ± 70.5</td>
</tr>
<tr>
<td>Males (n = 7)</td>
<td>28.7 ± 10.1</td>
<td>56.0 ± 8.7</td>
<td>352.4 ± 39.0</td>
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<tr>
<td>Females (n = 5)</td>
<td>19.8 ± 1.5</td>
<td>48.0 ± 7.8</td>
<td>241.5 ± 34.3</td>
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<tr>
<td><strong>Self Talk (n = 12)</strong></td>
<td>24.3 ± 6.2</td>
<td>51.8 ± 9.1</td>
<td>319.5 ± 72.6</td>
</tr>
<tr>
<td>Males (n = 8)</td>
<td>25.4 ± 7.2</td>
<td>56.0 ± 6.0</td>
<td>361.0 ± 23.7</td>
</tr>
<tr>
<td>Females (n = 4)</td>
<td>22.0 ± 3.6</td>
<td>43.5 ± 9.0</td>
<td>236.5 ± 65.0</td>
</tr>
</tbody>
</table>

*Note.* PPO = peak power output
### Table 2

<table>
<thead>
<tr>
<th></th>
<th>BRUMS Subscales</th>
<th>Motivation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Anxiety</td>
<td>Confusion</td>
<td>Depression</td>
</tr>
<tr>
<td>Pre</td>
<td>Con</td>
<td>0.7 ± 1.6</td>
<td>1.6 ± 2.4</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>0.8 ± 1.7</td>
<td>1.9 ± 3.0</td>
</tr>
<tr>
<td>Post</td>
<td>Con</td>
<td>0.7 ± 1.3</td>
<td>1.1 ± 1.7</td>
</tr>
<tr>
<td></td>
<td>ST</td>
<td>0.9 ± 2.5</td>
<td>2.7 ± 3.0</td>
</tr>
</tbody>
</table>

*Note.* Pre = pre-intervention visit; Post = post-intervention visit; Con = control group; ST = Self-talk group.
Table 3

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th></th>
<th></th>
<th>Self-talk</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean Cad (RPM)</td>
<td>Pre</td>
<td>Post</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td></td>
<td></td>
<td>77.3 ± 6.2</td>
<td>77.0 ± 9.0</td>
<td>77.5 ± 9.4</td>
<td>81.2 ± 9.0</td>
</tr>
<tr>
<td></td>
<td>End Lac (mmol · l)</td>
<td>9.7 ± 2.8</td>
<td>9.0 ± 1.8</td>
<td>8.5 ± 2.3</td>
<td>8.9 ± 2.5</td>
</tr>
<tr>
<td></td>
<td>End HR (beats · min⁻¹)</td>
<td>187.0 ± 10.0</td>
<td>187.3 ± 10.7</td>
<td>182.4 ± 10.3</td>
<td>187.4 ± 11.5</td>
</tr>
<tr>
<td></td>
<td>End fEMG Amp (µV)</td>
<td>30.4 ± 25.1</td>
<td>30.4 ± 19.0</td>
<td>51.1 ± 61.2</td>
<td>45.8 ± 47.4</td>
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<tr>
<td></td>
<td>End RPE</td>
<td>9.2 ± 0.7</td>
<td>10.2 ± 2.0</td>
<td>10.1 ± 0.6</td>
<td>10.0 ± 0.3</td>
</tr>
</tbody>
</table>

*Note.* Mean Cad = mean cadence; End Lac = end exercise lactate; End HR = end exercise heart rate; End fEMG Amp = end exercise facial EMG amplitude; End RPE = end exercise perception of effort; Pre = pre-intervention visit; Post = post-intervention visit

* = significantly greater than pre-intervention visit
Table 4

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>Self-talk</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0%</td>
<td>50%</td>
</tr>
<tr>
<td>Cad (RPM)</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td></td>
<td>78.5 ± 6.1</td>
<td>79.2 ± 7.1</td>
</tr>
<tr>
<td></td>
<td>79.7 ± 9.3</td>
<td>81.7 ± 9.0</td>
</tr>
<tr>
<td>HR (beats · min⁻¹)a</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td></td>
<td>159.8 ± 12.2</td>
<td>178.8 ± 10.4</td>
</tr>
<tr>
<td></td>
<td>159.7 ± 10.7</td>
<td>179.1 ± 12.2</td>
</tr>
<tr>
<td>fEMG Amp (µV)b</td>
<td>Pre</td>
<td>Post</td>
</tr>
<tr>
<td></td>
<td>12.7 ± 9.7</td>
<td>16.0 ± 13.2</td>
</tr>
<tr>
<td></td>
<td>12.7 ± 6.6</td>
<td>19.2 ± 15.3</td>
</tr>
</tbody>
</table>

Note. Cad = cadence; HR = heart rate; fEMG Amp = facial EMG amplitude; Pre = pre-intervention visit; Post = post-intervention visit

a = significant increase over iso-time; b = significantly greater than pre-intervention visit