Effect of expected exercise duration on physiological and psychological variables

by

Timothy Robert Lindsay
Bachelor of Science, Dalhousie University, 1998

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University of Victoria

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Abstract

The consideration of the end-point of exercise (teleoanticipation) may influence fatigue development. This study examined the effect of expected exercise duration on physiological and psychological variables. 20 male cyclists participated in a graded maximal aerobic cycling test and two 20 minute cycling bouts. Participants expected to cycle for 20 minutes for the first bout (20 MIN), and for 40 minutes for the second (40 MIN). $\dot{V}O_2$ was higher at 2 minutes and lower at 17 minutes in the 40 MIN condition. RPE was lower throughout the 40 MIN condition. Following initial analyses, participants were separated into intensity groups based on whether they exercised above RER=1.00 at any time during either cycling bout. RPE was lower for 40 MIN in the lower intensity group only. Results suggest that teleoanticipation alters both physiological and psychological variables via separate mechanisms that may be intensity-dependent.

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Dedication

Dedicated to the glory of God in the name of my Lord Jesus Christ. This work is intended to exhibit the handiwork of God, our Creator, who created man from the dust of the earth.

So God created man in His own image; in the image of God He created him; male and female He created them.
Genesis 1:27 (NKJV)

The heavens declare the glory of God…
Psalm 19:1 (NKJV)

Introduction

For more than a century, the literature has been proliferated with studies exploring exercise-induced fatigue development. Factors that may contribute to fatigue development are numerous and often challenging to analyze. In one of the most recent reviews on this topic, Noakes (2000) discussed several models that have been typically used over the years to explain exercise fatigue under various conditions. In these models, the factors posited to contribute to fatigue development included skeletal muscle anaerobiosis, metabolic failures leading to energy supply depletion, hindered muscle recruitment, altered muscle structural function leading to inferior biomechanics, and psychological skills that do not allow for adequate levels of effort to overcome feelings of fatigue. This paper and others argues that many such models are not compatible with research findings related to fatigue. Thus, there is a need to re-evaluate the models that are used to explain fatigue development (Noakes, 2000; Noakes & St Clair Gibson, 2004). Thus, while the above-mentioned factors are undoubtedly necessary for the function of the exercising human body, they may not be the ultimate determinants of fatigue. Alternative models that more completely explain human response to exercise and fatigue development should be explored.

Kayser (2003) stated that the brain/central nervous system (CNS) should be credited with the "pivotal role as the ultimate site where exercise starts and ends." Assigning the greatest importance to the CNS for fatigue-induced termination of exercise is intriguing because it is here that the awareness of the human body arises. For example, markers of the physiological condition of the body, such as heart rate (HR) and metabolic changes can be detected in a process called interoception (Craig, 2003). Some of these

changes are perceived subjectively and consciously, and may play a role in emotional experience (Wiens, 2005). Thus, any activity that causes a physiological departure from homeostasis carries with it a centrally mediated system of interoceptive feedback that represents the associated changes. This argues that physiological processes during exercise never happen independently from corresponding psychological responses.

Except for forced exercise under extreme calamity, exercise in humans is a voluntary effort. The decision to terminate exercise is therefore a result of a conscious decision (Kayser, 2003) and, unless in an exceptional situation, always voluntary following the recognition that fatigue is too great to continue. Therefore, if it is acknowledged that conscious processes *ultimately* explain the termination of exercise, then it is possible that prior exercise research of fatigue has been hindered by a reductionistic approach that ignores the role of conscious and perhaps subconscious involvement of the brain. When investigating fatigue responses to exercise, it is therefore important to consider not only traditional objective physiological measures but also subjective measures because it is these that reflect the thoughts and feelings of a person as they exercise with a certain intensity and duration.

The most widely used subjective measure of exercise response is rating of perceived exertion (RPE). RPE is commonly used as a subjective measure of exercise intensity, but in its purest sense, reflects the perception of effort. The RPE scale was first developed by Borg (1970) to be used as a psychophysical indicator of exercise-induced somatic stress. Its scale was designed to approximate ten times the HR during exercise. This scale allows for the examination of the relationship between subjective and objective or physiological measures during exercise (Russell, 1997). RPE is at its highest when

fatigue is at its highest. Since any exercise carries with it the inevitable development of fatigue, as RPE rises to maximal or near maximal levels, exercise must either be terminated or the pace lowered to allow one to continue. Given this association, RPE may be used as an indicator of fatigue and its development during various exercise modes and protocols (Cairns, Knicker, Thompson, & Sjøgaard, 2005). This use of RPE represents the framework from which findings will be discussed in this study – factors that contribute to RPE will be considered to contribute to fatigue.

According to the above framework, an appropriate definition of fatigue is that it is an acute impairment of exercise performance that includes increased effort to exert a given workload (Davies & Bailey, 1997). One traditional paradigm explains fatigue as a failure of the energy systems to continue to provide an adequate supply of ATP to working muscles. An example of the use of this paradigm is given by Bassett & Howley (2000), who stressed the importance of the oxygen delivery system to help supply ATP during endurance performance. Other research has highlighted physiological and neurological processes that are involved in fatigue development. These include: spinal and supraspinal factors (Gandevia, 2001), intramuscular factors (Green, 1997), and metabolic factors (Coyle, 1999). Finding a high degree of association between physiological variables and fatigue development and exercise performance seems to suggest that physiological variables are therefore the ultimate cause of fatigue, with RPE only being a byproduct (Figure 1). However, it may be that fatigue is more of a perception rather than an absolute physiological state of condition of the body (St Clair Gibson et al., 2003), and that this perception of fatigue is reflected in RPE (Figure 2). It would then be likely that the above mentioned processes are part of a complex system

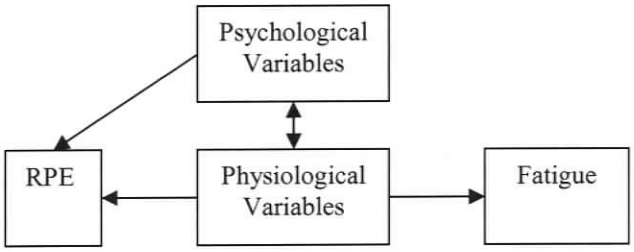

Figure 1. Traditional view of contributors to fatigue and RPE.

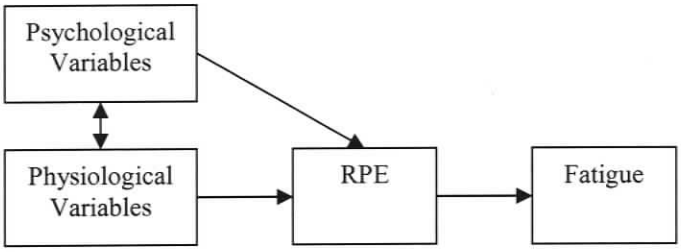

Figure 2. Alternate view of contributors to fatigue and RPE.

that informs RPE (Lambert, St Clair Gibson, & Noakes, 2005).

Because perception of effort is a conscious process, it may be that other consciously appraised information can contribute to RPE as well. Therefore, in addition to sensing of bodily cues (interoception), the sensing of external environmental cues arising from outside the body may also account for some changes in RPE. These might include varying expectations of distance, intensity, and duration of the activity which, when interpreted via cognitive processes, may help inform RPE and mediate the development of fatigue. Thus, there might be both an interoceptive/perceptual (regarding information from within the body) and cognitive (regarding the exercise environment) contribution to RPE.

While studies such as those reviewed in Mihevic (1981) show an association between various physiological variables and RPE, there is also evidence that RPE can dissociate from certain physiological variables under several conditions. For example, Hampson, St Clair Gibson, Lambert, & Noakes (2001) reviewed studies that showed that heart rate, although strongly correlated with RPE, can dissociate from RPE under conditions such as pharmacological intervention, eccentric exercise, varying environmental temperatures, cycling cadence (RPM), training status, and exercise modality. RPE has also been shown to have psychological components (Morgan, 1973), which can be mediated by competition for attention by various cues, whether external (such as environmental temperature) or internal (such as muscle tension) (Pennebaker & Lightner, 1980; Nethery, Harmer, & Taaffe, 1991).

Compared with studies examining physiological contributions to RPE, there is less work describing the possible role psychological and cognitive processes play in determining RPE. In addition to attentional factors, there is growing evidence that external feedback can alter RPE between bouts of identical exercise. It is unclear whether this phenomenon occurs independently of any physiological change, or if it is mediated by some measurable physiological changes. This is an important consideration because it helps resolve whether RPE is directly or indirectly altered by external cues. For example, varying expected task duration is associated with changes in RPE, but it is unknown if this is accompanied by physiological changes such as running economy, as was suggested but not directly investigated by Baden, Warwick-Evans, & Lakomy (2004). Thus, an important question is whether RPE is altered by expected task duration

or whether expected task duration alters physiological variables, which then in turn alters RPE. This therefore begs the question if the perceptions of effort and fatigue are a result of a complex set of interactions of between physiological, psychological, and cognitive variables. This possibility has received recent attention in the literature as part of the theory of teleoanticipation (such as Noakes, St Clair Gibson, & Lambert, 2004).

Teleoanticipation is a hypothetical response during exercise that takes into account internal and external information, as well as the end point of the task (Ulmer, 1996). The proposed purpose of this response is to allow the body to work at an intensity and duration that does not pose a threat of tissue damage or severe departures from homeostasis due to exercise. A key component of this model is that the strain of exercise is continuously appraised. This model is comprised of an afferent/efferent feedback system where information from active body parts is integrated within the CNS, resulting in a response which directs subsequent actions. For this process to include a teleoanticipatory component, input from exogenous reference signals is needed (Ulmer, 1996); as this defines the parameters within which the exercise must be completed. An example of such a signal could be the distance to be covered during exercise bout. In this case, it would not only be feedback from the muscles that would inform the integrative center within the CNS, but also other cognitively appraised exogenous cues such as task duration. The CNS would continuously update RPE, interpreting the information from afferent feedback against an expected outcome (Hampson et al., 2001). The result could be altered intensity and/or muscle function so that exercise can continue within the parameters initially set by the program unit in the CNS. If this is the process that occurs during exercise, the most important consideration may not be how long one has been

exercising, but how long one has yet to go to finish the task (Baden, Warwick-Evans, & Lakomy, 2004).

Long before the term "teleoanticipation" was coined by Ulmer (1996), Walster and Aronson (1967) reported a possible teleoanticipatory effect in participants performing a visually fatiguing task. In this study, those who were led to believe that their task was almost completed reported a greater increase in fatigue, compared with those who expected to continue in their task for a longer duration. This increased subjective fatigue measure was not associated with objectively measured task performance, so the effect of the intervention was solely a psychological one. In another study, however, altered physiological measurements were associated with expected task duration (Vidaček & Wishner, 1971). Participants in this study held a weight for either a shorter (30 sec.) or longer time (as long as possible). Compared to those in the shorter group, participants who held the weight for the longer duration had significantly lower iEMG activity in the active muscles at the same time points throughout the hold, even though the work performed was the same. This result may suggest that expected task duration can alter the function of active muscles to make force production more efficient. Thus, while it is unknown which situations elicit physiological changes concomitant to altered RPE, altered expectation of task duration appears to modify perception of effort and fatigue.

Alterations due to expected task duration have also been found in an endurance exercise paradigm. Rejeski and Ribisl (1980) studied participants who expected to run for either 20 or 30 minutes at an identical intensity, but both runs were terminated at the

20 minute mark. Participants who expected to run for 30 minutes reported lower RPE values at the end of 20 minutes than the shorter group at the same timepoint. No physiological correlates of lowered RPE were found. However, the physiological measures used in this investigation were few: only HR, respiratory rate (RR) and minute ventilation ($\dot{V}_E$) were measured. Because there was no expired gas analysis, discussion regarding potential changes in metabolism was not possible. It was proposed that the runners used a greater percentage of dissociative thoughts as a cognitive strategy to attend less to physiological feedback, resulting in a lowered RPE. Baden et al. (2004) provided further evidence for the use of an altered thought strategy. In two separate experiments, participants who expected to run for a longer distance or duration reported lower RPE throughout the runs. This lower RPE was correlated with a higher percentage of dissociative thoughts in both experiments.

The percentage of associative thoughts (% ASSOC) employed during exercise may modify RPE because it influences the information that reaches an integrative center within the CNS. This system is grounded in the concept of attentional capacity (Leventhal & Everheart, 1979). In this model, a limited attentional capacity means that multiple cues must "compete" for recognition. Thus, a predominantly dissociative thought strategy may serve as a perceptual filter that would lessen the impact of information about physiological processes because other information primarily occupied the attention of the exerciser. An important question, then, is why different expected task duration seems to shift the cognitive strategy used. This phenomenon may be simply a reaction of the CNS to exogenous cues to alter perception so that the exerciser is able to complete the exercise with a lower RPE, that is, with the least discomfort. Alternatively,

exogenous cues may result in altered behavior, which lowers the physiological strain, perhaps to protect the body against risk of injury.

Affect is another measure may be associated with RPE. Affect refers to a short duration, high intensity emotion or feeling related to an idea or object (Crews, 1992), and thus represents an alternative subjective response that may be measured during exercise. Affect has been shown to be negatively correlated to RPE, and seems to have stronger correlations at higher intensities of exercise (Hardy & Rejeski, 1989). Given the relationship between interoceptive cues and emotion (Weins, 2005), it may be important to investigate not only the role of *awareness* of effort (RPE) but also the *experience* of effort (affect). This relationship has been investigated by Baden, McLean, Tucker, Noakes, & St Clair Gibson (2005), who proposed that affect, as measured by Feeling Scale (FS) (Hardy & Rejeski, 1989), contributed to RPE during exercise bouts where expected task duration was either altered midway through exercise bouts, unaltered, or not defined for participants.

Whereas classical theory accepts an intracellular or neuromuscular mechanism for fatigue, an alternate theory suggests that fatigue and RPE ultimately depend upon the CNS. Important to this function is how the CNS interprets and responds to both interoceptive cues, regarding the intracellular condition of the working body and external information apart from the body, that contribute to the mechanism of regulation (Ulmer, 1996). This involves a complex system of information transfer and processing that takes into account the nature of the task at hand, the physiological condition of the body, the processing of sensory cues and the preset tolerable limits to disturbances to homeostasis

and comfort of the individual. This mechanism may accomplish its goal by mediating psychological process, physiological processes, or both.

Purpose

The purpose of this study was to examine, in trained cyclists, the effect that expected exercise duration has upon metabolic variables, % ASSOC, RPE, and affect during bouts of cycling.

Research Questions

1. Does expected exercise duration alter metabolic variables at the same absolute time point for a given workload?
2. Does expected exercise duration alter the % ASSOC used at the same absolute time point for a given workload?
3. Does expected exercise duration alter RPE at the same absolute time point for a given workload?
4. Does expected exercise duration alter affect at the same absolute time point for a given workload?

Significance

The services of exercise testing and prescription usually focus only on establishing baseline physiological capacity/function and providing a plan for improvement. Tests such as that for maximal aerobic power ($\dot{V}O_{2max}$) are usually done in the form of open-loop incremental exercise leading to volitional fatigue. However, most sports require self-paced activity in a closed-loop setting such as for a set time (team sports) or distance (individual sports). Thus traditional aerobic testing may not

take into account conscious or sub-conscious pacing strategies that may be based on teleoanticipatory responses. Additionally, subjective response and not just physiological response to exercise is important to consider when concerned with the effectiveness of programs and compliance. Although one may be adequately meeting guidelines for physiological response, psychological aspects may not be adequately developed. Additionally, the subjective response may be so uncomfortable that programs are not maintained. If RPE and fatigue during exercise are ultimately regulated by a complex system that is as yet unquantifiable, and is influenced by non-physiological factors, then conventional exercise testing and prescription may be inadequate, as these tests are based solely on physiological criteria. Likewise, if RPE and therefore fatigue can be altered or mediated via non-physiological processes, such as those that reside within the cognitive domain, exercise testing and prescription should account for this. Thus, this study explores the role that expected exercise duration plays in altering the perception of effort and developing fatigue and effort perception, possibly independently of physiological function. Results will help direct the development of exercise testing and prescription guidelines by considering the changeable nature of RPE as well as fatigue development.

Hypotheses

It was hypothesized that:

1. Oxygen consumption ($\dot{V}O_2$) would be lower when participants expected a longer duration of exercise throughout the 20 minutes of cycling;
2. % ASSOC would be lower throughout the 20 minutes of cycling when participants expected a longer duration of exercise;

3. RPE would be lower at the same absolute time point when participants expected a longer duration of exercise;
4. Affect (as measured by FS) would be higher at the same absolute time point when participants expected a longer duration of exercise.

Delimitations

So that participants could report % ASSOC, RPE, and FS values reliably, that they could safely perform the incremental test to exhaustion, and that this study was reliable and valid, the following restrictions were placed to help with this investigation:

1. Participants were males, 20-39 years old who were trained in endurance cycling (cycling, on average at least 2 times per week, for at least 30 minutes per day, for at least 1 year);
2. Following instruction, participants were able to competently rate their own % ASSOC, RPE, and FS during the paced cycling bouts.

Limitations

While every attempt was made to control threats to the validity and reliability of results, this investigation was conducted within the context of the following limitations:

1. That the presence of metabolic analysis equipment (i.e., mouthpiece and breathing tube) may have drawn the participants' attention to these processes within their own bodies, thus altering the type of attention that would normally be employed;
2. That the novelty of participation may have altered those attentional processes that are normally employed by participants;

3. That personal (mental, emotional, and psychological) factors beyond the ability of the investigator to appraise may have influenced the subjective responses of participants during exercise.

Assumptions

The following assumptions were made during this investigation:

1. That participants complied with pretest guidelines designed to reduce extraneous influences;
2. That participants were fully familiarized with the reporting of associative thoughts, RPE and FS; and that they gave an honest and accurate indication of their state;
3. That participants who volunteered for this study were not different from the rest of the study population in the way that they perceived and anticipated various durations of exercise;
4. That participants performed to their maximum ability during testing when required;
5. That participants did not divulge information about the deception to other participants who had yet to complete their testing sessions.

Operational Definitions

Fatigue	an acute impairment of exercise performance that includes an increase in the effort to exert a given workload (Davies & Bailey, 1997).

Teleoanticipation	a process by which an integrative system within the CNS alters efferent signals to the periphery based on afferent feedback and the consideration of the end point of exercise duration (Ulmer, 1996).
Rating of perceived exertion (RPE)	subjective rating of perceived exertion or effort during an exercise task, as measured using the RPE scale (Borg, 1970). This scale consists of 15 points (6-20) and is verbally anchored on the odd numbers, from "very, very light" (7) to "very, very hard" (19).
Affect	a short duration, high intensity emotion or feeling related to an idea or object (Crews, 1989), as measured using the FS (Hardy & Rejeski, 1989). This is an 11-point bi-polar scale, verbally anchored from very good (+5) to very bad (-5), with neutral (0).

Methods

Study Design

This study used a single group research design with repeated measures. The design was comprised of two conditions, each with seven levels of time. All participants were informed that they would be completing a maximal graded aerobic test, a 20 minute submaximal test, and a 40 minute submaximal test, each done on separate days. Each participant acted as his own control and took part in three laboratory sessions. Session 1 involved familiarization to the study, informed consent, completion of questionnaires, and the maximal graded aerobic test to exhaustion on an electrically braked Lode Excalibur cycle ergometer (Lode, Groningen, The Netherlands). Session 2 included familiarization to the objective and subjective measures, followed by a 20 minute cycling bout for which participants expected to cycle for 20 minutes (20 MIN). During session 3, participants expected to cycle for 40 minutes, but were only required to cycle for 20 minutes at the same exercise intensity as that in session 2 (40 MIN). A diagram of procedures is given in Figure 3. A timeline for testing procedures for each 20 minute cycling bout is given in Figure 4.

Participants

The volunteer participants were trained male endurance athletes, self-identified as cyclists, triathletes, and adventure racers. They were recruited by word of mouth and through notices given to local cycling and triathlon clubs, as well as local cycling shops. Participants were informed of the purpose of the study and signed an informed consent form (Appendix C). All procedures for this study were approved by the University of

Victoria Human Research Ethics Committee. A total of 22 men were recruited for this study. The criteria for participation in this study were:

1. male, between 20 and 39 years old;
2. trained in cycling for at least 1 year;
3. cycled at least 2 sessions per week for at least 30 minutes duration;

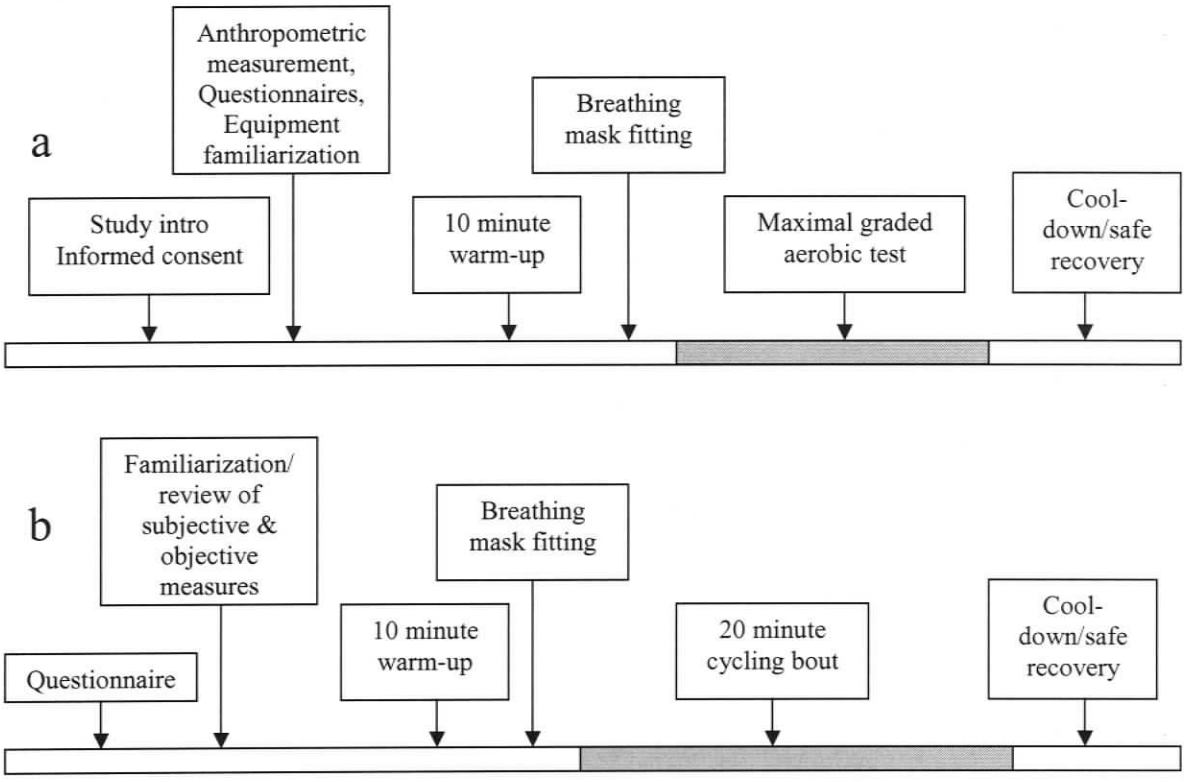

Figure 3. Procedures for session 1 (a), and sessions 2 and 3 (b).

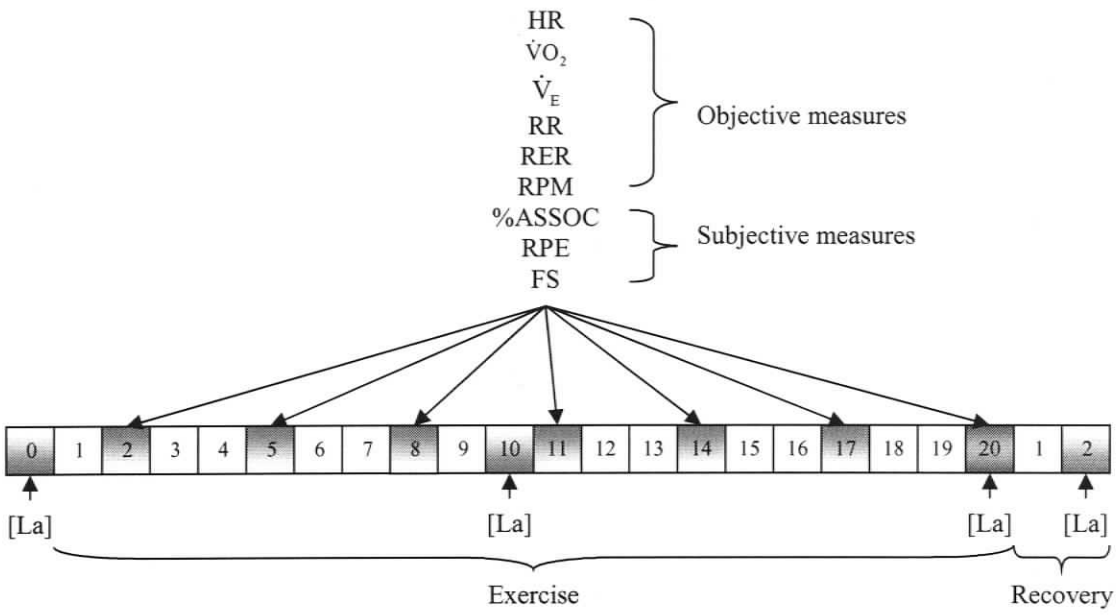

Figure 4. Timeline of measurements for the 20 minute cycling bouts.

These criteria were selected for the purpose of ensuring that participants were considered trained cyclists, according to the classifications presented in Jukendrup, Craig, & Hawley (2000). While cycling was not the primary sport for some participants, their usual exercise habits included cycling to such an extent that they were considered trained according to the above criteria, despite spending time doing other modes of exercise such as swimming and running. Participant characteristics are presented in Table 1.

Of the 22 recruited, 20 participants completed all the testing. The attrition of 2 participants was a result of scheduling difficulties that prevented participation in one or more testing sessions. Data are presented for those 20 participants who completed all the testing sessions, unless otherwise noted.

Table 1
Participant Characteristics

Characteristic	Mean (SEM)	Range
Age (years)	33.4 (.98)	25 – 39
Height (cm)	178.5 (1.11)	170 – 187.1
Weight (kg)	75.0 (1.41)	64.5 – 85.4
Training experience (years)	8.2 (1.36)	2 – 18
Number of training sessions per week	3.9 (.27)	2 – 6
Training duration per day (hours)	2.1 (.14)	1 – 3
$\dot{V}O_{2max}$ ($ml \cdot kg^{-1} \cdot min^{-1}$)	57.0 (1.09)	49.7 – 68.9
VT (% $\dot{V}O_{2max}$)	74.4 (2.54)	54 - 90

Testing sessions

All testing sessions for each participant were completed within 3 weeks of each other, with a minimum of 48 hours, and a maximum of 12 days between each session. Participants were required to be 4 hours post absorptive, refrain from caffeine (12 hours), alcohol (24 hours), and intense exercise (48 hours) prior to each exercise testing session. All sessions for each participant were conducted at approximately the same time of day to minimize effects due to circadian rhythms. All sessions were conducted in the same laboratory on the same equipment.

Session 1

During session 1 participants were familiarized with the study, and completed questionnaires regarding their personal characteristics and training history (Appendix D), recent exercise and training sessions (Appendix E), and Physical Activity Readiness Questionnaire (PAR-Q) (Appendix F). Participants were measured for mass using an electronic scale (Avery Berkel, model HL120, Fairmont, MN) and height using a wall-

mounted sliding measurement device (Tanita, model HR100, Arlington Heights, IL). In all cases, the cycle ergometer was fitted with the participants' own clipless pedals and the seat height was recorded for subsequent tests. Participants then completed a 10-minute warm-up on the cycle ergometer at a self-selected intensity. This intensity was always less than the initial workload for the graded maximal aerobic test, set a priori at either 200 or 250 watts. The warm-up power output was recorded for use in subsequent sessions. Participants were then fitted with a respiratory face mask and head gear (Hans Rudolph, Inc., Kansas City, Missouri), and a HR monitor chest strap (Polar Electro Oy, Kempele, Finland).

The graded maximal aerobic test began at 200 or 250 watts, depending on the participants' size, and experience. The workload was increased by 50 watts in stages of 2 minutes until it was judged that ventilatory threshold (VT) had been reached. Thereafter, 1 minute stages in increments of 25 watts were used to bring the participant to volitional fatigue. Workload was controlled by computer interface with the cycle ergometer. Participants were verbally encouraged throughout the test to give their best performance. A fan was provided for participants during this test, if they so desired. Heart rate (HR), oxygen consumption ($\dot{V}O_2$), carbon dioxide production ($\dot{V}CO_2$), minute ventilation ($\dot{V}_E$), and respiratory exchange ratio (RER) were continuously monitored during the test and updated on the computer screen every 15 seconds. From this test, maximal oxygen consumption ($\dot{V}O_{2max}$) and VT were determined, along with the power outputs corresponding to those measures. Following the test, participants were permitted time for a cool-down at a self-selected intensity and duration. HR continued to be monitored

during this time to ensure appropriate and safe recovery prior to each participant leaving the lab (i.e., less than about 120 bpm).

Session 2

Participants expected the cycling bout in session 2 to be 20 minutes long. At the beginning of this session, participants recorded their recent exercise on the questionnaire (Appendix E) and were asked if they had adhered to the other pre-test instructions. They were then familiarized to the subjective measures of associative thoughts (%ASSOC), rating of perceived exertion (RPE), and feeling scale (FS) (Appendixes G, H, and I). Following a 10 minute warm-up at the same intensity used for warm-up in session 1, participants began the 20 minute cycling bout at a power output corresponding to 10% $\dot{V}O_{2max}$ below their VT. While sitting on the cycle ergometer, participants were measured for resting blood lactate concentration ([La]) before the cycling bout began. Participants were then instructed to begin cycling and were reminded that they would be cycling for 20 minutes at a constant intensity. The participants were allowed to see this intensity (watts) as well as cycling cadence (RPM) on the cycle ergometer control screen. The elapsed time on the control screen was covered and a countdown timer was placed in view of the participants. A fan was also provided, set at the same level as that used for the incremental exercise test in session 1.

Objective measures. During the 20 minute cycling bout, HR, $\dot{V}O_2$, $\dot{V}_E$, respiratory rate (RR), and RPM were measured continuously by the computer and recorded as averages for the 2nd, 5th, 8th, 11th, 14th, 17th, and 20th minute of exercise. HR and RPM were collected via computer interfaces to the metabolic analysis system (True One, Parvomedics, Salt Lake City, Utah). Respiratory variables ($\dot{V}O_2$, $\dot{V}_E$, and RR) were

measured using the automatic metabolic analysis system and pneumotach (3813 heated pneumotach, Hans Rudolph, Kansas City, Missouri), using a two-way valve (2700 series, Hans Rudolph, Kansas City, Missouri). A breath-by-breath gas collection method was used. Post-test analysis used 15-second averaging to determine $\dot{V}O_{2max}$ and 1-minute averaging to determine metabolic variables for the submaximal cycling bouts during sessions 2 and 3. Prior to each testing session, all equipment was calibrated using standard procedures.

[La] was measured with a fingertip-prick technique using an autolancet and portable lactate analyzer (Lactate Pro, Akray, Japan). [La] was taken immediately before the cycling bout, at 10 minutes into the bout, and immediately following the bout. Recovery [La] was taken after 2 minutes of recovery (Medbø & Toska, 2001), while the participant was still sitting on the bicycle ergometer.

Subjective measures. % ASSOC, RPE and FS were reported by the participants at 2, 5, 8, 11, 14, 17, and 20 minutes into the test. Verbal feedback regarding time left in the test was given immediately prior to the request for each subjective response according to a script (Appendix J). Participants were instructed to indicate their responses according to how they felt during the past 3 minutes of the exercise bout (the past 2 minutes for the first measure), rather than at that instant. Participants pointed to signs held in front of them that showed numbers corresponding to the different levels of each scale (Appendixes G, H, and I).

Session 3

At the beginning of session 3, participants recorded their recent exercise on a questionnaire (Appendix E) and were asked if they had adhered to the other pre-test

instructions. The subjective measures were reviewed to ensure that each participant remembered how to meaningfully respond to the measures used in session 2. Participants were fitted with the breathing mask, head gear, and HR monitor. For this session, participants were reminded that they would be cycling for 40 minutes at an identical workload to that used in session 2. Measurement procedures were consistent with those of session 2. However, following the measurements for the 20th minute, participants were told they could stop cycling, and that no further data were needed. At that time they were informed that the intention was to have them mentally prepare for 40 minutes while only completing 20 minutes of exercise. Participants were then asked to remain seated on the bicycle ergometer until the 2-minute recovery [La] reading was taken. Following this, participants completed two questionnaires used to assess whether the participants honestly believed they would be cycling for 40 minutes, as well as solicited their general thoughts and experiences regarding that session (Appendix K). None of the participants indicated that they suspected that the exercise bout was only 20 minutes long. All of the participants indicated that they were "surprised when [they] were told [they] could stop after only 20 minutes". After completing these questionnaires, participants were asked not to divulge the deception to others who were participating in the study.

Determination of Maximal Oxygen Consumption

$\dot{V}O_{2max}$ was determined using the automatic metabolic analysis system. $\dot{V}O_2$ was monitored continuously and $\dot{V}O_{2max}$ was expressed as the highest 15-second average attained during the maximal incremental exercise test.

Determination of VT

VT was determined visually from computer-generated graphs using one or more of the following criteria (Santos & Gianella-Neto, 2004):

1. the breakpoint on the $\dot{V}CO_2$ versus $\dot{V}O_2$ plot;
2. the RER versus time curve showing a sustained increase above 1.00;
3. the $\dot{V}_E$ versus $\dot{V}O_2$ curve, having been flat or decreasing, beginning to rise as the $\dot{V}_E$ versus $\dot{V}CO_2$ remained constant or decreased.

Determination of Workload for 20-minute Cycling Bouts

The workload for the 20-minute cycling bouts was set at the power output required to elicit an oxygen consumption corresponding to approximately 10% $\dot{V}O_{2max}$ below the VT.

Statistical Analysis

An initial analysis was conducted to determine the presence of erroneous values in the data. [La] was the only variable for which this was the case because it was not automatically measured. For example, where [La] values were extraordinarily high given the workload (i.e., above 8.0 $mmol \cdot L^{-1}$), they were considered erroneous. Missing data occurred when measurement time points were missed due to equipment challenges. This occurred for [La] and HR. Where erroneous values or missing data occurred, data were imputed using the series mean method using a statistical software program (SPSS, Chicago, Illinois). [La] values were erroneous at all four time points for two participants during one 40 MIN trial each. In this case, the values were omitted and the analysis was conducted without these values (n=18).

Data were analyzed using a repeated-measures ANOVA. The within-subjects factors included the experimental condition and time. The experimental condition had 2 levels: short condition = expect 20 minutes (20 MIN) and long condition = expect 40 minutes (40 MIN). Time had 7 levels: at 2, 5, 8, 11, 14, 17, and 20 minutes. The dependent variables used were HR, $\dot{V}O_2$, $\dot{V}_E$, RR, RPM, [La], % ASSOC, RPE, and FS. Where data failed the assumption of sphericity, Greenhouse-Geisser-corrected values are reported. Exercise [La] was analyzed using the repeated measures ANOVA (for minutes 0, 10, and 20), while recovery [La] was analyzed using a 2*2 ANOVA (using time at 20 minutes and 2 minutes of recovery and condition). Where reported, effect size was calculated using a pooled standard deviation according to the equation:

$$d = M_1 - M_2 / \sigma_{pooled}$$

When a significant interaction was found, a Tukey HSD post hoc test was used to determine where significant differences existed. [La] values for each condition were compared using one-tailed paired t-tests. An alpha level of .05 was used for all statistical analyses. Tables showing the results of each analysis of variance are presented in Appendix B. To determine relationships between variables, Pearson Product Moment Correlations were performed between all variables at the same time point (i.e., RPE at 2 minutes with all other variables at 2 minutes). Finally, the slope of increase for RPE was fitted with a linear regression line and equation using a spreadsheet program (Excel, Microsoft, Redmond, WA).

Post hoc analysis

As part of a post hoc analysis, data were separated into two intensity groups. The higher intensity group (INT-A) included those participants who exercised at an RER value above 1.00 at any time during either of the cycling bouts. The lower intensity group (INT-B) included those participants who did not exceed an RER of 1.00 at any time during either of the cycling bouts. Following separation of the data into intensity groups, separate analyses of variance were performed for each group to investigate any effects that may be due to the relative intensity of exercise. The higher intensity group (INT-A) had 9 participants and the lower intensity group (INT-B) had 11 participants. Because data for two participants were omitted for lactate analyses, there was one fewer participant for both INT-A and INT-B (n=8 and n=10, respectively). Exercise and recovery [La] was analyzed as described above.

Results

Data presented within the text are presented as mean (SD). In an effort to maintain the clarity of data presented in the figures, mean values are presented in graphical form, with error bars indicating the SEM.

Rating of Perceived Exertion

A main condition effect indicated that, overall, RPE values for 40 MIN were lower than 20 MIN, $F(1, 8) = 8.590$, $p<.05$ (Figure 5). Mean (SD) for RPE over the 20 minutes of exercise was 12.7 (1.63) for 20 MIN and 12.2 (1.45) for 40 MIN. This showed an effect size of .324, which would be considered small according to Cohen (1988). Rating of perceived exertion (RPE) increased significantly over time throughout the exercise session for both 20 MIN and 40 MIN, $F(1.875, 15.003) = 13.435$, $p<.05$ (Figure 6). A linear regression analysis indicated that this increase of RPE over time occurred according to the equations:

$$RPE = .25 \text{ (time)} + 11.657 \text{ (20 MIN)}$$

$$RPE = .2518 \text{ (time)} + 11.179 \text{ (40 MIN)}$$

Explained variance (R^2) was .9273 for 20 MIN and .9842 for 40 MIN. There were no other main effects or interactions.

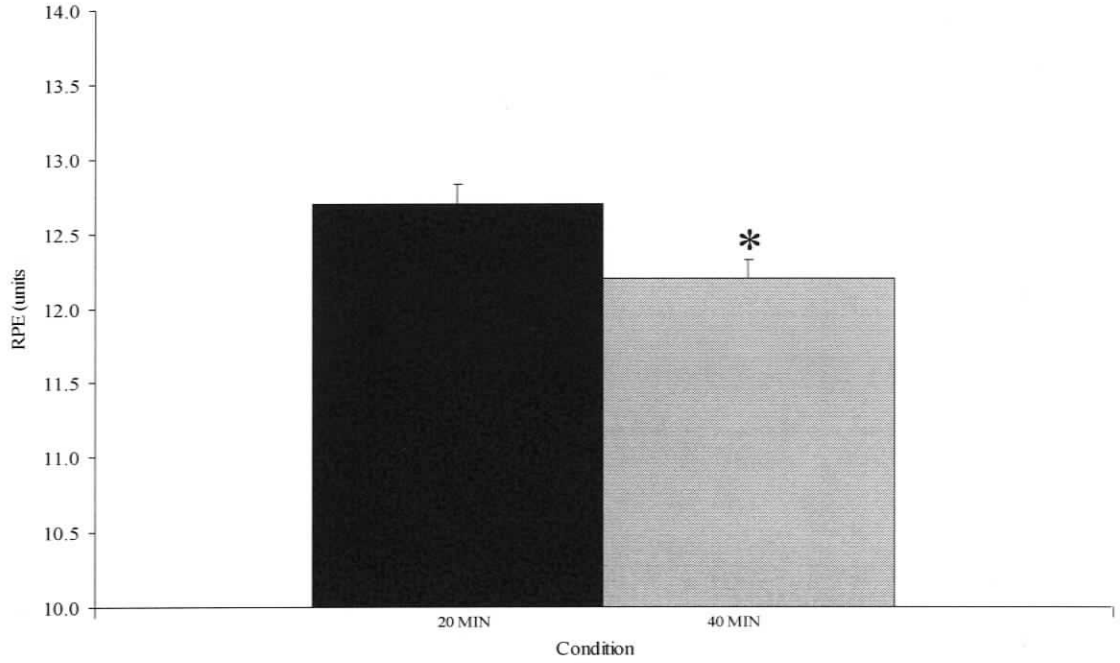

Figure 5. Mean rating of perceived exertion for 20 MIN and 40 MIN. *significant difference between means ($p<.05$). Error bars represent SEM.

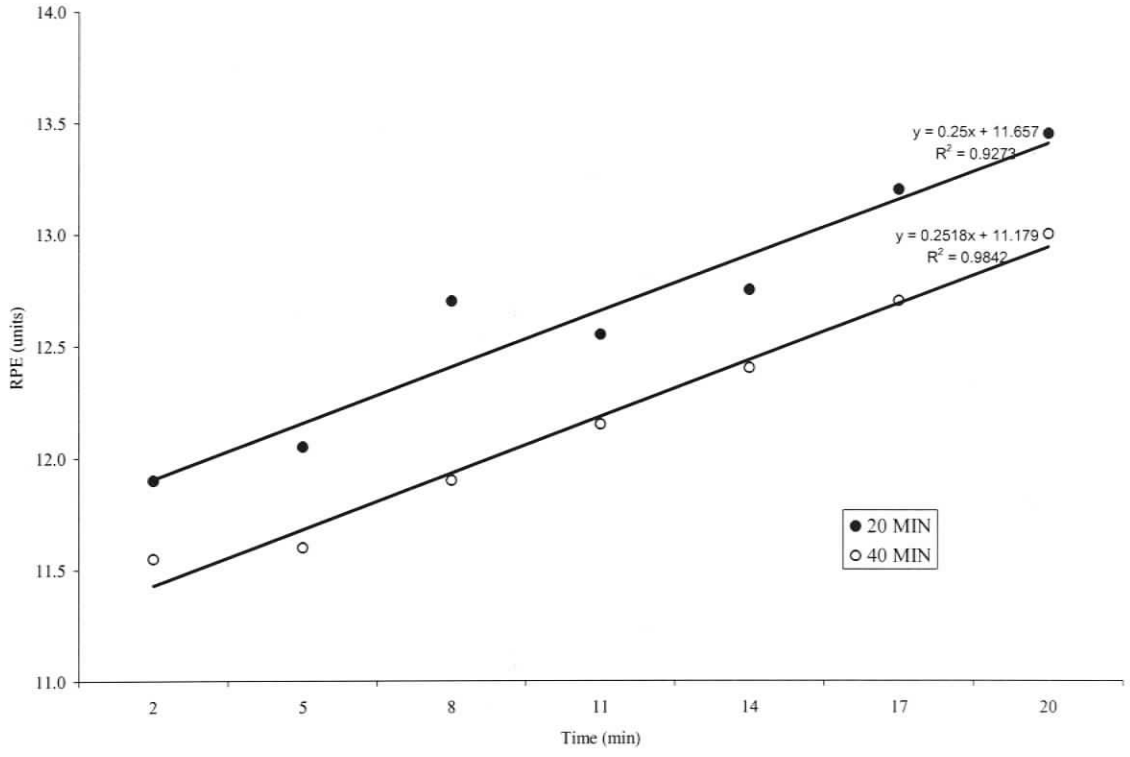

Figure 6. Linear regression lines and explained variance for mean rating of perceived exertion for 20 MIN and 40 MIN.

Heart Rate and Oxygen Consumption

Heart rate (HR) and oxygen consumption ($\dot{V}O_2$) both demonstrated a significant increase over time throughout the 20 minutes of exercise in both the 20 minute expectation condition (20 MIN) and the 40 minute expectation condition (40 MIN). Mean (SD) HR increased from 137 (11.3) to 154 (16.1) bpm during 20 MIN and from 136 (8.7) to 154 (13.7) during 40 MIN (Figure 7). $\dot{V}O_2$ increased from 2.76 (.29) to 3.03 (.37) $L \cdot min^{-1}$ during 20 MIN and from 2.79 (.22) to 3.00 (.34) during 40 MIN (Figure 8). There were no statistically significant main effects due to intensity or condition for either of these variables.

There was a statistically significant condition by time interaction found for $\dot{V}O_2$, $F(6, 48) = 2.474$, $p<.05$ (Figure 8). A Tukey HSD post hoc test indicated significant differences between means at minutes 2 and 17 ($p<.05$). $\dot{V}O_2$ for the 2nd minute was higher during 40 MIN as compared to 20 MIN (2.79 (.22) and 2.76 (.29) $L \cdot min^{-1}$, respectively), while $\dot{V}O_2$ for the 17th minute was lower during 40 MIN as compared to 20 MIN (2.97 (.38) and 3.04 (.34) $L \cdot min^{-1}$, respectively). The effect size was .117 for the 2nd minute and .194 for the 17th minute. These values would be considered lower than "small" according to Cohen (1988). There were no significant interactions found for HR.

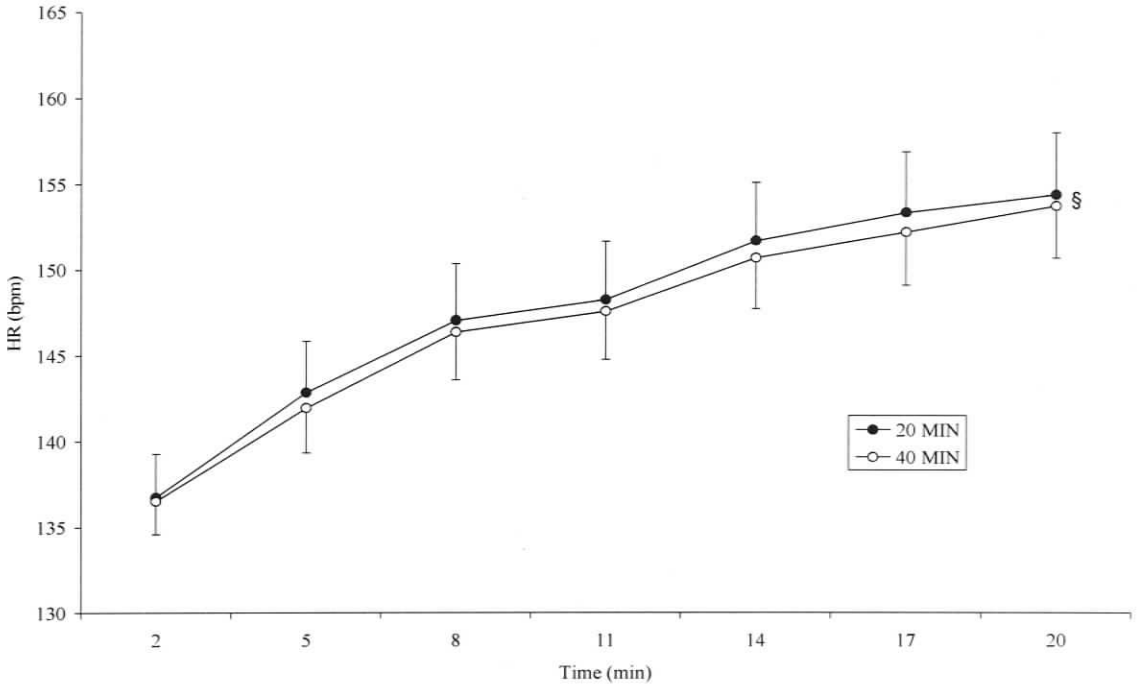

Figure 7. Mean heart rate for 20 MIN and 40 MIN. § significant increase over time for both conditions. Error bars represent SEM.

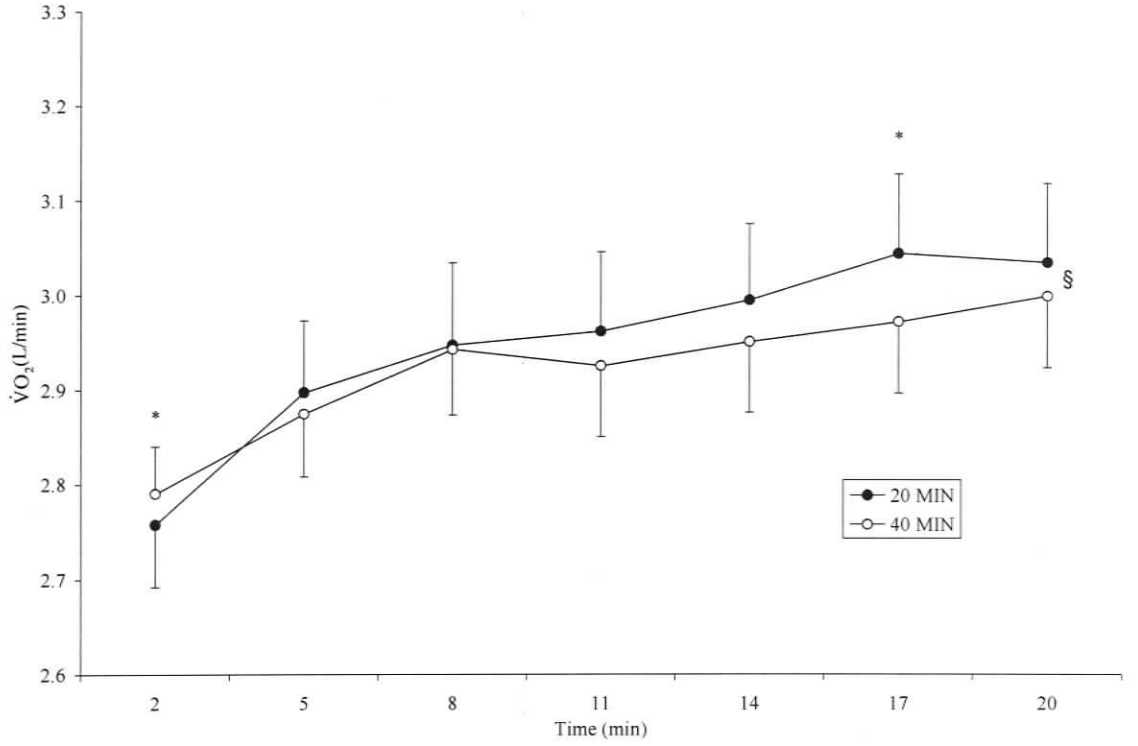

Figure 8. Mean oxygen consumption for 20 MIN and 40 MIN. *significant difference between means ($p<.05$). § significant increase over time for both conditions. Error bars represent SEM.

Blood Lactate

Blood lactate concentration [La] data were analyzed with only 18 participants as described in the Methods section. [La] during exercise showed a significant time main effect, $F(1.454, 24.713) = 30.109$, $p<.05$. There were significant differences in [La] between 0 and 10 minutes and between 0 and 20 minutes for both the 20 MIN and 40 MIN conditions ($p<.05$) (Figure 9). There were no other significant effects or interactions for exercise [La]. Further, there were no significant effects or interactions for recovery [La].

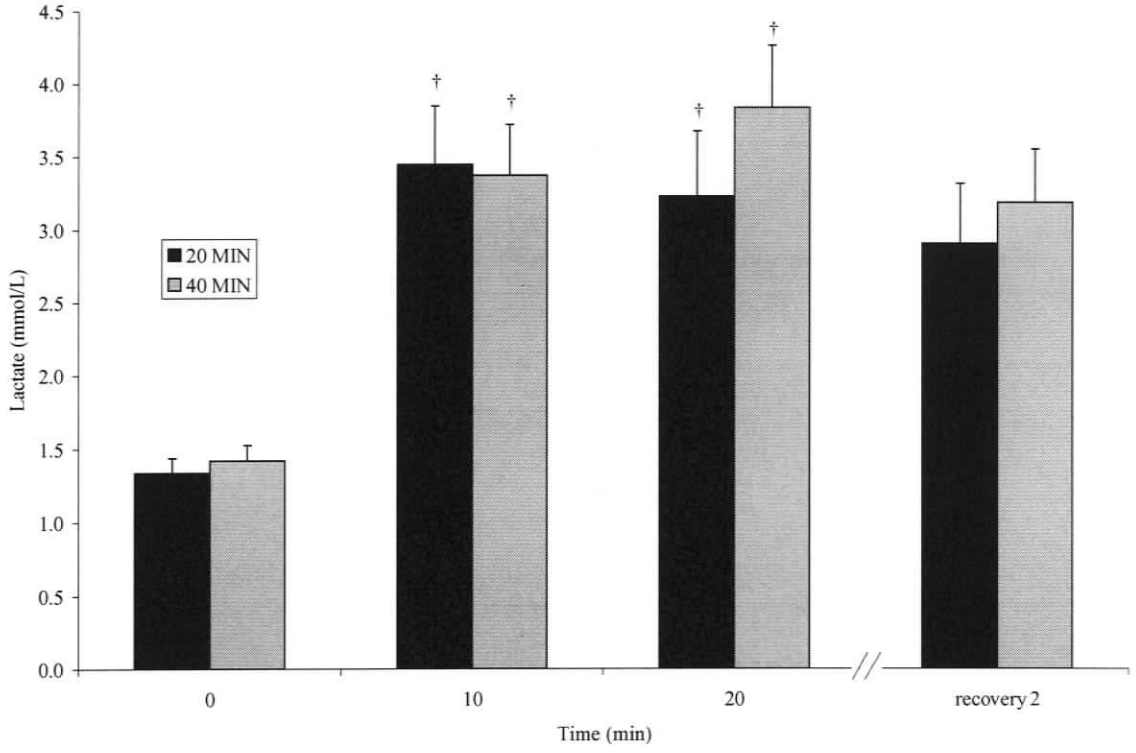

Figure 9. Mean blood lactate concentration for 20 MIN and 40 MIN. Error bars represent SEM. †significant increase from time 0.

Minute Ventilation and Respiratory Rate

Minute ventilation ($\dot{V}_E$) and respiratory rate (RR) both demonstrated significant increases over time throughout the 20 minutes of exercise in both the 20 MIN and 40 MIN conditions. Mean (SD) $\dot{V}_E$ increased from 47.61 (8.0) to 62.21 (12.0) $L \cdot min^{-1}$ during 20 MIN and from 48.78 (6.4) to 60.53 (11.5) during 40 MIN (Figure 10). Average RR increased from 20.8 (3.2) to 26.3 (4.9) bpm during 20 MIN and from 21.0 (3.8) to 25.6 (4.9) bpm during 40 MIN (Figure 11). There were no statistically significant main effects due to intensity or condition for any of these variables.

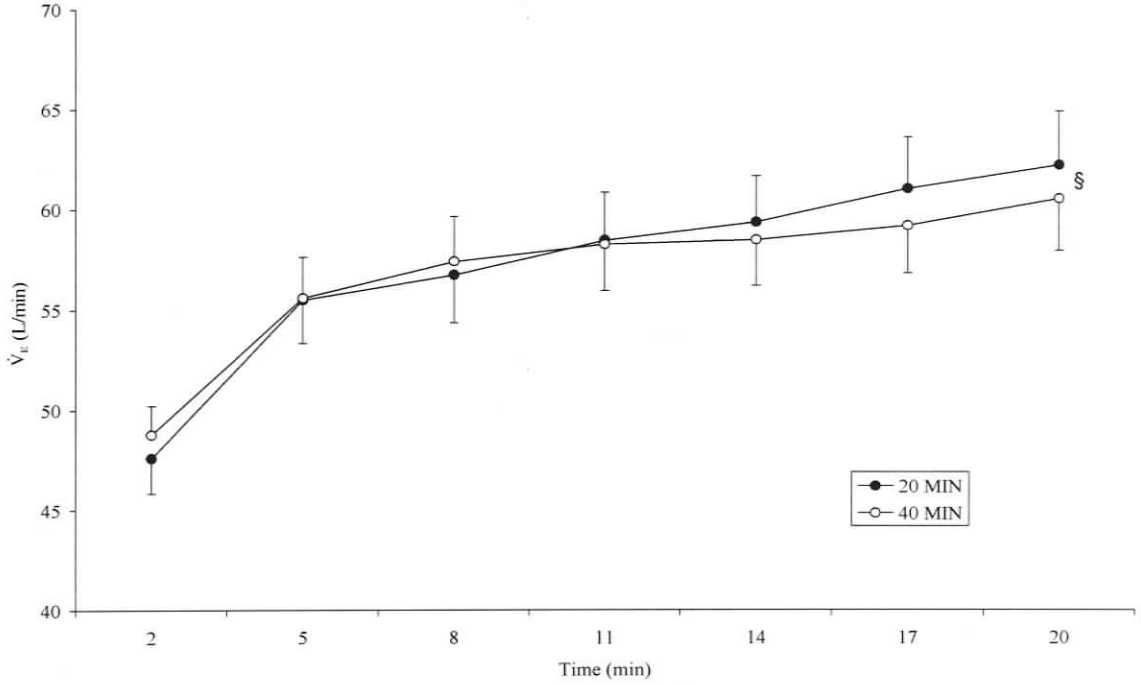

Figure 10. Mean minute ventilation for 20 MIN and 40 MIN. § significant increase over time for both conditions. Error bars represent SEM.

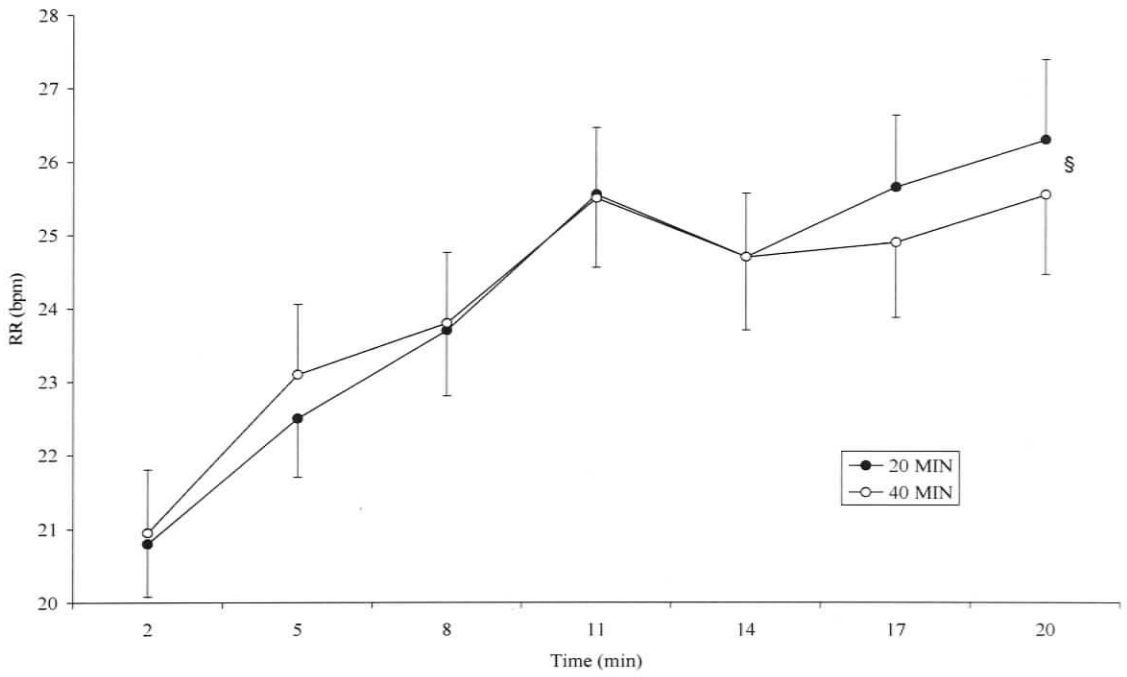

Figure 11. Mean respiratory rate for 20 MIN and 40 MIN. § significant increase over time for both conditions. Error bars represent SEM.

Cycling Cadence

Because of a prominent decrease in cycling cadence (RPM) at minute 11 corresponding to the measurement of [La] during the 10th minute, RPM at this time point was omitted from the statistical analysis. As a result, two separate ANOVAs were performed with minutes 2, 5, and 8, analyzed separately from minutes 14, 17, and 20. RPM significantly increased over time during the first 3, but not the last 3 time points. There were no main effects for intensity, condition, nor were there any interactive effects at any time point. RPM data are presented in Figure 12.

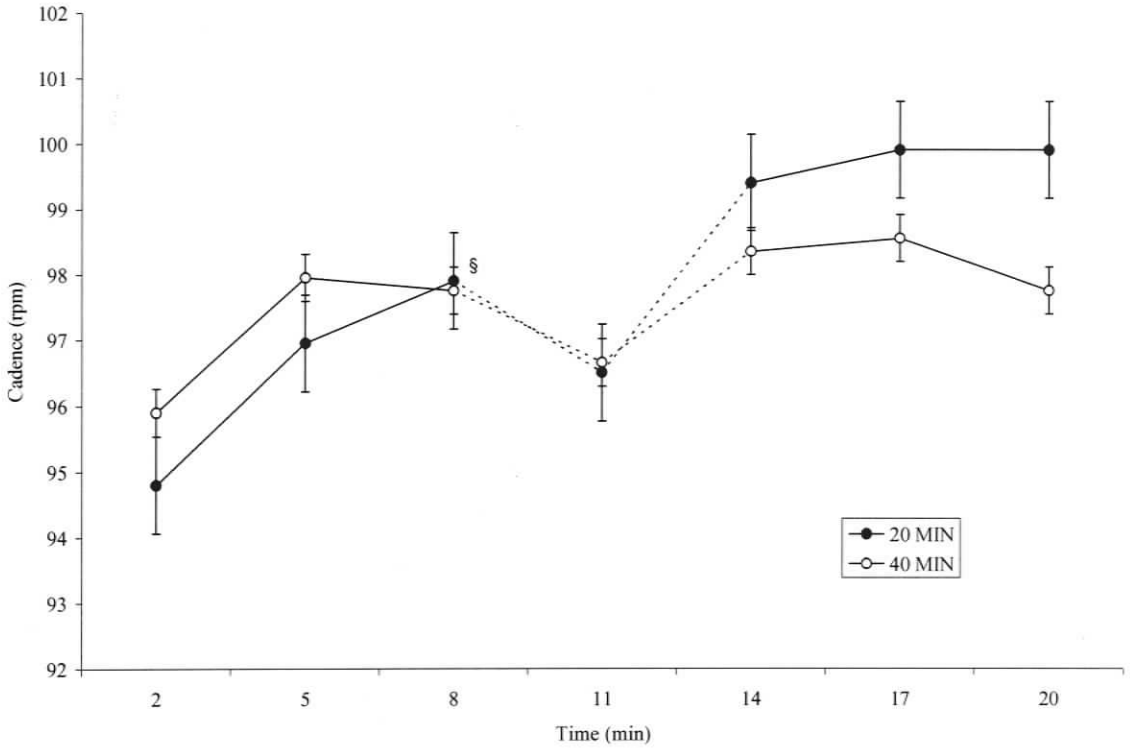

Figure 12. Mean cycling cadence for 20 MIN and 40 MIN. § significant increase over time for the first 3 time points. Error bars represent SEM. Dotted lines represent the omission of the 11 minute time point from the analysis.

Associative Thoughts and Feeling Scale

Due to a prominent decrease in percentage of associative thoughts (%ASSOC) at minute 11 corresponding to the measurement of [La] during the 10th minute, the ANOVA for %ASSOC was performed by omitting the 11 minute time point. Analysis was conducted in the same manner as previously described for cycling cadence. %ASSOC did not show any main effects or interaction effects. %ASSOC data are presented in Figure 13. No significant main effects or any interactions were found for feeling scale (FS) when data was analyzed by condition. FS data are presented in Figure 14.

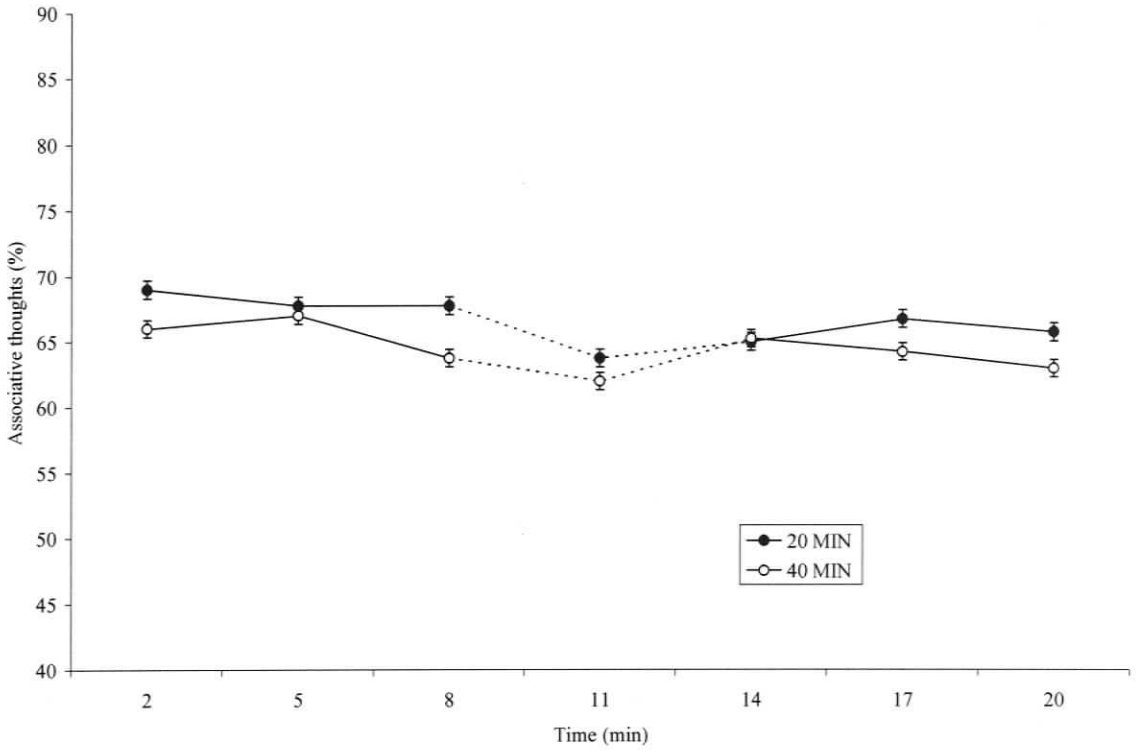

Figure 13. Mean percentage of associative thoughts for 20 MIN and 40 MIN. Error bars represent SEM. Dotted lines represent the omission of the 11 minute time point from the analysis.

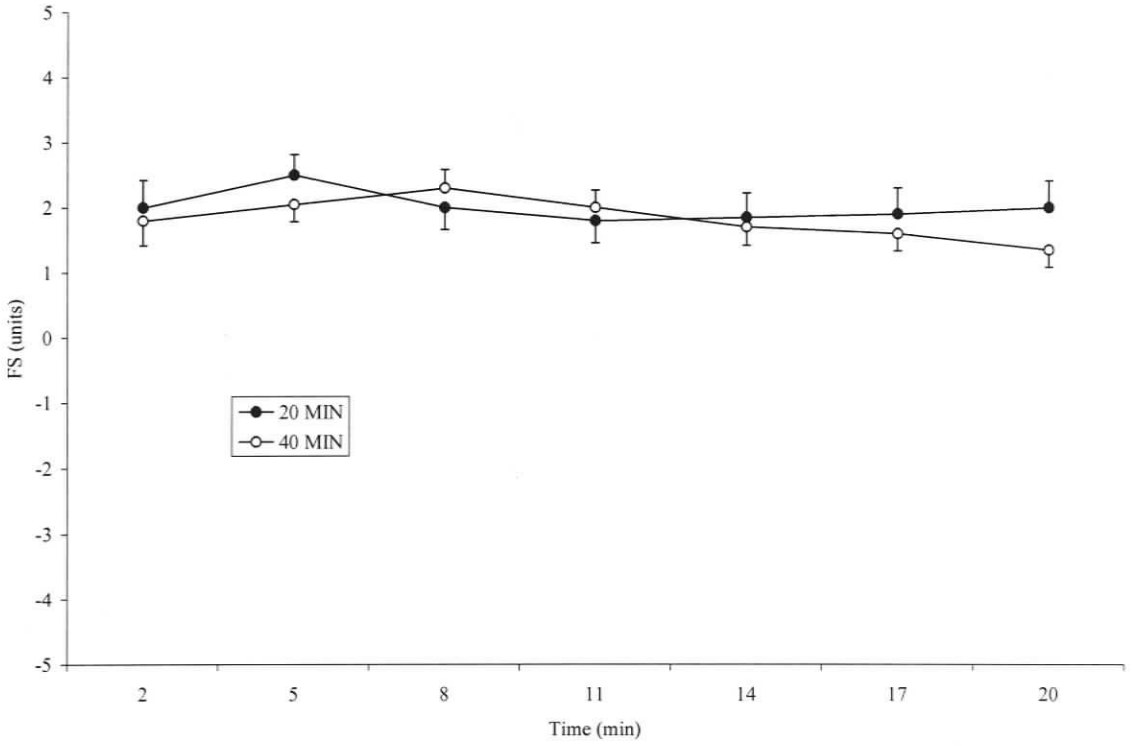

Figure 14. Mean feeling scale scores for 20 MIN and 40 MIN. Error bars represent SEM.

Relationships Between Variables

A Pearson product moment correlation was performed to assess association between each variable and the others. Analysis indicated that there were no significant correlations at each corresponding time point between RPE and any variable other than FS, for either 20 MIN or 40 MIN, except between RPE and HR at the 11th minute during 40 MIN. Significant negative correlations were found between RPE and FS at all time points during the 20 MIN (Table 2) and the first three time points during the 40 MIN trial (Table 3).

Table 2
Correlations Between each Variable and Rating of Perceived Exertion at Each Corresponding Time Point for the 20 MIN Trial

Variable	Statistic	RPE						
		2	5	8	11	14	17	20
HR	*r*	.286	.204	.040	.289	.435	.228	.298
	p	.222	.388	.865	.217	.055	.333	.201
$\dot{V}O_2$	*r*	-.037	-.112	-.294	.117	.209	-.124	.118
	p	.878	.638	.208	.623	.376	.603	.619
$\dot{V}_E$	*r*	.109	.114	-.182	.161	.179	-.037	.148
	p	.648	.633	.442	.497	.451	.878	.534
RR	*r*	.054	.272	.165	.045	-.059	-.078	.150
	p	.820	.245	.487	.852	.806	.745	.528
RPM	*r*	-.092	-.112	.047	.118	.237	.150	.205
	p	.701	.638	.845	.621	.315	.528	.386
%ASSOC	*r*	.301	.251	.197	.146	.327	.273	.206
	p	.196	.286	.405	.539	.160	.243	.384
FS	*r*	-.612**	-.672**	-.726**	-.734**	-.685**	-.788**	-.690**
	p	.004	.001	.000	.000	.001	.000	.001

**significant at $p<.01$, *significant at $p<.05$.

Table 3
Correlations Between Each Variable and Rating of Perceived Exertion at Each Corresponding Time Point for the 40 MIN Trial

Variable	Statistic	RPE						
		2	5	8	11	14	17	20
HR	*r*	.295	.231	.396	.463*	.403	.199	.416
	p	.207	.328	.084	.040	.078	.400	.068
$\dot{V}O_2$	*r*	-.004	-.028	.248	.156	.050	-.065	.219
	p	.985	.908	.291	.512	.833	.785	.353
$\dot{V}_E$	*r*	.318	.274	.373	.225	.231	.166	.306
	p	.172	.243	.105	.339	.327	.484	.189
RR	*r*	.280	.215	.283	.062	.186	.192	.345
	p	.232	.363	.227	.796	.423	.418	.137
RPM	*r*	-.241	-.093	-.053	.050	.093	.007	.035
	p	.306	.696	.826	.834	.698	.978	.883
%ASSOC	*r*	.052	.189	.100	-.031	.078	-.112	.073
	p	.828	.424	.674	.897	.743	.639	.758
FS	*r*	-.610**	-.679**	-.499*	-.344	-.111	-.273	-.390
	p	.004	.001	.025	.138	.641	.244	.089

**significant at $p<.01$, *significant at $p<.05$.

Exercise Intensity

The exercise intensity during the two 20-minute cycling bouts varied between individuals due to the difficulty of precisely estimating the workload that would require an oxygen consumption 10% $\dot{V}O_{2max}$ below ventilatory threshold (VT). The average intensity across participants during the 20 MIN trial was 64% $\dot{V}O_{2max}$ (3% $\dot{V}O_{2max}$ below VT) at the beginning, and 70% $\dot{V}O_{2max}$ by the end of the trial (10% $\dot{V}O_{2max}$ below VT). During the 40 MIN trial, the average exercise intensity was 65% $\dot{V}O_{2max}$ at the beginning, and 70% $\dot{V}O_{2max}$ at the end (4-9% $\dot{V}O_{2max}$ below VT). In order to further investigate the effect of proximity to VT, the participants' data were separated into two groups: 1) those who exceeded an RER value of 1.00 during either the 20 MIN or the 40 MIN trial (INT-A), and 2) those who did not exceed RER = 1.00 at any time during either trial (INT-B). Because of this organization, the repeated-measures ANOVA included 2 levels of intensity (INT-A and INT-B). RER values for all subjects together are presented in Figure 15, and RER values after separation into the higher intensity group (INT-A) and the lower intensity group (INT-B) are presented in Figure 16. Participant characteristics for the resultant groups are given in Tables 4 and 5.

Table 4
Participant Characteristics and Exercise Test Performance for INT-A and INT-B.

							Exercise intensity*		
Group	*N*	Age	Height (cm)	Weight (kg)	$\dot{V}O_{2max}$ ($L \cdot min^{-1}$)	VT (% $\dot{V}O_{2max}$)	% $\dot{V}O_{2max}$	% $\dot{V}O_{2max}$ relative to VT	RER
INT-A	9	34.4	178.9	76.8	4.29	75	66-74	-9 to -1	0.90-1.01
SD		3.7	5.8	6.0	.4	9.8	-	-	-
INT-B	11	32.5	178.2	73.6	4.26	74	63-68	-11 to -6	0.84-0.96
SD		4.9	4.5	6.4	.4	12.9	-	-	-

*ranges given are from the lowest average and the highest average values for either 20 MIN or 40 MIN.

Table 5
Participant Training History Presented as Mean (SEM) for INT-A and INT-B.

Group	*N*	Years training	# Sessions per week	Session duration (hours)
INT-A	9	9.8 (1.94)	3.9 (.39)	2.0 (.20)
INT-B	11	6.8 (1.89)	4.0 (.44)	2.2 (.21)

A two-tailed independent samples *t* test indicated that there were no significant differences for anthropometric measures, $\dot{V}O_{2max}$, VT, or training history between the two groups ($p>.05$).

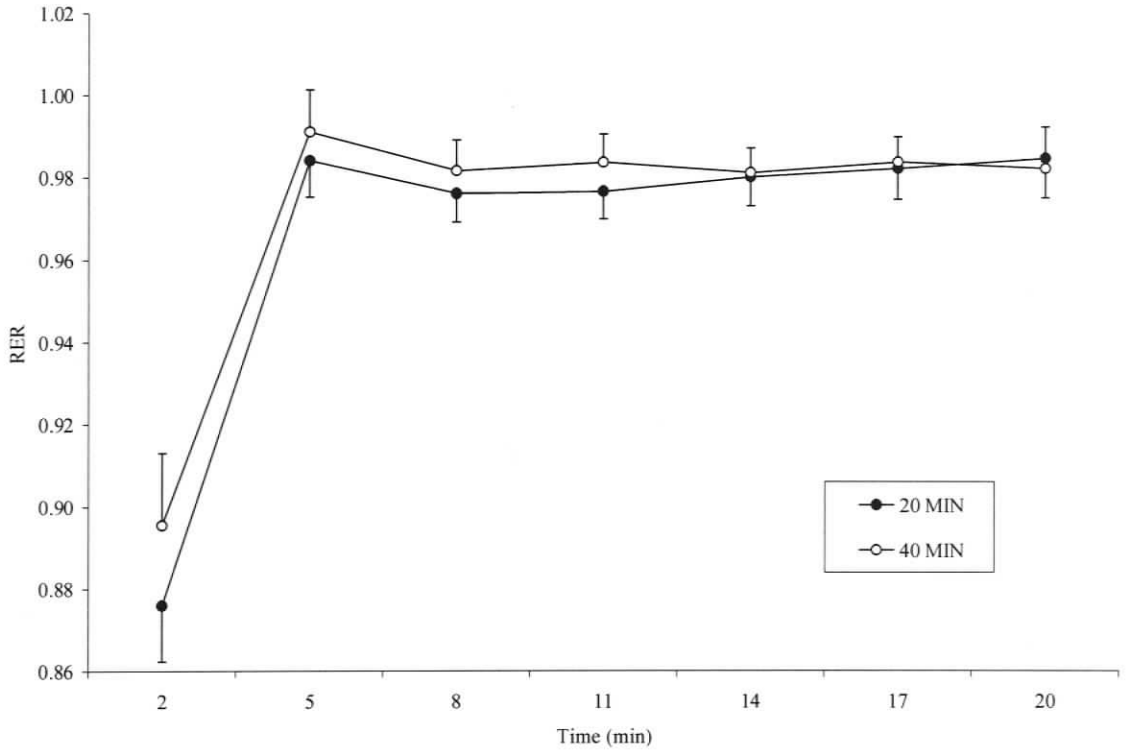

Figure 15. Mean respiratory exchange ratio for all participants together (n=20) for 20 MIN and 40 MIN. Error bars represent SEM.

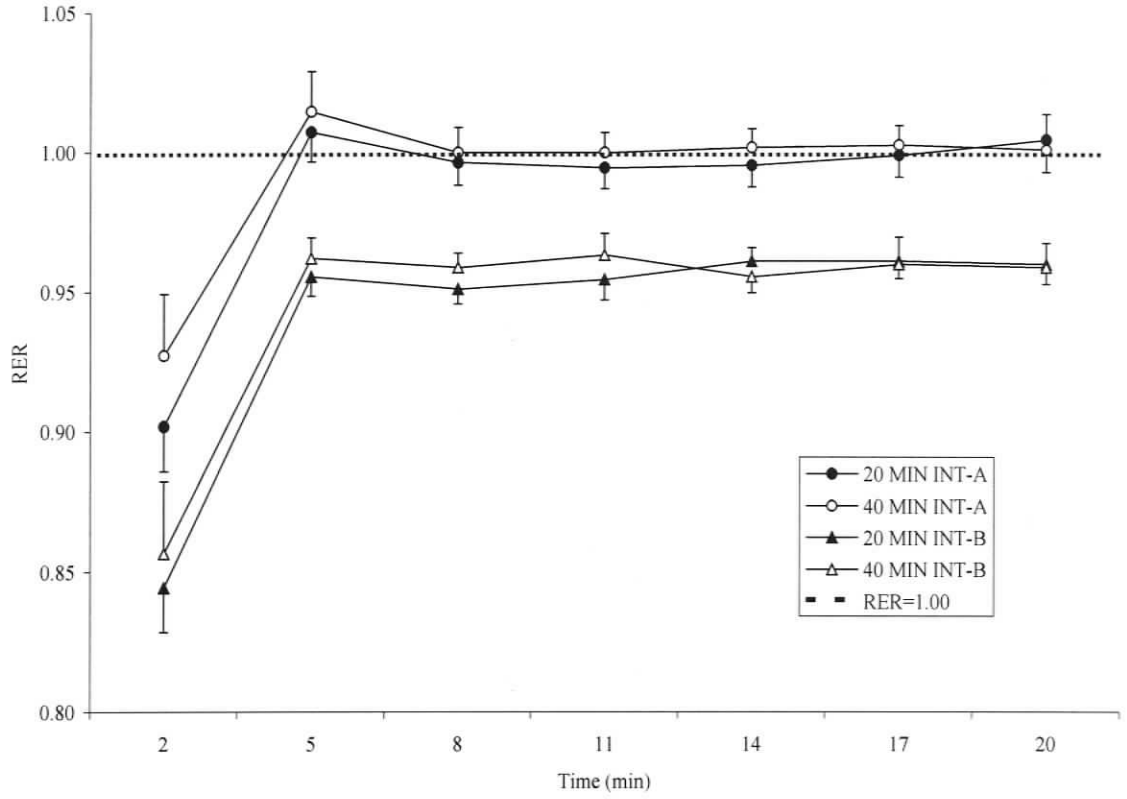

Figure 16. Mean respiratory exchange ratio for 20 MIN and 40 MIN, separated between participants who exceeded RER=1.00 at any time during either trial (INT-A, n=9), and those who did not (INT-B, n=11). Error bars represent SEM.

Rating of Perceived Exertion for INT-A and INT-B

Analysis following separation into intensity groups showed significant increases over time in both INT-A and INT-B. A significant condition effect for INT-B was found, $F(1, 8) = 6.780$, $p<.05$, indicating that, overall, RPE in INT-B was lower for 40 MIN as compared to 20 MIN. Mean (SD) RPE in INT-B was 12.2 (1.5) for 20 MIN and 11.6 (1.3) for 40 MIN. The effect size for this was .417, which would be considered small according to Cohen (1988). No other main effects or interactions were found. RPE data separated into two intensity groups are presented in Figure 17.

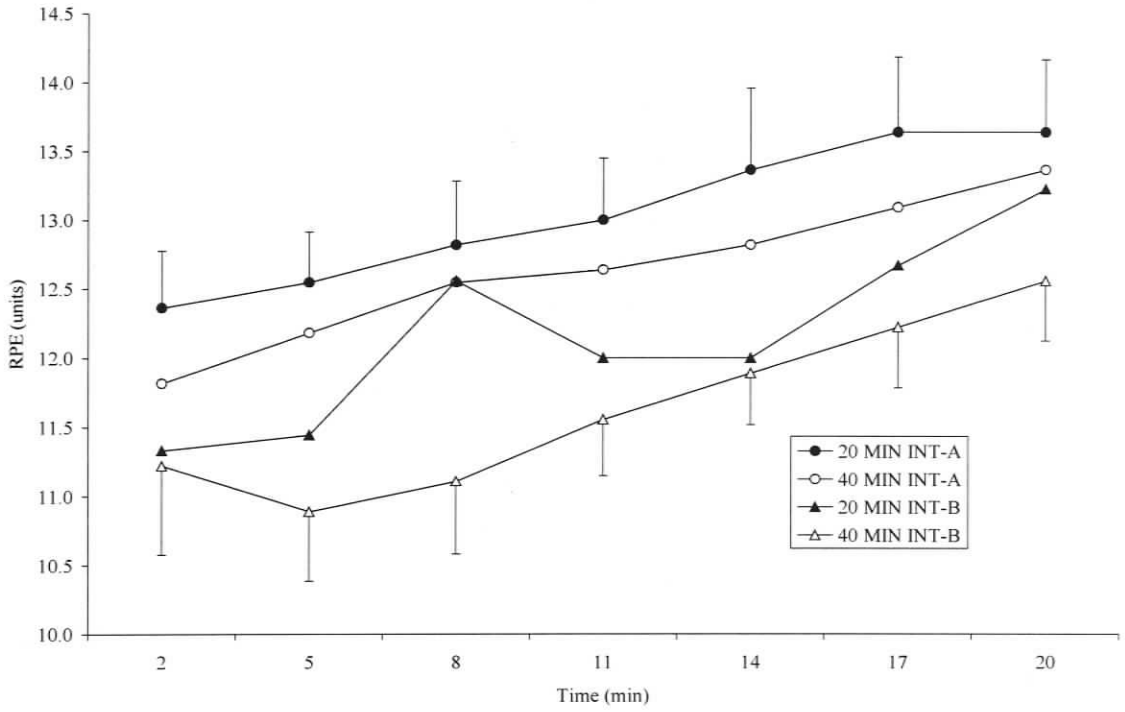

Figure 17. Mean rating of perceived exertion for the 20 MIN and 40 MIN trials, separated between participants who exceeded RER=1.00 at any time during either trial (INT-A, n=9), and those who did not (INT-B, n=11). Error bars represent SEM.

Blood Lactate for INT-A and INT-B.

Following separation into intensity groups, an analysis of variance indicated significant time effects for both INT-A and INT-B (n=8 and n=10, respectively) (Figure 18). There were significant differences in exercise [La] between 0 and 10 minutes and between 0 and 20 minutes for 20 MIN INT-A, 40 MIN INT-A, and 40 MIN INT-B. During 40 MIN INT-A, there was a significant difference in [La] between 0 and 10 minutes only ($p<.05$). There were no other main effects or interactions for [La] for either INT-A or INT-B or during recovery.

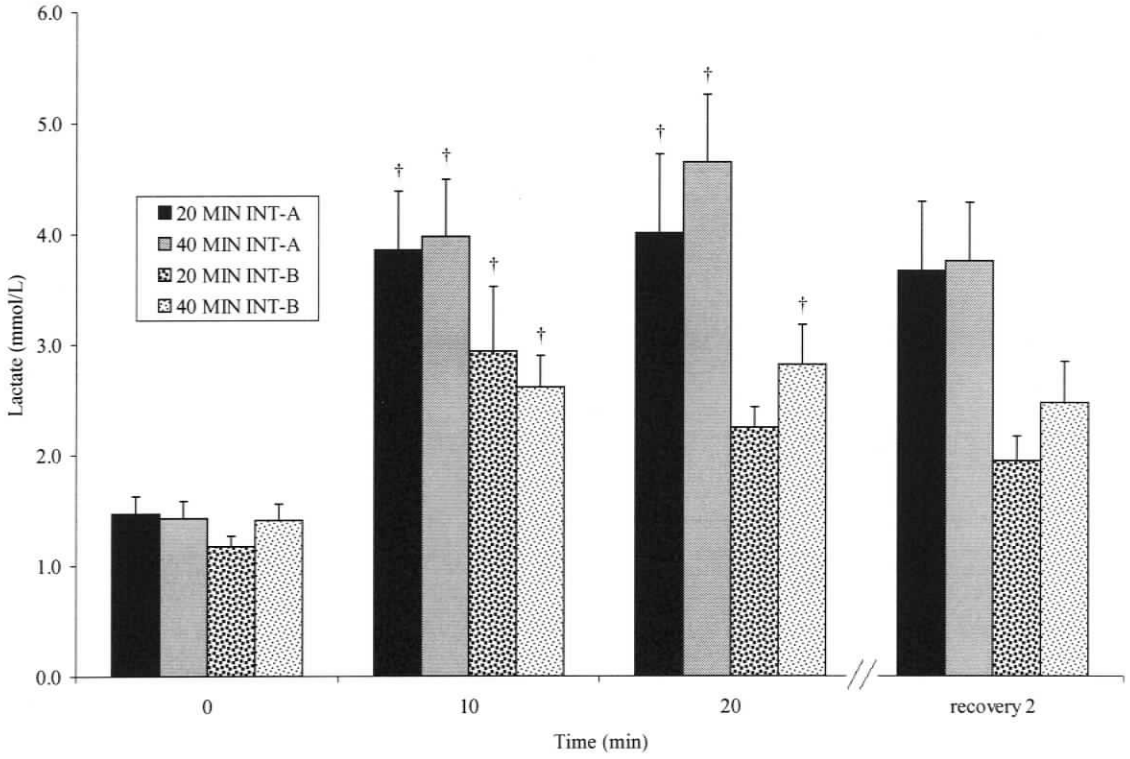

Figure 18. Mean blood lactate concentrations for 20 MIN and 40 MIN, separated between participants who exceeded R=1.00 at any time during either trial (INT-A, n=8) and those who did not (INT-B, n=10). Error bars represent SEM. † significant increase from 0 minutes ($p<.05$).

Cardiorespiratory Variables for INT-A and INT-B

Data for the cardiorespiratory variables after separation into intensity groups are presented in Figures 19 – 22. Analysis following separation indicated that all variables for each intensity group demonstrated a significant increase over time ($p<.05$). There were no other significant main effects for intensity group or experimental condition, nor were there any significant interactions.

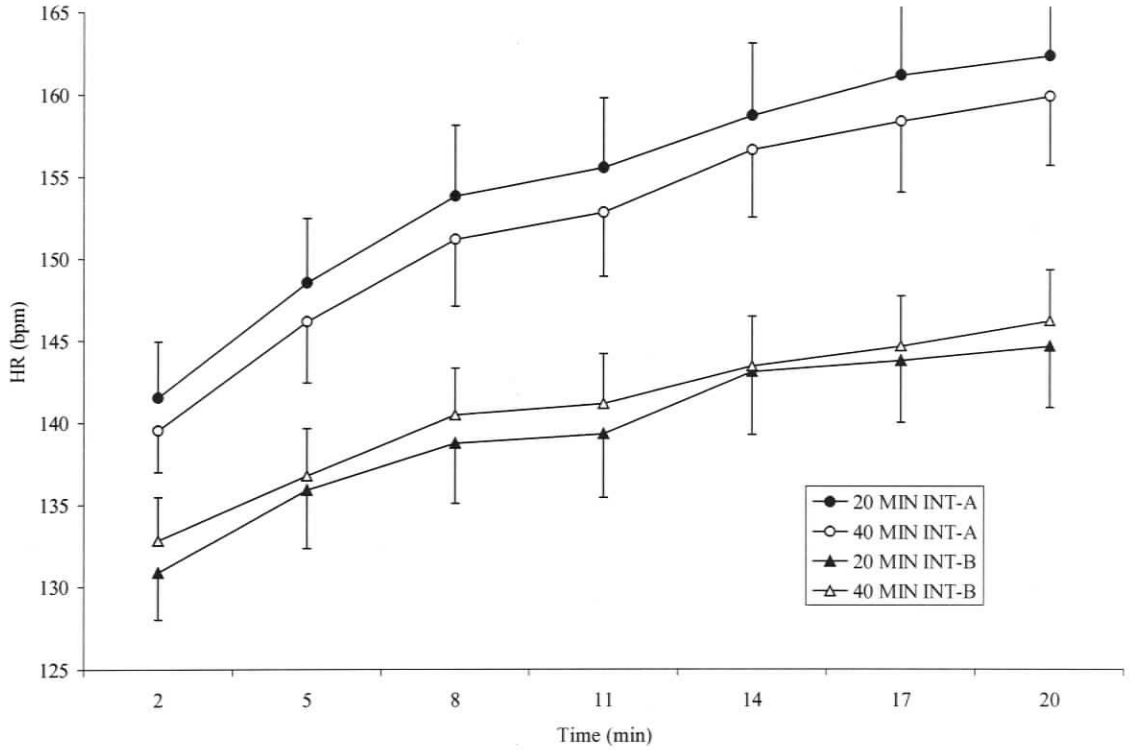

Figure 19. Mean heart rate for 20 MIN and 40 MIN, separated between participants who exceeded RER=1.00 at any time during either trial (INT-A, n=9), and those who did not (INT-B, n=11). Error bars represent SEM.

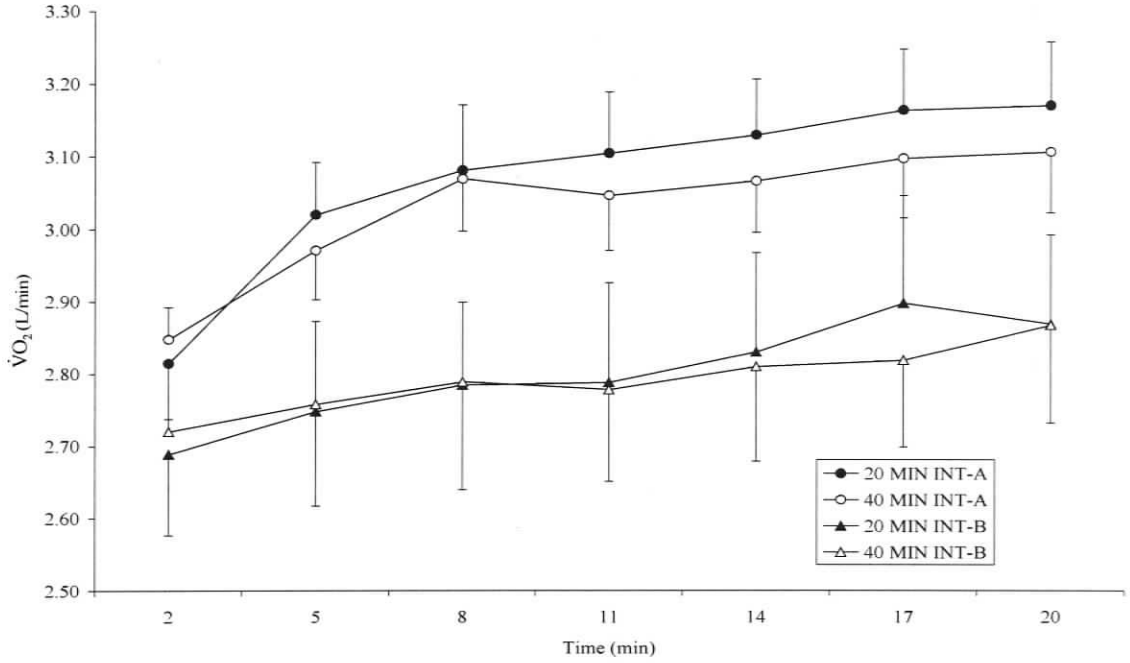

Figure 20. Mean oxygen consumption for 20 MIN and 40 MIN, separated between participants who exceeded RER=1.00 at any time during either trial (INT-A, n=9), and those who did not (INT-B, n=11). Error bars represent SEM.

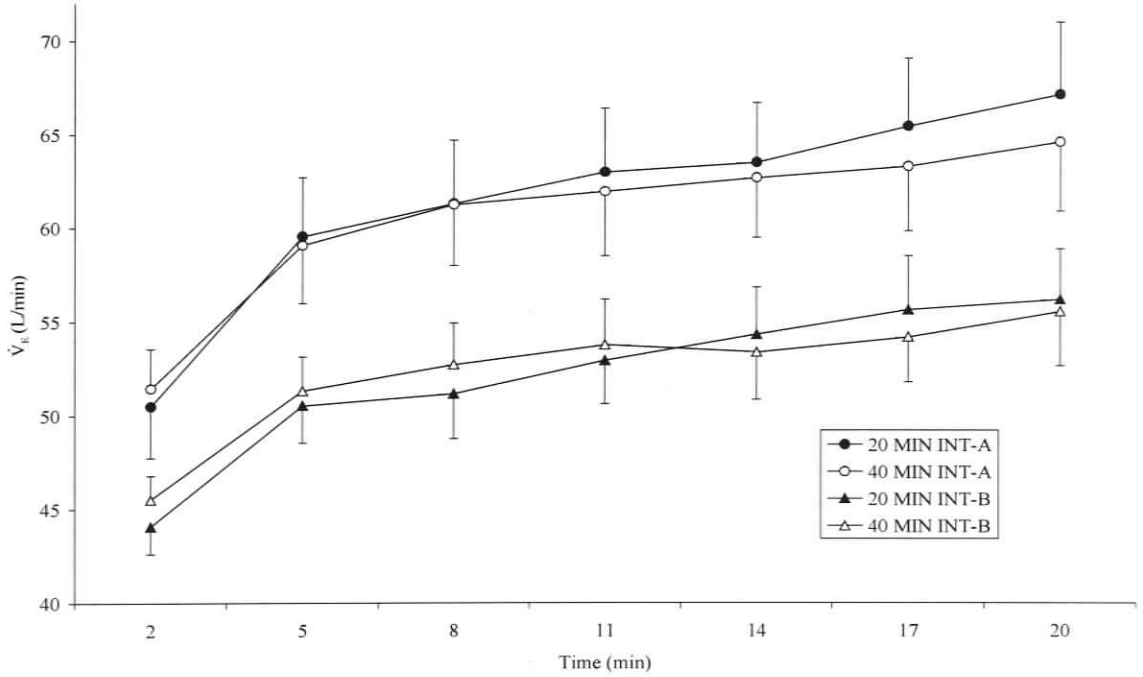

Figure 21. Mean minute ventilation for 20 MIN and 40 MIN, separated between participants who exceeded RER=1.00 at any time during either trial (INT-A, n=9), and those who did not (INT-B, n=11). Error bars represent SEM.

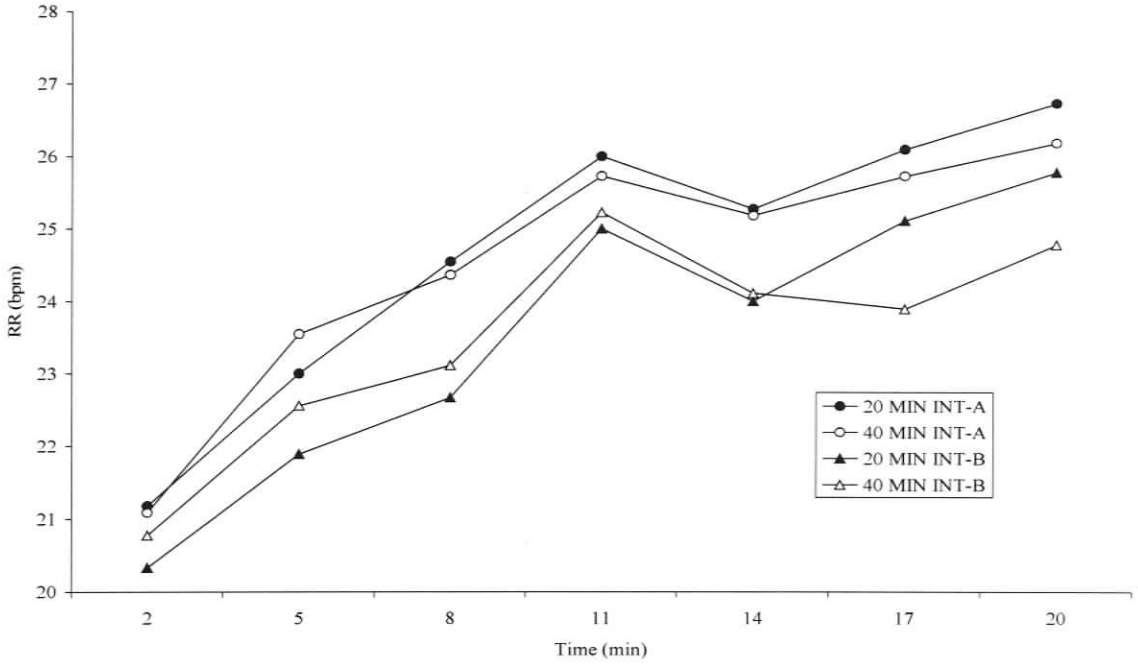

Figure 22. Mean respiratory rate for 20 MIN and 40 MIN, separated between participants who exceeded RER=1.00 at any time during either trial (INT-A, n=9), and those who did not (INT-B, n=11). Error bars represent SEM.

Cycling Cadence for INT-A and INT-B

Data for RPM after separation into intensity groups are presented in Figure 23. As was done for unseparated cycling cadence data, two separate ANOVAs were performed with minutes 2, 5, and 8 analyzed separately from minutes 14, 17, and 20. There were no significant main effects or any interactions.

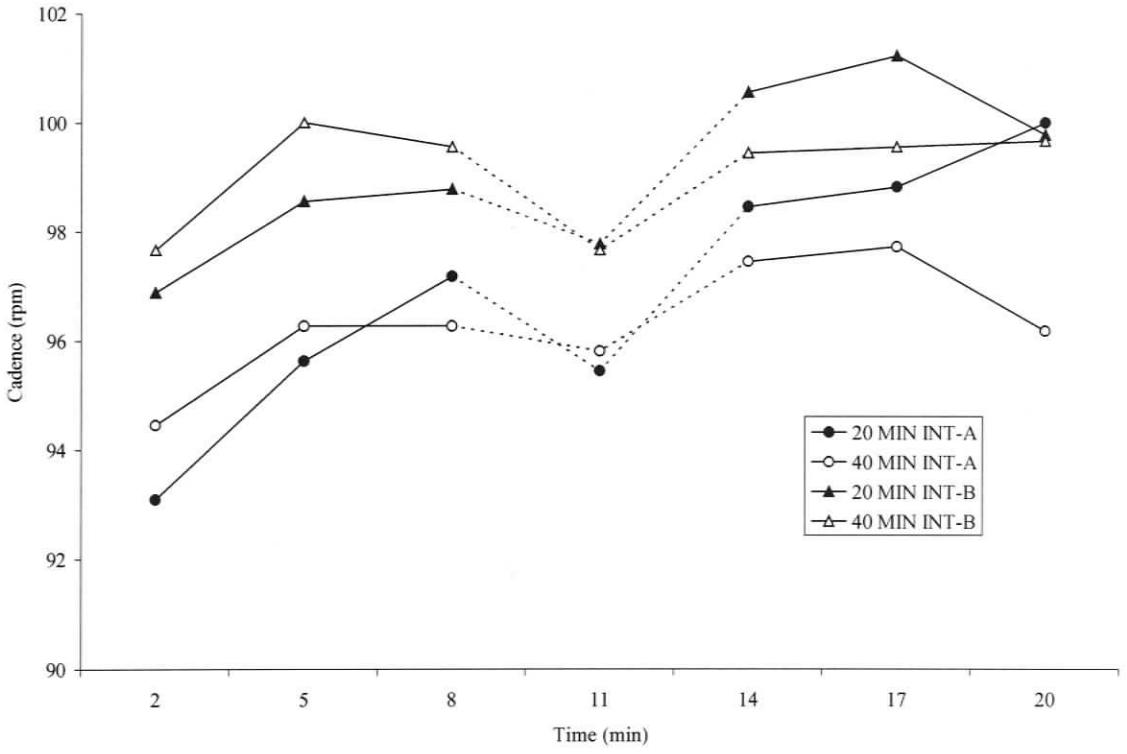

Figure 23. Mean cycling cadence for 20 MIN and 40 MIN, separated between participants who exceeded RER=1.00 at any time during either trial (INT-A, n=9), and those who did not (INT-B, n=11). Dotted lines represent the omission of the 11 minute time point from the analysis.

Percentage of Associative Thoughts and Feeling Scale for INT-A and INT-B.

Following separation into intensity groups, analysis indicated that there were no main or interaction effects for either %ASSOC or FS. As was done for unseparated %ASSOC data, two separate ANOVAs were performed with minutes 2, 5, and 8 analyzed separately from minutes 14, 17, and 20. %ASSOC data for INT-A and INT-B are presented in Figure 24. FS data for INT-A and INT-B are presented in Figure 25.

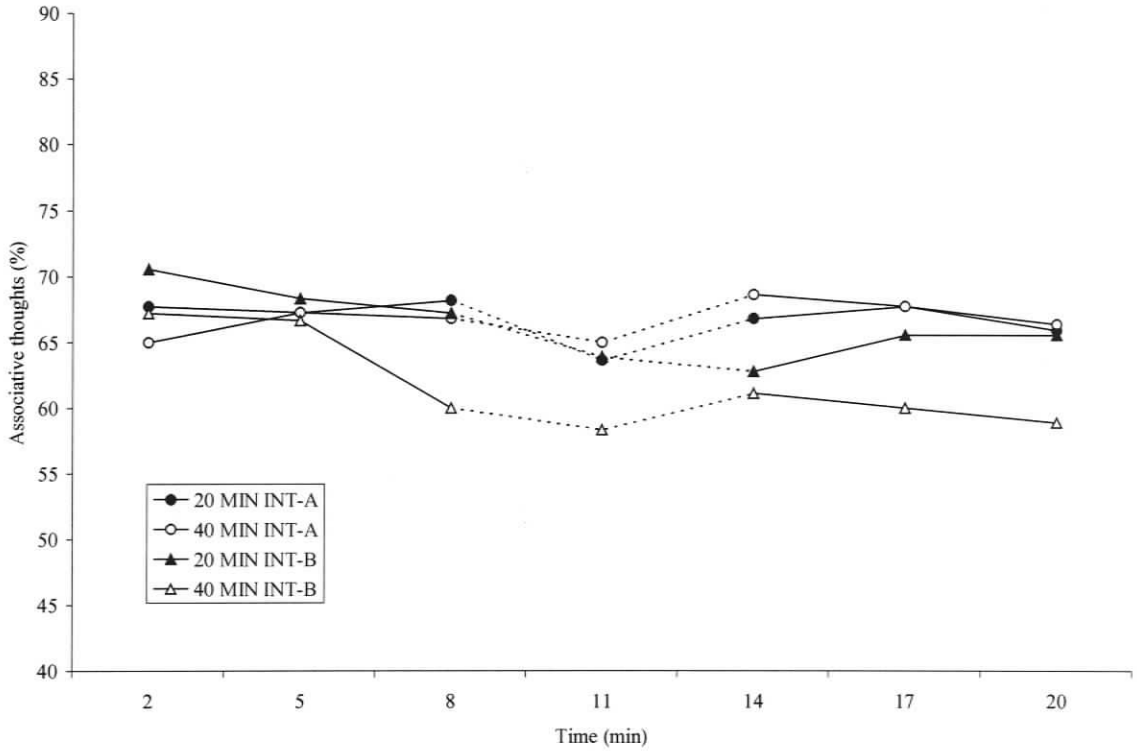

Figure 24. Mean percentage of associative thoughts for 20 MIN and 40 MIN, separated between participants who exceeded RER=1.00 at any time during either trial (INT-A, n=9), and those who did not (INT-B, n=11). Dotted lines represent the omission of the 11 minute time point from the analysis.

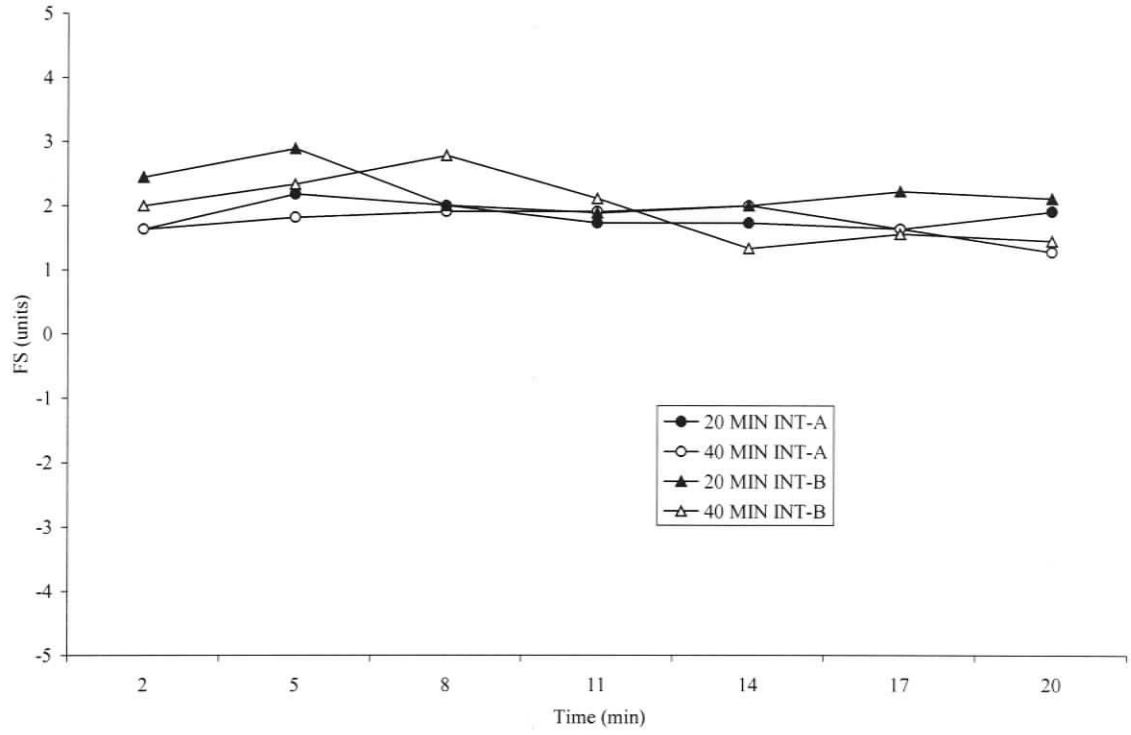

Figure 25. Mean feeling scale scores for 20 MIN and 40 MIN, separated between participants who exceeded RER=1.00 at any time during either trial (INT-A, n=9), and those who did not (INT-B, n=11).

Discussion

The objective of this study was to determine whether expected task duration influences psychological and physiological variables. The main findings of this study were that rating of perceived exertion (RPE) was significantly reduced when participants expected to exercise for 40 minutes (40 MIN). Oxygen consumption ($\dot{V}O_2$) was higher for the longer condition during the 2nd minute, and lower for the 17th minute of measurement. RPE and feeling scale (FS) were the only variables that were associated with each other. There was a significant negative correlation between RPE and FS throughout the 20 minute expectation condition (20 MIN) and this was only significant for the first three time points during the 40 MIN trial.

When participants were separated into high (INT-A) and low (INT-B) intensity groups, significant effects were found for the lower intensity group only: RPE was significantly lower for the longer condition.

Teleoanticipatory Effects on Psychological Variables

The finding of lowered RPE due to experimental condition has been shown several times by others using altered expected task duration: 8 mile vs. 11 mile and 10 min vs. 20 min (Baden et al., 2004), 20 min vs. 30 min (Rejeski & Ribisl, 1980), and 10 min vs. 20 min vs. unknown (Baden et al., 2005). These studies all used running as the mode of exercise and the present research may be the first to examine this effect during cycling.

In the present study, average RPE was higher for the 20 MIN condition compared to the 40 MIN condition (12.7 and 12.2, respectively). While RPE was not significantly

different at any one time point, the difference in RPE seems to be present from the onset of exercise. This may be because expected task duration is used as information with which to anticipate exercise before it begins. Indeed, expected duration may be pre-programmed prior to the onset of exercise, in that this cue exists prior to exercise and is thus able to exert an influence from the very beginning of the bout (Ansley, Robson, St Clair Gibson, & Noakes, 2004). If this is the case, then it is likely that alterations in RPE at the beginning of the bout occur to make the longer duration of exercise more psychologically manageable.

Participants studied by Baden et al. (2005) reported lower RPE for the trial in which they expected to exercise for a longer duration or longer distance. RPE in this study did not increase differently as a result of condition, but rather the values were consistently different throughout exercise. These findings differ from those of Rejeski & Ribisl (1980), whose participants expecting to run for 30 minutes but ran for only 20 minutes reported lower RPE values when compared to when they correctly expected a 20 minute duration. These differences in RPE were significant at minute 2 through minute 15. As the authors commented, no differences were found at the beginning of exercise, when fatigue would be minimal, nor after exercising for some time, when internal cues would be strong.

While the calculated effect size of .324 would be considered small according to Cohen (1988), this nevertheless may be a meaningful finding, especially in the context of athletic performance, where even small improvements in performance can contribute to competitive success. Future research is needed to determine the effect of such reductions in RPE on endurance performance.

It is notable that in the present study, the slopes of the increase of RPE during 20 MIN and 40 MIN are similar (Figure 6), with the only difference being the y-intercept, which would be the RPE value for the first measurement point. This observation is consistent with data that have been previously reported. Although Baden et al. (2004) and Rejeski & Ribisl (1980) did not fit linear regression lines to changes in RPE over time, changes in one condition seemed to track changes in the other condition, even though the absolute values were different. This may indicate an immediate appraisal of the task duration, which lowers the beginning RPE for that particular exercise bout. RPE may then simply rise linearly toward a particular terminal value, pre-set prior to the exercise bout. Thus, it is suggested that the dampened RPE at the onset of the 40 MIN condition compared the 20 MIN condition may be explained by the expected task duration. It is possible that the longer duration was conceptualized as a goal in the participant's mind, allowing the initial RPE to be preset based on the experience of the shorter duration cycling bout, which was always done first, or based on years of training experience. This mechanism may be so that exercise can be completed in the most comfort. The lower RPE may be interpreted to mean that the development of fatigue, while occurring at the same rate, was postponed for the longer expected duration.

Mechanical strain, muscle damage, carbohydrate availability, and core/skin temperature may all contribute to RPE (Hampson et al., 2001). However, the role of some of these measures in moderating psychological teleoanticipatory effects cannot be central in discussion of this study. For instance, mechanical strain was not measured for the limbs and muscles and thus discussion regarding this variable cannot be conclusive. However, since the workload was kept constant and there were no condition effects upon

cycling cadence, it could be hypothesized that teleoanticipatory effects upon RPE due to this variable are minimal. Because the exercise was submaximal and of only 20 minutes duration, it is thought that significant muscle damage or carbohydrate depletion did not occur. Core/skin temperature could influence RPE, but this may only be the case during exercise of high intensity or long durations (Mihevic, 1981). Efforts to reduce the impact of core temperature were made with the use of a fan during each of the incremental cycling tests. The fan setting was kept the same for all tests.

Teleoanticipatory Effects on Physiological Variables

When participants expected to exercise for 40 minutes, $\dot{V}O_2$ was higher at minute 2 as compared to the shorter condition. However, as the session progressed, by the 17th minute, $\dot{V}O_2$ was higher for 20 MIN as compared to 40 MIN. Thus, during 40 MIN, participants were less economical at the beginning of the cycling bout (at 2 minutes), and more economical near the end of the cycling bout (at 17 minutes). Calculated effect sizes for the 2nd and 17th minute were .117 and .194, respectively. Because the effect size for the 2nd minute was not large enough to be considered "small" according to Cohen (1988), and the effect size for the 17th minute only approached the designation of small, discussion regarding oxygen consumption should be considered cautiously.

Effects on heart rate (HR) might be expected because of measured effects in RPE, since the RPE scale was designed to approximate changes in HR. Yet, previous research such as that reported by Rejeski & Ribisl (1980) did not show any significant findings for HR, thus the absence of effects in the present study is supported. It is noted, however, that in the present study as well as in Rejeski & Ribisl (1980), there was a consistent non-significant trend for lower HR during the longer conditions. Other measures that have

been hypothesized to contribute to RPE, including respiratory (RR), minute ventilation ($\dot{V}_E$), and exercise and recovery blood lactate ([La]) did not show any significant main effects. These findings are consistent with those of Rejeski & Ribisl (1980). Lactate has not been measured previously in similar research, but does not seem to be included in teleoanticipatory effects based on the data from the present study.

Effects occurring early in exercise. Alterations in physiology at the beginning of exercise may be due to anticipation that prepares the body for the work to come. There are known mechanisms that may influence a higher $\dot{V}O_2$ at the beginning of exercise in 40 MIN as compared to 20 MIN. For instance, a number of studies several decades ago examined the effect of anticipation prior to various modes of exercise. Anticipatory tachycardia was found prior to skiing (Hanson & Tabakin, 1964), swimming (Magel, McArdle, & Glaser, 1969), and running (McArdle, Foglia, & Patti, 1967). Hyperpnea has also been found as an effect of anticipation of exercise (Tobin, Perez, Guenther, D'Alonzo, & Dantzker, 1986). Such effects are likely due to increases in sympathetic discharge and reduced vagal tone in preparation for upcoming exercise. These preparatory mechanisms may only be present only at the very beginning of exercise, after which feedback processes assume predominant control over physiology (Torelli & Brandi, 1964).

Superior economy of movement (lower $\dot{V}O_2$) as a teleoanticipatory effect has been hypothesized by Baden et al. (2004) on the basis of lowered HR during running in the longer condition. Effects of this nature have been found near the end of exercise by Baden et al. (2005), however, finding superior economy at the beginning of exercise is a finding believed to be unique to this study.

It is possible that, during the 40 MIN bout in the present study, participants began cycling at an inferior economy (higher $\dot{V}O_2$) because of anticipation of a more difficult exercise bout (double the duration at the same intensity). This mechanism may represent a feed-forward response to the longer goal. Although inferior economy is less desirable, it is possible that feed-forward responses overshoot what is actually required physiologically during the exercise bout, possibly because of uncertainty of being able to complete the more difficult exercise bout. Uncertainty may give rise to excessive mobilization of energy relative to the actual task demand, but this probably declines as the task progresses and feedback processes enable a more appropriate level of energy mobilization (Requin, Brener, & Ring, 1991). Because uncertainty may be an important factor in teleoanticipatory responses, future research should explore teleoanticipatory responses during tasks that are not novel, as they would be in a laboratory setting.

Effects occurring late in exercise. The finding of superior economy of movement near the end of the 40 MIN bout finds support in the literature. As mentioned previously, Baden et al. (2005) found that participants who were not told the exercise duration exercised with superior economy (lower $\dot{V}O_2$) near the end of exercise, compared to those given the duration of exercise of an identical workload. In this study, a significant effect occurred from the 10^{th} to the 19^{th} minute of exercise, as compared to those expecting to run for 20 minutes. An initial observation of the oxygen consumption data for the present study (Figure 8) suggests a change in oxygen consumption after the halfway point (i.e., increased $\dot{V}O_2$ in the shorter conditions as compared to the longer or undefined conditions). This is similar to the trend found in Baden et al. (2005). While statistical significance was not found for all time points after halfway in the present

study, the same tendency was found in both studies, in that, after about 10 minutes in the present study and that of Baden et al. (2005), the shorter group demonstrated $\dot{V}O_2$ values that were diverging from those of the longer or uninformed group. Because the values in the present study were not all significantly different, future research should ensure adequate statistical powering to ascertain the true presence a divergence of this nature. It may be that the passing of the halfway point of exercise represents an important event psychologically. That is, after halfway, participants may be less cautious about their performance and are more likely to waste energy at this point in the bout. Of course, the half-way point only truly occurs for those in the correctly-informed shorter group, but it is likely that in this case it is the alteration in this group's values that contribute to the significant difference between conditions. An end-spurt phenomenon occuring in the shorter group is suggested to be a reason why this effect may occur near the end of exercise.

An end-spurt is a change in behavior because of proximity to the end-point of exercise. Baden (2001) found evidence for an end-spurt effect in increased cycling cadence (RPM) near the end of 8 minute or 16 minute cycling bouts where participants were blinded to the speed maintained on a cycle ergometer. Increases in RPM occurred near the end of each bout, but these were not associated with changes in HR or RPE. Nevertheless, it may be that in the present study, an end-spurt behavior included an increase in $\dot{V}O_2$, possibly because the exercise was soon to end and therefore the importance of conserving energy was lower.

Changes in oxygen consumption during a constant workload may reflect a behavioral change. Changes in rate of movement, altered muscle recruitment, or

biomechanical changes reflecting extraneous movement may explain changes in $\dot{V}O_2$. However, there were no findings in this study to suggest that changes in rate of movement (cycling RPM) occurred as a result of altered expected task duration. Indeed, this may confirm what has been shown by Baden et al. (2005). In the present study, no changes in stride frequency (rate of movement in running) concomitant with altered oxygen consumption, suggesting that this stride frequency was not involved in measured physiological changes. It may, therefore, be that the body subconsciously manipulates the activation patterns of the exercising musculature. If this was exhibited in the present study, then it may be that improved muscular efficiency of movement allowed the participants' legs to require a lower $\dot{V}O_2$ at that particular workload. Perhaps changes in co-contraction during pedaling enabled a less wasteful and more circular pedal stroke. This hypothesis is supported by the study of Vidaček & Wishner (1971), who found improved muscular efficiency during a series of weight-holding tasks where participants had more trials to complete, as compared to those who were finished. EMG for multiple muscle groups was not measured in this study, nor in any other subsequent studies, so the hypothesis that altered recruitment patterns explain alterations in metabolism remains untested. Additionally, biomechanical assessment has not been performed within this research design, thus this also remains an important question for future research.

In summary, it may be that physiological variables changed in order to allow the body to ideally prepare for the expected exercise and to complete the expected exercise with minimal physiological departure from homeostasis. Feed-forward processes may provide the physiological mechanisms by which this occurs.

Relationships Between Variables

While association among variables cannot necessarily indicate a cause and effect relationship, this type of examination is the first step in understanding the mechanisms involved in teleoanticipation. Despite both RPE and $\dot{V}O_2$ demonstrating effects in this study, there were no significant correlations between these variables for any of the corresponding time points (i.e., RPE at 2 minutes with $\dot{V}O_2$ at 2 minutes). It is possible that the homogeneity of participant performance masked any relationships that might be present, in that the ranges of RPE and $\dot{V}O_2$ values may have been too narrow to have enough variance for an adequate correlation analysis.

Although RPE was lower from the onset of exercise for 40 MIN, $\dot{V}O_2$ showed differences at the beginning (2 minutes) and near the end (17 minutes) of exercise. Even though $\dot{V}O_2$ for 40 MIN was higher at 2 min, this did not seem to influence RPE. It is unlikely that an elevated $\dot{V}O_2$ at 2 minutes would have significantly affected RPE anyway, because the presence of fatigue and internal cues would be minimal at that point.

That $\dot{V}O_2$ was significantly lower for 40 MIN during the 17^{th} minute, and showed a similar trend for the second half of exercise (albeit not statistically significant) may explain a physiological mechanism independent of psychological processes. There were no significant associations between $\dot{V}O_2$ and RPE. This may indicate that a cognitive teleoanticipatory effect (emerging as altered RPE) exists separately from a physiological teleoanticipatory effect (showing up as altered $\dot{V}O_2$).

A finding unique to this study is that there was no association between RPE and % ASSOC. Prior discussions (Walster & Aronson, 1967; Baden et al., 2005) have proposed that cognitive strategies can explain changes in RPE within this research design. For example, it has been suggested that people suppress feelings of fatigue until their task is almost complete (Walster & Aronson, 1967). Additionally, Baden et al. (2005) found high correlations between dissociative thoughts and lowered RPE. This has lead to the hypothesis that one of the ways in which participants "achieve" a dampened RPE is by consciously or subconsciously selecting a cognitive strategy that tends to ignore the physiological cues that inform RPE (Baden et al., 2004; Rejeski & Ribisl, 1980). It may be that this relationship was not seen in the present study either because altered percentage of associative thoughts did not lower RPE, or that there were complications arising from the use of the scale to measure %ASSOC. If the former is correct, it may be that there are multiple physiological or psychological methods by which RPE is lowered despite identical workloads. If the latter is the case, perhaps the narrow range of %ASSOC responses hindered the correlation analysis.

The only variable pairs that showed consistent significant correlations were RPE and FS. The relationship of RPE to FS is well established. Hardy & Rejeski (1989) found significant negative correlations between RPE and FS at several intensities, with stronger correlations at higher exercise intensities. Although there were significant correlations between RPE and FS in during 40 MIN at the beginning of exercise, the correlations ceased to be significant for the second half of the bout. This was also when $\dot{V}O_2$ also seemed to diverge from those values measured during 20 MIN, providing yet another instance of significant effects in the last half of exercise only. It may be that the

observed teleoanticipatory response included an uncoupling of the RPE-FS relationship. In the shorter condition, as RPE increased, there were associated decreases in how well the participants felt. However, in the longer condition, as RPE increased there ceased to be corresponding decreases in FS after the 8th minute of measurement. This mechanism may exist as a coping strategy to deal with changes in mood and feeling during longer exercise bouts. Future research is needed to examine this effect more closely.

Exercise Intensity

Exercise intensity may play a role in determining subjective responses to acute exercise. Earlier studies in this area identified intensity in relation to maximal oxygen consumption ($\dot{V}O_{2max}$), however, it has been recently argued that intensity should be monitored with consideration of the proportion of aerobic and anaerobic contribution to energy supply (Ekkekakis & Acevedo, 2006). For example, intensity in relation to the gas exchange threshold (Ekkekakis, Hall, & Petruzzello, 2001) and the onset of blood lactate accumulation (OBLA) (Acevedo, Kraemer, Haltom, & Tryniecki, 2003) have been shown to affect subjective responses during acute exercise. Thus, it is important to consider proximity to the anaerobic threshold when investigating such responses.

Although it was originally intended in the present study, that participants perform the planned exercise lower than ventilatory threshold (VT) (~10% of $\dot{V}O_{2max}$ below VT), the exercise intensity actually performed during the 20 minute cycling bouts was proximal to VT (3-10% of $\dot{V}O_{2max}$ below VT). Average RER reached .98 for both 20 MIN and 40 MIN. To examine whether exercise intensity mediated the development of RPE in the present study, participants were divided for analysis into two intensity groups based upon their physiological responses to the exercise bouts, as there was some

variation in the relative intensity of exercise. Resultant groups of higher and lower intensity showed oxygen consumption 1-9% of $\dot{V}O_{2max}$ below VT (higher) and 6-11% of $\dot{V}O_{2max}$ below VT (lower).

Post-test analysis of the exercise intensity during the cycling bouts indicated that the participants as a group did not exercise at a steady state, because there were significant increases over time in all cardiovascular variables. For example, average HR among all participants increased by 12 % during 20 MIN and by 13 % during 40 MIN. Average $\dot{V}O_2$ increased by 10 % for 20 MIN and by 8 % for 40 MIN.

Of studies examining the effects of expected task duration, at least one study (Rejeski & Ribisl, 1980) was conducted using endurance exercise that did not exhibit a steady-state. In this study, although not specifically reported, HR appeared to increase significantly throughout the exercise, from approximately 142 to 178 bpm. Thus, it may be appropriate to compare the present findings with this study and possibly others.

The finding of altered RPE in INT-B but not INT-A may be in contrast to the framework of Ekkekakis & Acevedo (2006), who suggested that intensities lower than the aerobic-anaerobic transition have low to moderate contribution of cognitive factors to affect, while intensities proximal to the aerobic-anaerobic transition are highly influenced by cognitive factors. If this is indeed the case, then it would be expected that INT-A would show differences in RPE due to condition, since that intensity domain is most likely to be changed by cognitive factors, which may include anticipated task duration. The model of Ekkekakis & Acevedo (2006) refers to changes in affective valence and not RPE, but since both subjective measures depend on afferent input and CNS integration, the same mechanism may apply. Certainly, it remains possible that teleoanticipatory

responses should not be included as one of the cognitive influences suggested in Ekkekakis & Acevedo (2006). It may also be that this finding is an artifact of lower power for the analysis. This would be because the separation into intensity groups cut roughly in half the number of participants in the analysis.

Integrated Model of Teleoanticipatory Mechanisms

A model suggesting possible sites of teleoanticipatory effects based on the present findings is presented in Figure 26 (adapted from Ulmer, 1996). This model has been developed as a way of explaining the findings of this study. It is comprised of the well-known system of efferent command and afferent feedback. A key component of this model is a program unit that would exert its influence on the teleoanticipatory system based on prior experiences of the individual. For example, the teleoanticipatory mechanism may act differently depending on the the novelty of the activity and the quality of the experiences. The program unit would thus determine the action of the integrative center and the series of processes that it initiates and by which it is influenced. Teleoanticipation may depend on a number of mechanisms within this system. Three possible sites are proposed: 1) changes in efferent signaling resulting in altered muscle recruitment; 2) changes in passive gating of afferent signals; and 3) changes in active perceptual processes. Logically, it is only possible to suggest at this time that at least one of these changes is present. If only one of these three mechanisms were present, then other sites in the system might show secondary changes because of the initial single primary change.

This model considers the possibility that exogenous information can either pass through a psychological filter or directly to the integrative center. For example, signals

given to the exerciser may be subject to the cognitive strategies employed during the bout. Here, the individual may add their own value to the information and consider it of little or great importance. Alternatively, it may be that such information cannot be modified prior to or during exercise. In this case, it would then only be the bodily processes that would be subject to cognitive strategies, not the expected task duration.

Many of the processes described in this model are speculative at this time, and future research should address and test such hypothetical mechanisms in this model.

Efferent Command

It is proposed that there are changes in efferent command leading to alterations in behavior and/or muscle recruitment due to teleoanticipatory responses. As a result of altered expected task duration, changes in behavior or muscle recruitment would most likely be exhibited as an altered physiological response such as reduced $\dot{V}O_2$ during 40 MIN. Specifically, it may be that changes in EMG activity are, at least in part, responsible for changes in $\dot{V}O_2$, if altered efferent command has the result of making muscular activity more efficient or less efficient, such as was found in a weight-holding task studied by Vidaček & Wishner (1971). The hypothesis of altered efferent command as a teleoanticipatory response has previously been set forth by Baden et al. (2005). Presently, there is no work that has measured EMG activity within this research design.

While RPM changes were not found to have an impact in the present study, biomechanical changes cannot be ruled out. The presence of extraneous movement that did not contribute to the measured power output may have influenced changes in $\dot{V}O_2$. For example, if there were contraction of opposing muscle groups during a particular

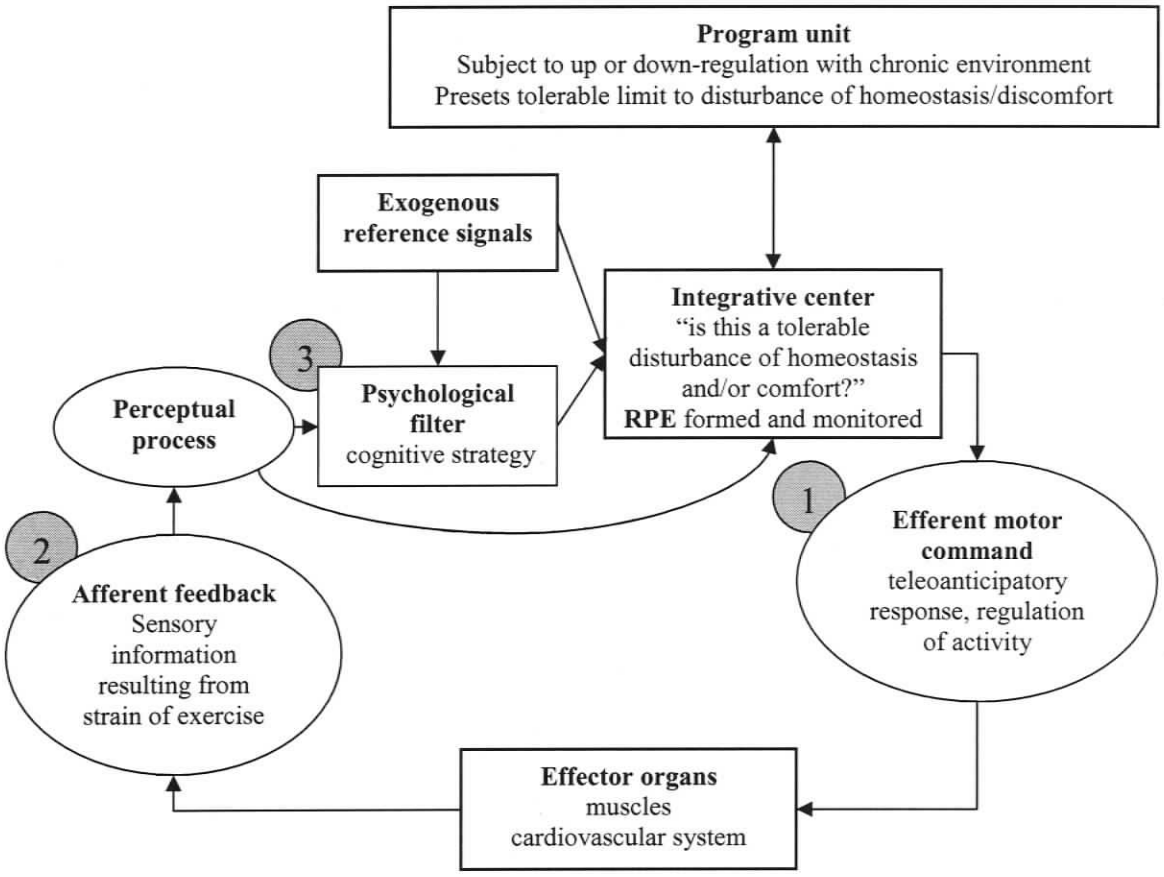

Figure 26. An exogenous reference signal (i.e., task duration) exerts an influence on one or more sites in the teleoanticipation model. Exogenous signals may be processed through a psychological filter or transferred directly to the integrative center. Modified from Ulmer, 1996.

point in the pedal stroke, some energy would be wasted and would not contribute the circular motion of pedaling but would rather oppose the work of the muscles primarily responsible for turning the pedals. Because biomechanical teleoanticipatory effects have not yet been investigated, this remains a possible hypothesis.

Active Cognitive Processes

The active cognitive hypothesis posits that participants suppress perceptions of fatigue until exercise is nearly finished (Walster & Aronson, 1967). Under this framework, the integration and appraisal of sensory cues, such as breathing or mechanical

strain in the limbs, is considered to be an active process (Rejeski, 1985), and is grounded in the parallel-processing model of Leventhal & Everhart (1979). This model holds that active perceptual processes integrate physiological, cognitive, and affective information. While many signals are present within a given perceptual field (i.e., all cues that might be attended to), the presence of active processes that can modify attentional channels means that only a select number of cues reach the focal awareness of the exerciser. It is this information only that is consciously represented and can therefore contribute to subjective responses such as RPE and affect (Leventhal & Everhart, 1979).

One strategy that has been proposed to explain the attention to sensory cues is the use of associative or dissociative thoughts. If this strategy is used effectively, dissociative thoughts form a sort of perceptual filter, allowing one to attend less to those physiological cues that contribute to RPE. Baden et al. (2004) found negative correlations between RPE and % ASSOC in runners. However, a later study Baden et al. (2005), as well as data from this present study failed to measure such a relationship. Baden et al. (2005) did not discuss the reason for this, but the associative thoughts scale may not have been sensitive enough to measure changes occurring during the exercise bouts. There may also be an alternate mechanism of active thought processes involved, but future research is needed to address this possibility.

Passive Gating of Afferent Signals

Passive gating of afferent signals may occur because of the multiple pathways that can be taken by exercise-associated interoceptive stimuli, as proposed by Ekkekakis & Acevedo (2006). Although this model seeks to explain exercise-associated changes in affect, it may be useful to use regarding RPE because both subjective measures depend

on the transmission and interpretation of sensory cues during exercise. In this model, the amygdala is hypothesized to be the site of integration of affective information. Alternatively, RPE is thought to be appraised in the thalamus-insula-sensory cortex (Cafarelli, 1982). The model proposed by Ekkekakis & Acevedo (2006) theorizes an intensity-sensitive mechanism of information transfer between sensory nerve endings and the higher centers of the CNS via the spinal cord. If this is true, then RPE may be influenced not only by intensity (the established use of this measure) but also may be influenced differently by teleoanticipatory mechanisms that are intensity-dependent.

If an intensity-dependent mechanism of teleoanticipation exists, the aforementioned pathway may be sensitive to small changes in intensity and thus may be passively involved in this gating of interoceptive signals. Because this is a passive process, information reaching the higher centers of the CNS may be altered or "ignored" without corresponding cognitive strategies that can be appraised by subjective measurement instruments. The results of this study support the passive gating hypothesis because no association was found between RPE and % ASSOC.

This intensity-dependent mechanism could potentially explain why RPE was lower in the longer condition for INT-B only. However, the results of this study were opposite to that which might be expected from the intensity-sensitive system proposed by Ekkekakis & Acevedo (2006) that cognitive factors exert a *higher* influence during intensities proximal to the anaerobic-aerobic transition as compared to lower intensities. Again, it may be that the smaller *n* in this subsequent analysis was not of sufficient power to correctly identify the effects. Future research should attempt to examine the effect of intensity of exercise on the presence of teleoanticipatory processes.

Effect of Order of Trials

As opposed to similar studies involving deception regarding task duration, such as Rejeski & Ribisl (1980) and Baden et al. (2004), the order of sessions 2 and 3 in the present study was not counter-balanced. In these earlier studies, half of the participants would have first done the deception session and then the non-deception session. It is possible that those participants doubted the sincerity of the experimenters during the last session. Thus, in the present study, the deception session was always the last session. Because both Rejeski & Ribisl (1980) and Baden et al. (2004) reported that there were no order effects found in their studies, it is therefore likely that the effects found in this present study are indeed true effects and not an artifact of testing.

Conclusions

The data in this study support the presence of physiological and psychological teleoanticipatory responses as a result of altered expected task duration. The presence of lower RPE for 40 MIN indicates a sub-conscious calculation of the task duration to be completed and a lowering of the sense of effort, possibly in order to suppress the feelings of fatigue until the task is finished. This effect may be more pronounced at lower exercise intensities. That this did not occur concurrent with changes in % ASSOC suggests that this mechanism may happen without involvement of conscious cognitive strategies. Altered physiology suggests that the body acts differently when a longer duration of exercise is expected, possibly by changing muscle recruitment patterns, although this is a presently untested hypothesis. It is proposed that psychological teleoanticipatory mechanisms exist to allow the body to complete exercise with the most comfort, and that physiological teleoanticipatory mechanisms exist to allow the body to

complete exercise with the least disturbance to homeostasis. Future research should examine the effect of intensity on this teleoanticipatory response as well as the possibility of muscle recruitment being involved in physiological teleoanticipatory responses.

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Appendix A - Literature Review

1. Introduction

The contributing factors to exercise performance and the related exercise-associated fatigue are numerous and complex. Fatigue has been defined as an acute impairment of exercise performance that includes an increase in the effort to exert a given workload (Davies & Bailey, 1997). Traditional explanations include cardiovascular limitations leading to anaerobiosis, failures in energy supply leading to energy depletion, neuromuscular fatigue, altered biomechanics, and psychological limitations leading to inadequate motivation. Reviews such as those done by Noakes (2000) and Abbiss & Laursen (2005) describe the many models used to explain exercise-induced fatigue development. A lengthy discussion regarding determinants of fatigue is given in each of these reviews and such discussion will therefore not be the focus of this literature review.

The main criticism regarding many traditional exercise-induced fatigue models seems to be that they are limited because of their reductionistic paradigm and thus are unable to explain fatigue development during every condition. As a result, one is faced with the arduous task of determining which model to use to explain each exercise situation. It may be that such traditional models should be considered, not in isolation, but together as part of a novel framework or in an integrated fashion.

In line with this thinking, recent articles have argued that fatigue should not be considered the result of a linearly-generated catastrophe in one of the above mentioned physiological or psychological processes. An example of a linear system would be one

variable approaching an undesirable physiological situation that reflects a state of fatigue. Rather it may be that a non-linear complex system monitors the interaction between all such processes during exercise and that resulting feed-forward (physiological) responses are guided by a subconscious appraisal of the entire system (Noakes, St Clair Gibson, & Lambert, 2004; Lambert, St Clair Gibson, & Noakes, 2005; St Clair Gibson & Noakes, 2005). Rather than seeking a physiological marker of the presence of fatigue, St Clair Gibson et al. (2003) suggested that fatigue should be considered a conscious perception. It is plausible that non-physiological processes are involved in the development of fatigue. If this is correct, then it would follow that this complex system informs the conscious perception of fatigue during an exercise bout. This system necessarily operates under a specific context, such as for a particular duration and within a particular environment, and it is also this context itself that plays a role in fatigue development. This review will investigate the relationship between these multiple informational processes and the development of exercise-induced fatigue within a context of varied expected task duration.

1.1 The role of the CNS in fatigue development

Contributors to fatigue are usually studied within a reductionist paradigm because fatigue is usually explained by physiological processes. When organized this way, it is possible to study many different physiological processes in isolation, without addressing contribution from the CNS or interaction with other physiological systems of the body. Integrated systems of information transfer and interpretation are important to consider because the CNS directly or indirectly controls all processes within the human body. Although processes such as those occurring inside the muscle are likely involved in

fatigue development (such as shown in Green, 1997), it may be that these are part of a larger integrative system. Thus, the CNS may be the ultimate regulator of exercise performance via its control of fatigue development. For example, it is through the CNS that voluntary decisions are made to decrease or increase intensity, or to terminate exercise (Kayser, 2003). What is then important, is how processing occurs regarding information that leads to the exerciser to decide to change their behavior (i.e., alter intensity or stop). This point should make it clear that the consideration of subjective measures is important when investigating exercise performance and the development of fatigue.

Physiological responses can be objectively monitored during exercise using modern equipment that is commonly available. However, for the above reasons, supplementing this information with subjective responses to exercise is required. In this literature review, evidence will be given that suggests it is not only physiological processes that contribute to fatigue, but that there is also a contribution from the psychological domain. Because increased effort is required during fatigued states, it follows that, when experimental conditions control for workload, increased RPE may signal the development of fatigue.

2. Ratings of perceived exertion

The framework of St Clair Gibson et al. (2003), that considers fatigue to be a conscious perception, suggests that subjective measures reported during exercise can help indicate the development of fatigue. One such measure commonly used is RPE, which was developed as a psychophysical indicator of somatic stress (Borg, 1970). RPE is a valid subjective measure of exercise intensity (Dunbar et al., 1992). For example,

Dunbar et al. (1992) found that regulation of exercise intensity using RPE resulted in an average 2% difference between the target intensity (measured in % $\dot{V}O_{2max}$) and the actual intensity produced. If RPE is used in monitoring the development of fatigue, it would be expected that as values in the original RPE scale (Borg, 1970) approach a maximal value of 20, exhaustion and therefore cessation of exercise would be imminent.

The cessation of exercise is commonly associated with one or more measurable physiological variables (Table A1), which have been discussed as possible cues that inform RPE (Hampson, St Clair Gibson, Lambert, & Noakes, 2001). Indeed, physiological variables are moderately associated with RPE (Chen, Fan, & Moe, 2002), but such variables can diverge from RPE under certain conditions such as modified fraction of inspired oxygen, task mechanics such as cycling cadence, deception, and heat/humidity (Hampson et al., 2001). Depending on the situation, perceived exertion may be primarily influenced by one or many of these measurable variables.

RPE has been examined as a construct consisting of two perceptual systems - homeostatic and comfort (Bartley, 1970). Within this construct, the homeostatic perceptual system would receive cues from internal receptors that are responsible for regulation of homeostasis. The comfort system includes senses of pain, temperature, kinesthesis, and touch - all which can contribute to the feeling of well-being or discomfort. Both homeostatic perceptions and comfort perceptions, functioning as informative cues would be integrated so that a subjective appraisal of effort can be formed.

2.1 Physiological foundations of RPE

To form a subjective response, the brain integrates information regarding the

physiological, neurological, and mechanical state of the body as it exercises (Table A1). While individuals of course cannot attend directly to actual physiological processes (such as chemical reactions), it is the effect of these processes, such as breathing rate and skin temperature that are consciously perceived (Noble, Metz, Pandolf, & Cafarelli, 1973). Processes contributing to effort sense include central components such as HR, $\dot{V}O_2$, $\dot{V}_E$, RR (Hampson et al., 2001; Chen, et al., 2002), and peripheral components such as lactate concentration and local limb/joint movements (Hampson et al., 2001; Cafarelli, 1982). These variables, when consciously attended to, can contribute to the perception of effort (Edwards, Melcher, Hesser, Wigertz, & Ekelund, 1972). Elevated catecholamine levels during exercise may also serve as a perceptual cue (Frankenhaeuser, Post, Nordheden, & Sjoeberg, 1969), but may only be important at higher exercise intensities (Mihevic, 1981). Skin temperature can be readily monitored during exercise, but it may be that core temperature most highly contributes to RPE. Core temperature cannot be consciously monitored during exercise, but it may provide a subconscious contribution to RPE (Mihevic, 1981). The variables presented in Table A1 are thought to play a role in determining RPE. The reader is referred to an excellent review by Mihevic (1981) for a discussion on sensory cues that may contribute to RPE.

2.1.1. Heart rate

Heart rate was one of the initial measures considered when the Borg scale was developed and validated using middle-aged males. The 15-point scale (Borg, 1970) was originally designed to match HR to approximately 10 times the RPE. The weighted mean validity coefficient between HR and RPE via a meta-analysis was found to be .62 (Chen, et al., 2002).

Table A1

Sources of Afferent Information That May Alter Ratings of Perceived Exertion (from Hampson et al., 2001)

Cardiorespiratory	Peripheral/metabolic
Heart rate	Blood lactate level
Oxygen uptake	Blood and/or muscle pH
Respiratory rate	Mechanical strain
Ventilatory rate	Muscle damage
	Core temperature
	Carbohydrate availability
	Skin temperature

2.1.2. Oxygen uptake

Studies suggest that metabolic demands are correlated with RPE during exercise, but there is no evidence that oxygen uptake itself can be perceived and monitored. Since oxygen uptake is closely related to other physiological processes such as ventilation rate, it is likely that the impact of this variable is mediated by other cues that are more easily monitored in exercising individuals (Mihevic, 1981). Using a meta-analysis, the $\dot{V}O_2$-RPE weighted validity coefficient was found to be .63 (Chen et al., 2002). Correlation coefficients between RPE and increases in % $\dot{V}O_{2max}$ in swimmers ranged between .893 and .988 (Kurokawa & Ueda, 1992).

2.1.3. Ventilation and respiratory Rate

Breathing and ventilation are some of the easiest cues to consciously self-monitor during exercise and may be important perceptual cues contributing to RPE (Mihevic, 1981). However, ventilation as a cue may be more important at higher exercise intensities (Edwards et al., 1972). Weighted validity coefficients between RPE and the pulmonary variables of $\dot{V}_E$ and RR were found to be .61 and .72, respectively with a meta-analysis (Chen et al., 2002).

2.1.4. Blood lactate and pH

Increased levels of blood lactate and the associated increase in acidity are one of the most common explanations for exercise-induced discomfort. Discomfort in the muscles usually occurs at intensities above the onset of blood lactate accumulation, and this likely is a major contributor to RPE at such intensities. At intensities lower than this point, it is unlikely that blood lactate or the associated metabolic acidosis contribute to RPE. Lactate at this intensity does not accumulate and would be constantly low throughout exercise. The [La] – RPE weighted validity coefficient was found to be .57 in a meta-analysis (Chen et al., 2002). Correlations between RPE and [La] in runners were found to be .79 - .98 (Steed, Gaesser, & Weltman, 1994).

2.1.5. Mechanical strain and discomfort

The sensation of mechanical strain in the active muscles and tendons during exercise can also be constantly monitored by the exercising individual. Kinesthetic cues may include Golgi tendon activity, general muscle sensations, localized pain (Mihevic, 1981) and force sensations (Cafarelli, 1982). Varying frequency of limb movements (i.e.,

stride rate or RPM) while keeping the metabolic requirements constant can be a useful experimental manipulation to explore the effects on RPE.

To sum, many physiological cues have only moderate correlations to RPE and their level of contribution can change under different conditions. Perhaps different conditions can change how physiological cues are cognitively appraised. Thus, it is likely that cognitive processes play a role in determining RPE, therefore mediating the development of fatigue.

2.2. Psychological foundations of RPE

In addition to the internal physiological environment, the cognitive environment seems to play a role in determining RPE. Under the framework suggesting that RPE signals the development of fatigue, evidence will be presented regarding different "cognitive environments" that can alter fatigue development.

2.2.1. Cognitive strategy

There is evidence that cognitive strategy may play a role in determining RPE under certain conditions. Besides the conscious monitoring of the senses, there may also be a subconscious monitoring and evaluative process (Mihevic, 1981). For example, many processes in the body are under autonomic control and thus are monitored subconsciously. However, it is still unclear how these subconscious cues become conscious enough to inform RPE. It is possible that various cues could drift between the conscious and the sub-conscious. However, it is also likely that different exercise conditions would involve different levels of contribution from each physiological variable. For instance, because of the known presence of neuromuscular fatigue during prolonged exercise (Millet & Lepers, 2004), HR and RR would probably contribute less

to RPE than other processes that are neuromuscular. In such a case, neuromuscular factors would be more likely to occupy attention during such an exercise condition.

2.2.1.1.Competition for attention

These statements indicate how it is possible that information from different sources compete for attention within a participant's perceptions during exercise (Rejeski, 1985; Leventhal & Everhart, 1979). Pennebaker and Lightner (1980) found that distracting sounds during exercise were associated with less reported fatigue, while participants reported increased fatigue when their breathing sounds were amplified. Additionally, it was found that the distance run in a set duration was increased when in environments where increased external attention was necessary. Additionally, a study from Nethery, Harmer, and Taaffe (1991) also supports the possibility of competition for attention by various sensory cues. In this experiment, participants were either assigned to either a deprived, normal, visual, or auditory stimulus condition. For a set running speed, it was found that those participants in the deprived group (i.e., no outside audio or visual stimulus) had the highest RPE measures, while those participants who were blindfolded and given music to listen to had the lowest RPE measure. In this case, it seems that an external source of information such as music can "demand" attention from a participant thus removing from focal awareness other sources of information such as breathing. A framework that takes into account cues from inside and outside the body is therefore useful.

2.2.1.2. Attentional strategy

Russell (1997) suggested that a dissociative attentional strategy may be successful in lowering RPE because sensory cues may occupy a limited channel capacity. Thus,

sensory cues that may increase RPE would be prevented from becoming part of focal awareness. A limited capacity means that there are many cues to which one could attend, but only a limited number of cues that could be attended to at one time. It would be these cues only that would enter focal awareness and be consciously attended (Russell, 1997). A dissociative attentional strategy, therefore, would tend to put into focal awareness information that is not related to the state of the working body and the task at hand.

There is evidence that this competition of cues for focal awareness (and thus contribution to RPE) occurs under conditions of varied expected task duration. Walster and Aronson (1967) found that expected task duration influence perceptions of fatigue. The authors proposed that this was because participants suppressed feelings of fatigue until the task was nearly finished. Indeed, Morgan (1978) found that non-elite marathoners dissociated pain by reconstructing events that were not related to their run. This finding has also been confirmed by Rejeski and Ribisl (1980) and Baden, Warwick-Evans, & Lakomy (2004), who found that reduced RPE during longer expected task duration was correlated with dissociative thoughts. Morgan, Horstman, Cymerman, and Stokes (1983) found that participants who employed a primarily dissociative cognitive strategy ran longer than other groups on a test to exhaustion, despite exercise metabolite and blood lactate concentrations being similar across all groups. Only plasma catecholamine levels were higher in the group who used the dissociative strategy. In another study, Weinberg, Smith, Jackson, and Gould (1984) found that those participants who employed either a dissociative or self-talk strategy performed better than associative or control participants on a muscular endurance task. However, there was no difference across groups for distance run in 30 minutes. Given the above evidence, cognitive

strategy appears to play a role in altering RPE in certain conditions. Expected task duration seems to be one precursor to cognitively-mediated changes in RPE.

In addition to mental strategies involving attention, there has been the suggestion that emotion (affect) may be associated with RPE (Baden, McLean, Tucker, Noakes, & St Clair Gibson, 2005). Affect, which is a feeling or emotion related to an idea or object, is considered to be of short duration and high intensity as a feeling (Crews, 1992). Hardy and Rejeski (1989) measured RPE and affect using the feeling scale (FS) during exercise at different intensities. A significant negative correlation between RPE and FS was found at various exercise intensities, with stronger correlations at higher intensities. To summarize, sensory cues derived from physiological processes within the body must be considered within the context of the cognitive environment and exercise-associated emotional changes. It is these contexts that can influence RPE and therefore fatigue.

3. Teleoanticipation

Since no single physiological variable or specific combination of variables has been shown to explain fatigue-related termination of exercise under all conditions, it is more likely that a complex system of information integration occurring within the CNS determines the termination of exercise. This complex system may receive input from exogenous signals that are integrated along with other afferent feedback from internal processes to create the conscious perception of fatigue. The existence of extracellular input has been proposed by Ulmer (1996) and this may contribute to a teleoanticipatory response. Teleoanticipation involves the consideration of the end point of exercise, and it is vital as one process that may explain alterations in RPE measured in the studies above. When teleoanticipation takes place, perceptual cues and cognitive processes are theorized

to be monitored from the beginning of the exercise bout but appraised in relation to the end-point of the bout rather than the beginning. These cues would be fed back to an integrating center within the CNS where they would be constantly monitored considering the current exercise demands and the parameters previously set by a subconscious programmer (Figure A1) regarding acceptable limits to the strain of the activity. If the exercise demands are deemed too lofty by the programmer either for homeostasis or comfort considerations, given the duration of exercise that remains, this may be reflected in a higher RPE. Since the body's goal is to maintain homeostasis, a severe disturbance would result in what has been termed a catastrophe (Noakes, St Clair Gibson, & Lambert, 2004). A healthy body would therefore strive to prevent this from happening. Thus in many cases, in addition to feedback processes, a feed-forward response could include lowering intensity, the termination of exercise, or the employment of a strategy to complete the task under the present conditions (St Clair Gibson, Lambert, Lambert, Hampson, & Noakes, 2001). Evidence for this third option will be presented shortly.

RPE has not traditionally been discussed with regard to exercise duration. However, an alternate scale of effort has recently been proposed, that is based on participants' subjective estimation of exhaustion time (estimated time limit, ETL) at a particular exercise intensity (Garcin, Vandewalle, & Monod, 1999; Garcin & Billat, 2001). This scale asks participants to rate how long they could continue working at a particular intensity, from "more than 16 hours" to "2 minutes". When examined against the traditional RPE scale, it was found that the ETL scale may be a valid subjective tool for prescribing exercise programs. If teleoanticipation occurs, and the current exercise intensity is processed by the CNS in light of the duration that remains, ETL may be a

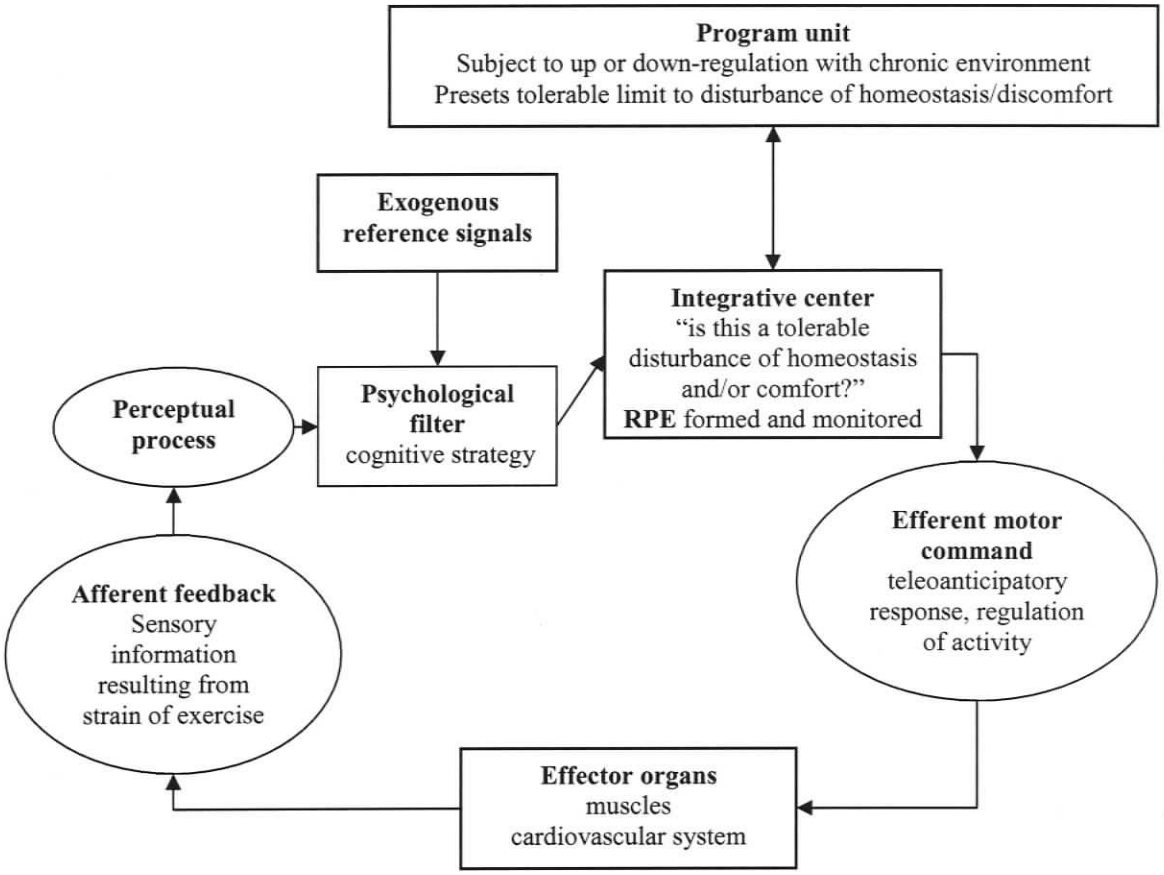

Figure A1. A model of teleoanticipation (modified from Ulmer, 1996)

useful subjective measure to use in future research on teleoanticipatory mechanisms. At any rate, the validity of this measure supports that the consideration of task duration occurs and that it may indeed be related to RPE and fatigue development.

3.1. Evidence for teleoanticipation

Teleoanticipatory responses of altered RPE have been observed under various conditions, sometimes with and sometimes without corresponding measurable physiological or other bodily changes (Rejeski & Ribisl, 1980; Baden et al., 2004). It has been found that providing deceptive feedback such as incorrect information regarding the intensity or duration of the activity can exhibit a teleoanticipatory response.

3.1.1. Effect of deceptive feedback

Providing deceptive feedback during exercise would alter RPE under the teleoanticipatory model. Studies using deception regarding the intensity, distance, and duration have seen recent attention in the literature (Ansley, Robson, St Clair Gibson, & Noakes, 2004; Albertus, Tucker, St Clair Gibson, Lambert, Hampson, & Noakes, 2005; Hampson, St Clair Gibson, Lambert, Dugas, Lambert, & Noakes, 2004). This exogenous (from outside the body) input may lessen the impact of traditionally measured objective variables on the formation of RPE. For example, Hampson et al. (2004) led participants to expect an increase in running speed during an exercise bout, when speed was actually held constant. Results showed a dissociation between speed and RPE – when participants expected an increase in speed, they reported higher RPE than those in the control group. Albertus et al. (2005) found that incorrect distance feedback did not alter pacing strategy in cyclists who completed a 20-km time trial. Thus, it may be that planning prior to an event determines the context in which and by which RPE is formed.

Ansley, Robson, et al. (2004) led cyclists to expect four 30 second, one 33 second, and one 36 second anaerobic cycling tests, but the participants actually did two of each duration for a total of six cycling bouts. When expecting 30 seconds and being required to do 36 seconds, participants showed declining power output in the last 6 seconds of the bout. This suggests that anticipated duration is "pre-programmed" as an end-point to exercise based on previous experiences. The aforementioned studies provide evidence that a cognitive cue directs exercise performance, RPE, and therefore fatigue development.

In a slightly different study design, Baden et al. (2005) measured physiological variables, RPE, FS, and % ASSOC in participants during running. Participants were either informed that they would be running for 20 minutes (20 MIN), expected to run for 10 and then were informed at the end of 10 minutes that they had 10 more minutes to go (10 MIN), or were not informed of the duration of exercise (UN). It was found that RPE had a significant increase from 10 to 11 minutes in 10 MIN, as compared to 20 MIN and UN. Lower $\dot{V}O_2$ (superior running economy) was also found in UN from 10 to 19 minutes of exercise, as compared to 10 MIN and 20 MIN. It is possible that those who expected to exercise for 10 minutes and were asked to continue for a further 10 minutes re-set their goals and appraised their effort in light of the adjustment.

3.1.2. Effect of anticipated task duration

In studies where expected exercise duration has been longer than expected, subjective ratings using an RPE or fatigue scale are lowered at the same absolute time point. This effect has been demonstrated in a visual task (Walster & Aronson, 1967), a strength movement task (Vidaček & Wishner, 1971), and endurance exercise (Rejeski & Ribisl, 1980; Baden et al., 2004).

Waster and Aronson (1967) found that participants who expected to perform 5 trials of a mentally fatiguing task reported lower RPE values at the end of 3 trials, compared with participants who expected to perform 3 trials only. Both groups completed just three trials and there was no relationship between objective fatigue measures (discernment of a white light of varying intensity) and subjectively reported fatigue. It is possible in this case, that a teleoanticipatory response brought about a conscious or subconscious decision to employ a cognitive strategy to facilitate task

completion. According to the authors, fatigue was probably underestimated until the task was virtually completed. At this point participants who expected 3 trials reported a sudden increase in fatigue while participants who expected 5 trials did not. The performance measure in this study was visual threshold, and while fatigue ratings were different between the two conditions, there were no changes in the objectively measured visual threshold. The reason for fatigue in this instance may not be the participants' perceptions of their own visual performances, but their own cognitive assessments regarding how long they would have to continue in the task – as the time until completion shortened, subjective fatigue ratings climbed.

Evidence for physical teleoanticipatory responses have also been found. Vidaček and Wishner (1971) had participants lift and hold a pulley attached to a weight, expecting to do this for either 30 seconds (condition 1) or for as long as they could (condition 2). In either case, participants completed that which they expected to do. Compared to those in condition 1, those in condition 2 had significantly lower iEMG activity in the active muscles throughout the hold although the work done was the same. Unfortunately, ratings of perceived exertion were not measured in this study, and this would be a useful measure to include in the future. Nevertheless, this experiment may suggest that, depending on the expected task duration, the active muscles used different recruitment patterns during contraction to make the force production more efficient, that is, less muscle activity may have been required to produce the same force.

In a study involving endurance exercise, Rejeski and Ribisl (1980) had participants run two 20 minute trials at 85% of $\dot{V}O_{2max}$. For one trial, participants were led to believe that they would be running for 30 minutes at that same intensity. For the

other trial, participants were correctly informed of the 20 minute duration. RPE values for the longer condition were lower than for the shorter condition, but this difference was only significant in the middle of the runs, and not at the beginning or end. This finding at the onset of the run may indicate that elapsed run time at that point was not yet long enough to form a valid subjective rating of effort. Convergence in RPE near the end of the run, may indicate that RPE was no longer suppressed because any stress from the task was easily tolerated for the period near the end. This altered RPE was not associated with any changes in HR, RR, or $\dot{V}_E$. Because objective measurements in this investigation were not comprehensive, this does not preclude the possibility that there are some other objectively measurable variables that mediated RPE. Because HR was lower, but not significantly so, there is a need for further research in this area, perhaps with large sample sizes. In the psychological realm, lower RPE values were associated with a lower % ASSOC, providing evidence in support of the framework mentioned above.

Finally, Baden et al. (2004) used two study designs to examine the effect of expected task duration on RPE. In study 1, participants ran outdoors for either 8 or 10 miles at a similar pace. Participants ran twice on a treadmill for 10 minutes in study 2. Participants expected to run for 20 minutes in one of these runs, while in the other run, they expected to run for 10 minutes. RPE values were lower for the longer conditions in both studies. The lowered RPE was associated with higher percentages of dissociative thoughts throughout the exercise bout. With the exception of HR, physiological variables were not measured in this study, so reported effects were limited to psychological teleoanticipatory responses.

The above evidence from multiple studies suggests that teleoanticipation can elicit both psychological and physiological responses. Evidence has been presented regarding mechanisms of altered psychological responses, and possible physiological mechanisms will be presented in the following section.

3.2. Physiological mechanisms of teleoanticipation

3.2.1. Early exercise

Since teleoanticipation involves the consideration of the end-point of exercise, alterations in expected task duration may cause feed-forward physiological changes prior to and at the beginning of exercise. The most extensively examined variable for this response is HR. A number of studies have shown the presence of anticipatory tachycardia prior to beginning of an exercise bout. Brouha & Heath (1943) found that anticipatory HR increases were greatest prior to running, as compared to treadmill walking or a medical examination.

Anticipatory responses appear to be related to the intensity of the exercise to come. Hanson & Tabakin (1964) found increases in HR prior to various skiing events. It was found that the greatest increases in HR were prior to the skiing events with the greatest intensity – HR increased by the highest percentage before the cross country race and the lowest before the ski jumping events. Magel, McArdle, & Glaser (1969) examined HR prior to swimming events. It was found that the highest increases in HR were prior to sprint swimming events and that the lowest increases were prior to long-distance swimming events. This effect has also been shown in running - McArdle, Foglia, & Patti (1967) found that the greatest percentage increase in HR was prior to a 60m sprint as compared to a 2 mile distance run.

Changes in ventilation have also been found prior to exercise. Hyperpnea has been found prior cycling exercise, likely as an increase secondary to circulatory changes (Tobin, Perez, Guenther, D'Alonzo, & Dantzker, 1986). Wasserman, Whipp, & Castagnia (1974) have also found the presence of cardiodynamic hyperpnea, in that increased ventilation was the result of the increased blood flow bringing more CO_2 to the lungs. It has been suggested that increases in sympathetic discharge and a decrease in vagal tone are mechanisms by which an exercising body prepares itself for the exercise bout to come. Such feed-forward increases are thought to last only briefly at the beginning of exercise, after which feedback systems probably predominate (Torelli & Brandi, 1964).

3.2.2. Late exercise

Teleoanticipatory responses found late in an exercise bout may be related to an end-spurt phenomenon. For example, Baden (2001) found increased RPM near the end of 8 minute or 16 minute cycling bouts where the workload was kept constant. These increases in RPM were not associated with increases in HR or RPE. This may have reflected an end-spurt by participants because the importance of conserving energy was lower near the end of the bout. Indeed, end-spurts were found in each of 3 consecutive 4km time cycling trials separated by 17 minutes of rest (Ansley, Schabort, St Clair Gibson, Lambert, & Noakes, 2004). Here, participants increased their cycling power output near the end of every time trial. This suggests that the consideration of the end point may bring about changes in performance that depend upon the proximity of that end point.

4. Significance

Understanding teleoanticipatory mechanisms includes, firstly, benefits to athletes, particularly those in endurance events. Because the development of fatigue seems to be mediated not only by physiological variables but also by expectations regarding an exercise bout, consideration given to teleoanticipatory processes may aid in training and performance. For example, a training program that reduces uncertainty for a particular task may reduce excessive feed-forward processes present early in an exercise bout. Additionally, training may also be designed to develop the ability to remain economical in movement despite proximity to the end-point. Psychological skills that allow RPE to be pre-set at a lower value upon the initiation of exercise may also prove useful in delaying feelings of fatigue and therefore improving performance. Although an understanding of how to develop such skills is not yet established, it is likely that this could be developed in the future as understanding of teleoanticipation increases.

Secondly, application from this area of research should aid in understanding of fatigue itself and its mediation by physiological variables, psychological variables, and the context in which one is situated. Evidence indicates that fatigue development and performance do not occur without contribution of all factors mentioned in the previous sentence. Understanding of contextual factors that increase or decrease feelings of fatigue is important for not only performance factors, but also those of health and well-being.

5. Directions for future research

Several issues highlighted in this literature review provide suggestions for direction in future research. First, the formation of RPE is complex and the study of this

construct is frequently conducted solely within either physiological or psychological paradigms. Thus, an integrated effort is required to fully understand the determinants of this complex measure. Second, changes in physiological variables may be present as a result of the process of teleoanticipation. Although it has been hypothesized on the basis of HR, and measured in a slightly research design, there is a need to further examine the possibility of altered economy of movement in exercise of varied expected duration. Evidence from Vidaček & Wishner (1971) provides a hypothesis that altered muscle recruitment explains this change, so future research should attempt to measure muscle electrical activity and the role that this plays in altering RPE.

6. Conclusion

Teleoanticipatory effects can occur as a result of alterations in expected task duration. When these occur, both physiological and psychological changes may be present. Physiological changes such as altered economy of movement may occur to allow the exercising individual to operate with less departure from physiological homeostasis. Psychological changes such as altered RPE may occur to allow the individual to complete an exercise bout with minimal discomfort, possible via a higher percentage of dissociative thoughts. It is unknown whether these processes are separate. The presence of teleoanticipatory responses argues that the development of fatigue occurs not only as a result of changing physiological variables but as a result of complex system of information integration that takes into account the parameters of exercise as well as afferent information regarding the state of the exercising body.

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Appendix B

Table A2

Analysis of Variance for Rating of Perceived Exertion

Source	*Df*	Df_{error}	*F*	*p*
Condition	1	8	8.590*	.019
Time	1.875	15.003	13.435*	.001
Condition*time	6	48	.659	.683

*significant at p<.05

Table A3

Analysis of Variance for Heart Rate

Source	*Df*	df_{error}	*F*	*p*
Condition	1	8	.032	.862
Time	1.419	11.354	105.293*	.000
Condition*time	1.692	13.534	.337	.685

*significant at p<.05

Table A4

Analysis of Variance for Oxygen Consumption

Source	*Df*	df_{error}	*F*	*p*
Condition	1	8	.295	.602
Time	1.935	15.477	27.721*	.000
Condition*time	6	48	2.474*	.036

*significant at p<.05

Table A5

Analysis of Variance for Blood Lactate

Source	*Df*	df_{error}	*F*	*p*
Condition	1	7	1.342	.285
Time	2	14	19.084*	.000
Condition*time	1.720	8.189	1.239	.382

*significant at p<.05

Table A5

Analysis of Variance for Blood Lactate Recovery Values

Source	*Df*	df_{error}	*F*	*p*
Condition	1	68	1.158	.286
Time	1	68	1.383	.244
Condition*time	1	68	.154	.696

*significant at p<.05

Table A6

Analysis of Variance for Minute Ventilation

Source	*Df*	df_{error}	*F*	*p*
Condition	1	8	.041	.845
Time	1.723	13.781	57.135*	.000
Condition*time	1.820	14.563	2.304	.138

*significant at p<.05

Table A7

Analysis of Variance for Respiratory Rate

Source	*Df*	df_{error}	*F*	*p*
Condition	1	8	.126	.732
Time	6	48	34.121*	.000
Condition*time	6	48	1.444	.218

*significant at p<.05

Table A8

Analysis of Variance for Cycling Cadence (2, 5, 8 minutes)

Source	*Df*	df_{error}	*F*	*P*
Condition	1	8	.726	.419
Time	2	16	24.063*	.000
Condition*time	2	16	1.785	.200

*significant at p<.05

Table A9

Analysis of Variance for Cycling Cadence (14, 17, 20 minutes)

Source	*Df*	df_{error}	*F*	*P*
Condition	1	8	.891	.373
Time	2	16	1.931	.177
Condition*time	2	16	.246	.785

Table A10

Analysis of Variance for Percentage of Associative Thoughts (2, 5, 8 minutes)

Source	*Df*	df_{error}	*F*	*P*
Condition	1	8	.352	.570
Time	2	16	.632	.544
Condition*time	2	16	.396	.679

*significant at p<.05

Table A11

Analysis of Variance for Percentage of Associative Thoughts (14, 17, 20 minutes)

Source	*Df*	df_{error}	*F*	*P*
Condition	1	8	.061	.811
Time	2	16	.157	.856
Condition*time	2	16	.280	.759

*significant at p<.05

Table A12

Analysis of Variance for Feeling Scale

Source	*Df*	df_{error}	*F*	*p*
Condition	1	8	.775	.404
Time	1.830	14.640	1.412	.273
Condition*time	3.037	24.295	1.395	.268

*significant at p<.05

Table A13

Analysis of Variance for Rating of Perceived Exertion Separated by Intensity Group

Intensity group	Source	*df*	df_{error}	*F*	*p*
INT-A	Condition	1	10	2.191	.170
	Time	2.285	22.846	9.941*	.001
	Condition*time	6	60	.464	.832
INT-B	Condition	1	8	6.780*	.031
	Time	1.867	14.938	6.179*	.012
	Condition*time	6	48	1.541	.185

Appendix C

University of Victoria | School of Physical Education

Participant Consent Form

Relationship Between Physiological Variables and Psychological Variables During Cycling Exercise

You are being invited to participate in a study investigating the relationship between physiological variables, psychological variables, and cognitive strategy that is being conducted by Tim Lindsay and Dr. Kathy Gaul.

Tim Lindsay is a graduate student in the department of Physical Education at the University of Victoria and you may contact him if you have further questions at TIMOTHYL@UVIC.CA.

As a graduate student, I am required to conduct research as part of the requirements for a masters degree in kinesiology. It is being conducted under the supervision of Dr. Kathy Gaul. You may contact my supervisor at 721-8380 or KGAUL@UVIC.CA.

The purpose of this research project is to examine in trained cyclists the relationship between rating of perceived exertion (RPE), rating of feeling, metabolic variables, and percentage of associative/dissociative thoughts during bouts of cycling.

Research of this type is important because it will add to our understanding of the complex nature of fatigue development and endurance performance. There may be some strategies that can affect these variables that we do not yet completely understand. This study will examine some of those strategies.

You are being asked to participate in this study because you are a trained male cyclist.

If you agree to voluntarily participate in this research, your participation will include 3 testing sessions at the University of Victoria Exercise Physiology Lab in the McKinnon Building (room 171). These will include an incremental cycling test to exhaustion, one 20-minute bout and one 40-minute bout at a submaximal pace. You will breathe through a mask for each of the tests so that we can collect expired air. During the tests, you will be asked to rate your perceived exertion, rate how you feel, and the approximate percentage of associative thoughts used during each bout. Full instruction will be given on what these measures mean and how you will give us the information are requesting. We will also take blood samples from your finger-tips during 2 of the sessions. Each session will be a maximum of one hour, and there will be at least 48-hours between each session

Participation in this study may cause some inconvenience to you, in that you will be required to commit some time for the three sessions (approximately 1 hour for each) and it may interfere with your personal training time.

There are some potential risks to you by participating in this research and they include fatigue, dizziness, soreness, and injury as a result of the cycling bouts. However, this will be no more than that which would be expected during and after a normal training session. Additionally, we will be sampling a drop of blood from you 4 times during each of sessions 2 and 3. This will use

an automatic finger prick method, similar to that used by diabetics to test their blood sugar. All blood collection will be performed using sterile procedures. To prevent or to deal with these risks mentioned above, we will give you a questionnaire that will help ensure there are no indicators that you have an apparent elevated risk for physical injury.

The potential benefits of your participation in this research include the state of knowledge regarding fatigue development and performance during endurance exercise. Additionally, you will receive the results of the VO_2 max test that indicates your maximal aerobic power and your power output at that workload.

Your participation in this research must be completely voluntary. If you do decide to participate, you may withdraw at any time without any consequences or any explanation. If you do withdraw from the study your data will not be used.

We cannot protect your anonymity because you will always be with an investigator during the testing sessions. However, your confidentiality and the confidentiality of the data will be protected by using a coded number rather than your name for further analysis once all the data from your tests has been collected. After analysis, reported data will not be for individuals but rather as averages.

It is anticipated that the results of this study will be shared with others in the following ways: we will let you know the results of your VO_2 max test after the completion of all three sessions; this data may be published in a scientific article, as part of a thesis, or presented in a class or scientific meeting. Your data may be analyzed again following the completion of this study/thesis, for additional scientific purposes.

Data from this study will be disposed of within 5 years of completion of the study. This will include both electronic data, which will be erased, and paper data, which will be shredded

In addition to being able to contact the researcher and the supervisor at the above phone numbers, you may verify the ethical approval of this study, or raise any concerns you might have, by contacting the Associate Vice-President, Research at the University of Victoria (250-472-4545).

Your signature below indicates that you understand the above conditions of participation in this study and that you have had the opportunity to have your questions answered by the researchers.

_____	_____	_____
Name of Participant	*Signature*	*Date*

A copy of this consent will be left with you, and a copy will be taken by the researcher.

Appendix D

Participant Questionnaire

Name_____

Age_____

Gender (circle) M F

What is your average training frequency? 1 2 3 4 5 6 7 (days per week)

What is your average training duration? _____ (hours:minutes)

How long have you been training? _____ years

What is your average number of race days per year? _____

What is your primary sport? (circle) cycling triathlon other (specify) _____

Appendix E

Session 1 – prior exercise

Name_____

What exercise have you done today?

1) _____ (mode) _____(duration) _____(intensity)

2) _____ (mode) _____(duration) _____(intensity)

3) _____ (mode) _____(duration) _____(intensity)

What exercise did you do yesterday?

1) _____ (mode) _____(duration) _____(intensity)

2) _____ (mode) _____(duration) _____(intensity)

3) _____ (mode) _____(duration) _____(intensity)

What exercise did you do two days ago?

1) _____ (mode) _____(duration) _____(intensity)

2) _____ (mode) _____(duration) _____(intensity)

3) _____ (mode) _____(duration) _____(intensity)

Appendix F

Physical Activity Readiness Questionnaire - PAR-Q (revised 2002)

PAR-Q & YOU

(A Questionnaire for People Aged 15 to 69)

Regular physical activity is fun and healthy, and increasingly more people are starting to become more active every day. Being more active is very safe for most people. However, some people should check with their doctor before they start becoming much more physically active.

If you are planning to become much more physically active than you are now, start by answering the seven questions in the box below. If you are between the ages of 15 and 69, the PAR-Q will tell you if you should check with your doctor before you start. If you are over 69 years of age, and you are not used to being very active, check with your doctor.

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each one honestly: check YES or NO.

YES	NO	
☐	☐	1. **Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?**
☐	☐	2. **Do you feel pain in your chest when you do physical activity?**
☐	☐	3. **In the past month, have you had chest pain when you were not doing physical activity?**
☐	☐	4. **Do you lose your balance because of dizziness or do you ever lose consciousness?**
☐	☐	5. **Do you have a bone or joint problem (for example, back, knee or hip) that could be made worse by a change in your physical activity?**
☐	☐	6. **Is your doctor currently prescribing drugs (for example, water pills) for your blood pressure or heart condition?**
☐	☐	7. **Do you know of any other reason why you should not do physical activity?**

If you answered

YES to one or more questions

Talk with your doctor by phone or in person BEFORE you start becoming much more physically active or BEFORE you have a fitness appraisal. Tell your doctor about the PAR-Q and which questions you answered YES.

- You may be able to do any activity you want — as long as you start slowly and build up gradually. Or, you may need to restrict your activities to those which are safe for you. Talk with your doctor about the kinds of activities you wish to participate in and follow his/her advice.
- Find out which community programs are safe and helpful for you.

NO to all questions

If you answered NO honestly to all PAR-Q questions, you can be reasonably sure that you can:

- start becoming much more physically active – begin slowly and build up gradually. This is the safest and easiest way to go.
- take part in a fitness appraisal – this is an excellent way to determine your basic fitness so that you can plan the best way for you to live actively. It is also highly recommended that you have your blood pressure evaluated. If your reading is over 144/94, talk with your doctor before you start becoming much more physically active.

DELAY BECOMING MUCH MORE ACTIVE:

- if you are not feeling well because of a temporary illness such as a cold or a fever – wait until you feel better; or
- if you are or may be pregnant – talk to your doctor before you start becoming more active.

PLEASE NOTE: If your health changes so that you then answer YES to any of the above questions, tell your fitness or health professional. Ask whether you should change your physical activity plan.

Informed Use of the PAR-Q: The Canadian Society for Exercise Physiology, Health Canada, and their agents assume no liability for persons who undertake physical activity, and if in doubt after completing this questionnaire, consult your doctor prior to physical activity.

No changes permitted. You are encouraged to photocopy the PAR-Q but only if you use the entire form.

NOTE: If the PAR-Q is being given to a person before he or she participates in a physical activity program or a fitness appraisal, this section may be used for legal or administrative purposes.

"I have read, understood and completed this questionnaire. Any questions I had were answered to my full satisfaction."

NAME _____

SIGNATURE _____ DATE _____

SIGNATURE OF PARENT or GUARDIAN (for participants under the age of majority) _____ WITNESS _____

Note: This physical activity clearance is valid for a maximum of 12 months from the date it is completed and becomes invalid if your condition changes so that you would answer YES to any of the seven questions.

Supported by: Health Canada Santé Canada

continued on other side...

Appendix G

Instruction on associative/dissociative thoughts (from Baden et al., 2004)

At regular intervals I will ask you to point to a number on a sheet of paper that represents the approximate percentage of associative thoughts over the last segment of your cycling bout. But please don't think that you have to be aware of exactly what you are thinking all the time, an approximate proportion is fine. Also, quite often dissociative-type thoughts are like daydreams and quickly forgotten. So although you may start off by thinking that your feet hurt, you may then go on to speculate whether to get new trainers and then may find you are in a daydream you may not remember. In this case, just the original thought counts as an associative thought and the rest is dissociative.

Additional instruction on associative/dissociative thoughts (Baden et al., 2004)

This experiment will monitor the types of thoughts you have while running. I will not want to know details of what you are thinking, only whether your thoughts are broadly associative or dissociative.

Associative Thoughts: Thoughts about your body and how it is reacting to the exercise, for example where you attention is focused on the body and your thoughts are about physical sensations such as heart pounding, sweatiness, heavy breathing, sore muscles, pain, etc.

Dissociative Thoughts: These are all thoughts that are not about physical sensations or the exercise. External thoughts are like daydreams and may distract you from the bodily signals arising from exercise.

Classify the following thoughts as associative or dissociative and then check at the bottom of the page to see if you got them correct.

1."I'm feeling tired"

2."I wonder how my friend is getting on in her new home"

3."Breathe deeply, relax shoulders..."

4."Just one more stretch to go and I can rest"

5."Oh dear, I forgot to get some bread"

6."Keep going, you can do it"

7."That new sitcom is very funny"

8."My feet are beginning to hurt"

Answers: Associative thoughts = 1, 3, 4, 6, 8; Dissociative thoughts = 2, 5, 7.

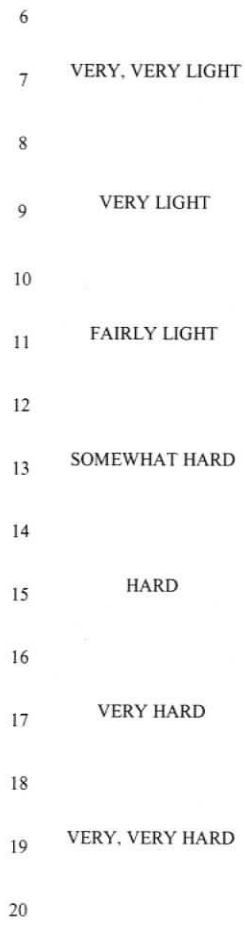
What percentage of your thoughts are **associative**?

100
95
90
85
80
75
70
65
60
55
50
45
40
35
30
25
20
15
10
5
0

Appendix H

Instruction on RPE (from Baden et al., 2004)

You are now going to participate in an exercise test. You will be running on a treadmill while we measure several physiological parameters. We also would like you to tell us how *hard* you think you are working. We call this your rating of perceived exertion. By this we mean the total amount of exertion and physical fatigue, combining all sensations and feelings of physical stress and effort. Do not concern yourself with any one factor such as leg fatigue, shortness of breath, or the work intensity, but rather please concentrate on your *total inner feelings of exertion*. We will ask you for your ratings of perceived exertion every 3 minutes during the exercise test. At these times, we will show you a chart and you may indicate your perception of effort by pointing to the appropriate value.



Rating of Perceived Exertion

6
7 Very, very light
8
9 Very light
10
11 Fairly light
12
13 Somewhat hard
14
15 Hard
16
17 Very hard
18
19 Very, very hard
20

Appendix I

Feeling Scale

+5 Very good
+4
+3 Good
+2
+1 Fairly good
0 Neutral
-1 Fairly bad
-2
-3 Bad
-4
-5 Very bad

Appendix J

Intervention for Session 2

"For this test, you will be cycling for 20 minutes at a power output of _____ watts. We would like you to indicate your perceived exertion every 3 minutes throughout the test by pointing to the chart. You may refer to the countdown timer in front of the bicycle, and we will provide you with the time left in your cycling bout."

Time	% Assoc. thoughts	RPE	FS	Verbal Feedback
2:00				"You have 18 minutes to go. Associative thoughts? RPE? How do you feel?"
5:00				"You have 15 minutes to go. Associative thoughts? RPE? How do you feel?"
8:00				"You have 12 minutes to go. Associative thoughts? RPE? How do you feel?"
11:00				"You have 9 minutes to go. Associative thoughts? RPE? How do you feel?"
14:00				"You have 6 minutes to go. Associative thoughts? RPE? How do you feel?"
17:00				"You have 3 minutes to go. Associative thoughts? RPE? How do you feel?"
20:00				"You are finished. Over the last 3 minutes: Associative thoughts? RPE? How did you feel? We will take lactate now and in two minutes."

Intervention for Session 3

"For this test, you will be cycling for 40 minutes at the same workload as when you did 20 minutes. We would like you to indicate your perceived exertion every 3 minutes throughout the test by pointing to the chart. You may refer to the countdown timer in front of the bicycle and we will provide you with the time left in your cycling bout."

Time	% Assoc. thoughts	RPE	FS	Verbal Feedback
2:00				"You have 38 minutes to go. Associative thoughts? RPE? How do you feel?"
5:00				"You have 35 minutes to go. Associative thoughts? RPE? How do you feel?"
8:00				"You have 32 minutes to go. Associative thoughts? RPE? How do you feel?"
11:00				"You have 29 minutes to go. Associative thoughts? RPE? How do you feel?"
14:00				"You have 26 minutes to go. Associative thoughts? RPE? How do you feel?"
17:00				"You have 23 minutes to go. Associative thoughts? RPE? How do you feel?"
20:00				"You have 20 minutes to go. Over the past 3 minutes: associative thoughts? RPE? How did you feel? Please stop cycling – we wanted you to mentally prepare for 40 minutes, but you don't need to continue. We will be taking lactate now and in 2 minutes. [after the 2 minutes] You may step off the bike. Please complete these two questionnaires regarding today's session."

Appendix K

Did you have <u>any</u> of these thoughts <u>at any time</u> during the time trial?

(Please check all that apply)

☐ I was mentally counting down the time from 40 minutes to 0 minutes.

☐ It was interesting to participate in a laboratory test.

☐ I was uncomfortable with the breathing mask or other equipment.

☐ I was surprised when I was told I could stop after only 20 minutes.

☐ I was hot.

☐ I was concentrating on delivering a smooth, circular pedal stoke.

Post-testing interview

Did you notice anything unusual for this particular session of cycling?

What do you believe was the main purpose of the study?
