3-26-2012

The Impact of Continuous and Discontinuous Cycle Exercise on Affect: An Examination of the Dual-Mode Model

Sam Greeley

University of South Florida, sgreeley@mail.usf.edu

The Impact of Continuous and Discontinuous Cycle Exercise on Affect: An Examination of the Dual-Mode Model

by

Samuel Greeley

A thesis submitted in partial fulfillment
of the requirements for the degree of
Master of Science
Department of Exercise Science
College of Education
University of South Florida

Major Professor: Marcus Kilpatrick, Ph.D.
Bill Campbell, Ph.D.
Candi Ashley, Ph.D.

Date of Approval:
3/26/2012

Keywords: affect, dual-mode, enjoyment, exercise, intensity, interval

TABLE OF CONTENTS

List of Tables iii

Abstract iv

Chapter 1: Introduction 1
- Rationale 1
- Purpose 5
- Study Variables 5
- Hypotheses 6
- Conceptual Model 6
- Operational Definitions 8
- Limitations 8
- Delimitations 9
- Significance 9

Chapter 2: Review of Literature 11
- Interval Training 11
  - Wingate-style interval training 12
  - Practical low-volume, high-intensity interval training 16
- Dual-mode Model 18
- Solomon's Opponent-process Theory of Acquired Motivation 23

Chapter 3: Methods 25
- Participants 25
- Instruments 25
- Equipment 26
- Procedures 26
  - First visit 27
  - Second visit 27
  - Visits three through six 28
    - Pre-exercise 29
    - During exercise 29
    - Post-exercise 29
- Statistical Analysis 30

Chapter 4: Results 31
- Enjoyment 31
- Affective Valence 32

Affective responses among groups 32
Affective responses within groups..33

Chapter 5: Discussion 35
Enjoyment...35
Affect 38
In-task affect 38
Post-exercise affect...39
Conclusions...39

Chapter 6: References Cited 41

Appendix A: Physical Activity Enjoyment Scale...46
Appendix B: Feeling Scale 47
Appendix C: CR10 RPE Scale..48
Appendix D: Exercise Enjoyment Scale...49

LIST OF TABLES

Table 4.1: Mean Ratings of Enjoyment with Standard Deviations 32

Table 4.2: Mean Ratings of Affect with Standard Deviations..34

Abstract

Low-volume, high-intensity interval training has been garnering attention in the exercise physiology literature recently due to its proposed time-efficiency. Also, recent work comparing continuous exercise to high-intensity interval training demonstrated superior ratings of perceived enjoyment following interval training. However, the dual-mode model suggests that exercise above ventilatory threshold (VT) done continuously will result in an almost homogenous decline in affect, which may reduce adherence.

Numerous studies confirm the dual-mode model's prediction of reduced affect when exercising above VT, but no research to date has applied the model's predictions to interval training. The purpose of this study was to examine the dual-mode model using interval training. Based on the model, interval exercise above VT should produce a homogenous and significant decline in affect during exercise.

Ten participants (mean age = 21.6 ± 2.4 yrs) completed the study. Participants were screened by a physician's assistant on their first visit to ensure they were low-risk and had no symptoms (cardiovascular, pulmonary, metabolic, or orthopedic) that would preclude safe participation in an exercise training program. Participants performed a maximal exercise test during their second visit to the lab. The final four visits were exercise trials 20 minutes in duration: 1) continuous at 20% below VT [Continuous-

Moderate], 2) continuous at VT [Continuous-Heavy, 3) 10 x 60-second intervals at VT [Interval-Heavy], 4) 10 x 60-second intervals at 20% above VT [Interval-Severe].

Results indicated that enjoyment and affect was significantly greater during Continuous-Moderate and Interval-Heavy compared with Continuous-Heavy. Interval-Severe approached inducing significantly greater enjoyment and affect compared with Continuous-Heavy, however the study was likely underpowered to achieve significance. The findings of this study suggest that utilizing interval training may help preserve affect, even when performing exercise above VT.

Chapter 1: Introduction

Rationale

Across gender and ethnicity, lack of time is the most common reason adults give as to why they do not exercise (Trost et al., 2002). Low-volume, high-intensity interval training is purported to be a time-efficient method of exercise to enhance health, wellness, and performance (Gibala, 2007). Interval training has become a renewed focus of the literature as a way to combat this barrier to exercise while providing performance and metabolic benefits similar to that of traditional, continuous aerobic endurance exercise. A traditional sprint interval training (SIT) session consists of four to six bouts of Wingate-style cycling for 30 seconds interspersed with four minutes of light pedaling at 30 watts. More recent models have shifted to prescribing intensity based on performance of a VO_{2peak} test, and are designed to elicit a near-maximal (~95%) percentage of heart rate maximum by the end of the exercise session. These modified protocols also lengthen the exercise interval to one minute and shorten the recoveries to one minute. Ten exercise intervals are completed.

Early work with the Wingate-style model of SIT demonstrated that after seven weeks of training, healthy men increased both glycolytic and oxidative enzyme activity as well as VO_{2max} and maximum, short-term power output (MacDougall et al., 1998).

Participants who engaged in a training program consisting of multiple Wingate-style bouts very similar to SIT saw increases in both their aerobic and anaerobic metabolism (Rodas et al., 2000; Parra et al., 2000). In as little as six sessions spread over two weeks, an SIT program induced an increase in muscle oxidative potential and endurance capacity (Burgomaster et al., 2005). The same lab found similar adaptations in skeletal muscle and exercise performance with approximately 90% less training volume using SIT compared to traditional endurance training over a span of two weeks (Gibala et al., 2006). A later study produced similar results over six weeks of training (Burgomaster et al., 2008).

The benefits of SIT appear to have staying power, as well. Following 6 weeks of training, markers of muscle oxidative metabolism have been shown to remain elevated after 6 weeks of detraining (Burgomaster et al., 2007). SIT spares skeletal muscle glycogen and decreases lactate accumulation after training by increasing the capacity for oxidation of pyruvate (Burgomaster et al., 2006). More recent research has sought to examine the mechanisms by which SIT induces rapid adaptations in skeletal muscle. Gibala and colleagues (2008) suggested that signaling through AMP-activated protein kinase (AMPK) and p38 mitogen-activated protein kinase (p38 MAPK) to PGC-1α may partly explain the mitochondrial biogenesis and increase in glucose and fatty acid oxidative potential associated with SIT.

These results indicate the potency of low-volume, high-intensity interval training. However, the prevailing criticism of Wingate-style SIT is that it requires a high level of motivation, and it remains to be determined what populations, if any, will adhere to and benefit from this type of exercise (Coyle, 2005; Hawley & Gibala, 2009). Some authors indicate that participants report nausea and light-headedness associated with this type of interval training (Richards et al., 2010), while others suggest that the work was well-tolerated by participants (Whyte, Gill & Cathcart, 2010).

The concerns regarding the tolerability of the Wingate-style interval training led to the creation of a 'practical' protocol, which aimed to apply the same time-efficiency demonstrated by previous SIT research (Little et al., 2010). Rather than an intensity of all-out effort against a fixed resistance, the practical protocol in this study used an exercise intensity of 100% of the peak power achieved (~355 W) during a ramp VO_{2peak} test, which is approximately half of the exercise intensity of the Wingate-style version used in previous studies. Other research indicates that reducing all-out sprint interval times to as little as 10 seconds can also result in aerobic and anaerobic performance improvements (Hazell, MacPherson, Gravell, & Lemon, 2010).

Practical SIT has also shown promise with regard to providing important health benefits. Insulin sensitivity was improved in healthy adults with approximately 250 kcal work per week over two weeks (Babraj, Vollaard, Keast, Guppy, Cottrell, & Timmons, 2009; Richards et al., 2010). Peripheral artery distensibility and endothelial function have been shown to be improved after six weeks of SIT (Rakobowchuk et al., 2008). One study investigated the effects of SIT conducted three times a week for two weeks on obese men (Whyte, Gill & Cathcart, 2010). This study showed insulin sensitivity and resting fat oxidation were increased while resting systolic blood pressure and resting carbohydrate oxidation were decreased after training. Participants also had significant reductions in waist and hip circumference.

While the benefits of low-volume, high-intensity interval training seem conclusive, there remains the question of adherence. This question is particularly pertinent with regard to those whom physical activity interventions would target: inactive individuals not accustomed to the stress of exercise. The dual-mode model proposes that exercise intensity below the ventilatory threshold (VT) results in relatively homogeneous improvements in affective valence, exercise intensity that approaches VT induces heterogeneous responses, while intensity exceeding VT will reduce pleasure (Ekkekakis, Hall & Petruzzello, 2005; Ekkekakis, Hall & Petruzzello, 2008). Since the intensity of SIT is well above VT, the dual-mode model would suggest that affective responses during exercise would be negatively impacted, thus possibly reducing the likelihood of adherence.

Raedeke (2007) points out that individuals who enjoy exercise may exhibit more positive affective responses compared to those who enjoy exercise less. His experiments utilizing both categorical and dimensional measures of affect found that enjoyment was associated with increases in positive affective states but not related to declines in negative affective states. The affective responses in his study were taken before and after exercise, so the results may have been very different if the relationship between enjoyment and in-task affective responses was examined. Bartlett and colleagues (2011) found that recreationally active males' ratings of perceived enjoyment were higher post-exercise following high-intensity interval running than moderate-intensity continuous running. The intensity of the intervals used in that study was well above VT (90% VO2max). These results provide some hope that various forms of interval training may be appealing to exercisers, and while the dual-mode model has investigated affective responses during continuous exercise, it has yet to be applied to discontinuous exercise.

Purpose

The physiological benefits of low-volume, high-intensity interval training are well-documented. However, empirical research has neglected the perceptual responses to such training. This is a crucial area, because psychological responses to exercise may impact adherence to a physical activity regimen. The dual-mode model (Ekkekakis 2003) provides a theoretical framework for the dose-response relationship between exercise intensity and affect. While this model has stimulated research examining continuous exercise, it has yet to be applied to discontinuous or interval training. The purpose of this study is to examine perceptual responses to four exercise sessions: an interval session above VT, an interval session at VT, a continuous session at VT, and a continuous session below VT. Affective response, self-efficacy, ratings of perceived exertion, and ratings of perceived enjoyment will be measured.

Study Variables

The independent variable in this study will be the exercise intervention. There will be four levels of this variable. There will be two trials of interval exercise and two trials of continuous exercise. All trials will have a two-minute warm-up, followed by 20 minutes of exercise, and finish with a two-minute cool-down. Both interval sessions will have 10 one-minute exercise intervals interspersed with 10 one-minute recovery intervals. The intensity for one interval session will be above VT, while the other will be at VT. The intensity for one continuous trial will be at VT, and the other will be below

VT. The dependent variables for this study will be affective valence and ratings of perceived enjoyment.

Hypotheses

H_{A1}: There will be a difference in perceived enjoyment among the trials.

H_{A2}: There will be a decline in affective response during the exercise intervals of the above-VT trial.

H_{A3}: Affective response will increase back to pre-exercise levels during the recovery intervals in the above-VT interval trial.

Conceptual Model

According to the dual-mode model, affective responses to exercise represent a continuous interplay between cognitive processes (e.g. exercise goals) and interoceptive cues (physiological responses) (Ekkekakis, 2003). The influence of these two factors varies depending on the intensity of the exercise. The dual-mode model suggests the relationship between exercise intensity and affective response is best understood with regard to the transition from aerobic metabolism to a greater reliance on the limited anaerobic systems (Ekkekakis, 2003; Ekkekakis et al, 2005). Three specific domains of exercise intensity are considered: moderate, heavy and severe (Ekkekakis et al., 2005).

Moderate intensity corresponds to exercise below lactate threshold, when aerobic metabolism is the predominant source of energy and a physiological steady state can be maintained. The expected affective response in this range of intensity is one of pleasure, with little variation between individuals. Ekkekakis and colleagues (2005) believed the influence of cognitive factors would play a small part in driving affect in this range of intensity. It is hypothesized that activity in this domain is adaptive, and thus there may be some mechanism that 'rewards' the action by increasing or maintaining pleasure (Ekkekakis et al., 2005).

Heavy exercise, the second range of intensity of concern, is that which encompasses the lactate threshold to the maximal work rate at which lactate can be stabilized (Ekkekakis et al., 2005). Physical activity in this range cannot be maintained indefinitely, but it is possible to work at this intensity for a period of time. The inter-individual variability in affective response is high, as cognitive factors have a very strong influence in this domain. Goal achievement, self-efficacy, and personality characteristics will drive affect during exercise at this intensity.

The third and final domain is termed severe intensity. This range begins when lactate can no longer be stabilized, and continues up to maximal exercise capacity. Exercise at severe intensity relies heavily on the limited anaerobic metabolism to meet energy needs. A physiological steady-state at this work rate cannot be maintained at this work rate. Energy stores will be depleted, threatening to send the body's muscles into rigor. Interoceptive cues (physiological responses to exercise) are believed to drive affect down during exercise in the severe intensity range. Ekkekakis and colleagues (2005) believe that affect acts as a preservation mechanism and is responsible for regulating the human ability to work in this domain.

Operational Definitions

In keeping with Ekkekakis et al. (2005), affective response will be defined in this study as a "change in self-reported pleasure-displeasure" (p. 478). It may be viewed as a bipolar continuum, where one end of the spectrum is extreme displeasure and the other end is extreme pleasure. Affect is the core of all valenced responses including moods and emotions and as such it is irreducible. It may occur both as a result or independent of cognitive appraisal.

Enjoyment reflects feelings about a stimulus and is a psychological state directly connected to that stimulus. It is an emotion and as such, requires a cognitive appraisal of a stimulus as having positive or negative implications for one's goals or well-being.

Sprint interval training will be defined as four to six bouts of Wingate-style cycling for 30 seconds interspersed with four minutes of light pedaling at 30 watts. Modified protocols discussed that deviate from these procedures will be explicitly outlined in the text.

Ventilatory threshold will be used as an index of the transition point from aerobic metabolism to an increased reliance on anaerobic energy.

Limitations

One limitation to this study is the effort given during the VO_{2peak} test. Peak heart rate and RPE will be recorded in order to help determine whether a maximal effort was given by each participant. A second limitation is that power output on the cycle ergometer must be manually adjusted by a member of the study staff. This will create a slight transition period while power output is adjusted during exercise. Each member of the study staff will be well-practiced in this task so as to make it as efficient as possible.

Delimitations

A delimitation of this study is that experimental trials will be matched for total duration, but not total work. A second delimitation will be the sample. It will consist of healthy, young adults. A third delimitation is that all exercise will be conducted on a cycle ergometer and in a laboratory setting. A fourth and final delimitation is that affective response will be measured from a dimensional rather than categorical approach.

Significance

The evidence demonstrating the benefits of SIT on performance, metabolism, and health markers is abundant. This form of exercise is purported to be a time-efficient method of training when compared to traditional continuous endurance training (Gibala et al., 2006; Burgomaster et al., 2008). This characteristic is very appealing because lack of time is one of the primary reasons given by adults for not exercising (Trost et al., 2002). There is also some evidence that interval training may be more enjoyable than continuous steady-state training (Bartlett et al., 2011).

Despite its demonstrated benefits and proposed time-efficiency, there is concern about the ability of the general population to adhere to SIT due to its extremely high-intensity. It is presumed, but not yet empirically tested, that a high level of motivation is required to adhere to such training (e.g., Coyle, 2005; Hawley & Gibala, 2009). Despite these concerns, there is little data to this point regarding perceptual responses during low-volume, high-intensity interval training, whether it is the Wingate-style or a modified protocol. This study aims to shed light in this area by investigating affect, ratings of perceived exertion, and perceived enjoyment during low-volume, high intensity interval training within the framework of the dual-mode model.

Chapter 2: Literature Review

Interval Training

Two broad descriptors that can be used to delineate categories of exercise are continuous and discontinuous. The former typically refers to traditional, steady-state exercise while the latter indicates something commonly known as interval training. Interval training consists of bouts of exercise at a certain intensity interspersed with periods of ‘recoveries’ at lower intensities. This type of training can vary in many ways, including number of intervals, interval duration, exercise interval intensity, recovery interval intensity, and work:recovery ratio.

Interval training is by no means a new concept, but it has been highlighted recently in research endeavors examining health and performance benefits. Various types of aerobic interval training have been demonstrated to improve cardiovascular health in heart failure patients, patients with coronary artery disease, and obese adults (Wisloff et al., 2007; Warburton et al., 2005; Schjerve et al., 2008). Athletes routinely use interval training as part of a periodized training regimen, and research supports the notion that high-intensity interval training can benefit performance in elite athletes (Psilander, Wang, Westergren, Tonkonogi & Sahlin, 2011). Thus, interval training holds potential benefits for a wide spectrum of the population, from those with cardiovascular disease to elite-level athletes.

Wingate-style interval training. Wingate-style interval training came into prominence in research in the last decade because of the positive benefits associated with an extremely low volume of work. Two studies have directly demonstrated the time-efficiency of this type of low-volume, high-intensity interval training compared to traditional endurance training (ET) (Gibala et al., 2006; Burgomaster et al., 2008). Six sessions of SIT over the course of two weeks have been shown to produce similar exercise performance improvements and metabolic adaptations as the same number of sessions of ET consisting of 90-120 minutes of continuous cycling at an intensity of 65% VO_{2peak} (Gibala et al., 2006). Both training programs significantly decreased the time to complete 50 and 750 kJ cycling time trials. The two groups also had similar increases in muscle oxidative capacity, muscle buffering capacity, and glycogen content after training. However, the improvements associated with SIT were accomplished with approximately 90% less training volume. Total training time over the course of the study was ~2.5 hours in SIT compared to ~10.5 hours in ET.

The same lab extended the findings of the previous study by comparing adaptations to SIT and ET in active but untrained participants (20 male, 20 female) over the course of six weeks (Burgomaster et al., 2008). Both groups increased VO_{2peak}, with no significant difference between the two protocols. The results showed SIT induced adaptations in skeletal muscle carbohydrate and lipid metabolism that were similar to those of ET. Maximal activities of citrate synthase (CS) and 3-hydroxy-acyl-CoA dehydrogenase (HAD) and the protein contents of PDH and PGC-1α were increased following training in both groups with no significant differences between them. The weekly training volume for those in the SIT group was just ~225 kJ, compared to ~2250 kJ in the ET group.

While most of SIT research has been conducted using a specialized cycle ergometer, utilizing running as the modality may be just as effective. Substituting running 'all-out' for 30 seconds for Wingate bouts, MacPherson, Hazell, Olver, Paterson & Lemon (2011) compared adaptations induced by SIT and ET in healthy, young participants over a six-week period. The ET group exercised three times per week at 65% VO_{2max} for 30-60 minutes. VO_{2max} was improved significantly in both SIT and ET groups, with no difference between groups. 2000-meter time trial performance was also improved in both groups.

SIT can significantly improve performance markers such as VO_{2peak}, both in healthy, active samples (MacDougall et al., 1998; Rodas, Ventura, Cadefau, Cusso & Parra, 2000; Burgomaster et al., 2008), as well as the sedentary and obese (Whyte et al., 2010). Several training studies have demonstrated the benefits of SIT using practical indicators of performance such as improved time-trials after two to six weeks (Burgomaster, Heigenhauser & Gibala, 2006; Gibala et al., 2006; Burgomaster et al., 2007; Burgomaster et al., 2008; Babraj et al., 2009; MacPherson et al., 2011). Both peak and mean powers have been shown to improve post-training (MacDougall et al., 1998; Burgomaster et al., 2006; Parra et al., 2000).

Much of the research regarding SIT adaptations have focused on enzymatic activity and muscle oxidative capacity. SIT has been demonstrated to reduce skeletal muscle glycogenolysis and lactate accumulation during exercise while increasing the skeletal muscles' capacity to oxidize pyruvate. After six sessions of SIT performed over two weeks, citrate synthase (CS) activity increased significantly while the maximal activity of 3-hydroxy-acyl-CoA dehydrogenase (HAD) remained unchanged in eight male participants. The authors proposed that these results indicate that short-term SIT does not stimulate a coordinated increase in all mitochondrial enzymes (Burgomaster et al., 2006). As hypothesized, net muscle glycogenolysis and lactate accumulation during matched-work exercise was reduced post-training and the capacity for pyruvate oxidation was enhanced.

A single session of SIT has been shown to stimulate cell signaling through AMP-activated protein kinase (AMPK) and p38 mitogen-activated protein kinase (p38 MAPK) (Gibala et al., 2009). These two signaling proteins are linked to peroxisome proliferator-activated receptor-y coactivator-1α (PGC-1α), which functions as a regulator of mitochondrial biogenesis. PGC-1α mRNA was also increased after the session of SIT; however, PGC-1α protein content was not. The authors proposed that more than one session of SIT might be needed to increase the protein content of PGC-1α. The authors also suggested that the cascade of signals from AMPK and p38 MAPK to PGC-1α may explain in part the adaptations induced by SIT which include mitochondrial biogenesis and an increased capacity for glucose and fatty acid oxidation.

Burgomaster and her colleagues (2007) examined the effects of six weeks of SIT and subsequent detraining on metabolite transport protein in human skeletal muscle. The authors found that GLUT4 and cytochrome c oxidase subunit 4 (COX4) content was significantly increased after one week of training and remained elevated even after six weeks of detraining. Monocarboxylate transporter 1 (MCT1) content was significantly higher after six weeks of training compared to baseline, while MCT4 content was increased after just one week of training. These increases in MCT1 and MCT4 did not persist over the six weeks of detraining. Neither fatty acid binding protein (FABPpm) nor fatty acid translocase (FAT/CD36) muscle content changed during or after training.

Perhaps the most important adaptations to SIT, particularly from a public health perspective, include improved health markers. Wingate-style interval training for six weeks produced similar improvements in peripheral artery distensibility and endothelial function as ET (Rakobowchuk et al., 2008). Two weeks of SIT have been shown to reduce the area under the plasma glucose, insulin and NEFA concentration-time curves in healthy, young male participants (Babraj et al., 2009). The same study saw a 23% improvement, according to the Cederholm index, in insulin sensitivity with a protocol involving just 250 kcal of work per week. Another study showed that six sessions of SIT increased insulin sensitivity compared to two control groups: a single-session of SIT and a sedentary condition (Richards et al., 2010)

Wingate-style interval training has even shown potential to be efficacious with an overweight/obese sample (Whyte et al., 2010). Resting fat oxidation in a fasted state was markedly increased and an improvement in insulin sensitivity was seen in participants after two weeks of training, extending previous literature that noted improved insulin sensitivity in healthy young adults. This change was transient, however, being lost at the 72-hour post-training assessment. Participants also reduced their resting systolic blood pressure. Four weeks of SIT has also improved circulatory function during submaximal exercise in sedentary, overweight/obese women (Trilk et al., 2011). A 20-minute exercise bout at 50% VO_{2peak} was completed pre- and post-intervention. Heart rate was significantly lower and stroke volume significantly higher during the post-intervention submaximal exercise.

Practical low-volume, high-intensity interval training. The extremely high intensity required in Wingate-style interval training begs the question of whether it is practical for the general population. In an effort to combat those concerns, modified protocols utilizing much lower intensities have been created and termed more 'practical.' The first study to create such a protocol prescribed an intensity corresponding to the peak power generated during a VO_{2peak} test (Little et al, 2010). The ~355 W generated using this method halved the intensity generated during Wingate-style intervals using a very similar sample. The exercise interval duration was lengthened to 60 seconds, and the recovery interval was shortened to 75 seconds. Instead of four to six sets of intervals, eight to twelve sets were completed in this training study.

This more practical version of low-volume-high-intensity training elicited increases in maximal activity and protein content of mitochondrial enzymes and regulators of mitochondrial biogenesis (Little et al., 2010). Maximal activity of COX increased by 29% and protein content of COX subunits II and IV also increased by 35% and 38%, respectively. CS maximal activity (16%) and protein content (20%) increased as well. Nuclear PGC-1α protein content was 24% higher after training. However, similar to previous work (Gibala et al., 2009), whole muscle PGC-1α protein was unaltered following training. Sirtuin 1 (SIRT1), which is a proposed activator of PGC-1α, was elevated by approximately 56% post-training. Resting levels of glycogen (17%) and protein content of GLUT4 (119%) were significantly increased after SIT.

Recent work has begun to highlight the potential health benefits of using practical models of SIT with sedentary or diseased samples (Hood, Little, Tarnopolsky, Myslik & Gibala, 2011; Little et al., 2011). A protocol consisting of 10 x 1-minute cycling at ~60% of peak power interspersed with a one-minute recovery between intervals induced improvements in muscle oxidative capacity (Hood et al., ahead of print). This intensity elicited ~80% of heart rate reserve (HRR) after the first completed interval and ~95% of HRR after the final interval. Participants completed six of these training sessions over two weeks. Protein contents of CS (31%) and COX IV (39%) and GLUT4 (~260%) content increased post-training. PGC1-α protein increased 56% while RIP140 protein content was not affected by training. Insulin sensitivity was improved by ~35% as estimated using the insulin sensitivity index (ISI) homeostasis model assessment (HOMA).

Not many SIT studies have examined diseased samples, particularly those with type-2 diabetes. Little and colleagues (2011) investigated the effects of practical SIT on glucose regulation and skeletal muscle metabolic capacity in eight patients with type-2 diabetes. The sessions were modified so that the intervals (10 x 60-s of cycling) elicited ~90% maximal heart rate. Work:recovery ratio was 1:1. Participants completed six sessions in two weeks. The results regarding glucose regulation were favorable. Post-intervention, average 24-hour blood glucose concentration was reduced from 7.6 ± 1.0 to 6.6 ± 0.7 mmol/L. The sum of the 3-hour postprandial areas under the glucose curve for breakfast, lunch, and dinner was significantly reduced post-training. These findings suggest that practical SIT can induce favorable health benefits in a diseased population.

While low-volume, high-intensity training has been shown to produce many positive physiological benefits, its impact on perceptual responses is currently speculative (Coyle, 2005; Hawley & Gibala, 2009). This understanding is important because perceptual responses play a large role in the ability and desire for individuals to comply with the high-intensity inherent to interval training. The impact of high-intensity interval training may be best examined through the conceptual framework of the dual-mode model (Ekkekakis 2003).

Dual-Mode Model

The relationship between the intensity of exercise and the associated affective responses has received considerable attention in exercise psychology. It was long thought that this relationship exhibited an inverted-U curve. According to this thinking, exercise intensity should not be too high nor too low but rather needed to fall somewhere in-between to elicit the optimal affective benefits. However, one major problem that has been pointed out with this theory is that it fails to account for inter-individual differences (Ekkekakis, Hall & Petruzello, 2005)

A review by Ekkekakis and Petruzzello (1999) uncovered two methodological shortcomings in the literature dealing with the relationship between exercise intensity and affect. One cause for confusion was the false assumption that any changes to affect during exercise would be linear from pre- to post-exercise. This led to the neglect of measuring affective responses during exercise and would have veiled any dose-response relationship that might have occurred between intensity and affect. The second issue has to do with the classification of exercise using ambiguous terms such as *light, moderate,* or *vigorous* without any concrete delineation as to what they entail. In order to stimulate new research into the relationship between exercise intensity and affect while allowing for inter-individual variability and clearly defining exercise intensities, Ekkekakis (2003) proposed the dual-mode model.

According to the dual-mode model, affective responses to exercise are a continuous interplay between cognitive processes (e.g. exercise goals) and interoceptive cues (e.g. physiological responses) (Ekkekakis, 2003). The influence of these two factors varies depending on the intensity of the exercise. There are three specific domains of exercise intensity to be considered: moderate, heavy and severe (Ekkekakis et al., 2005).

Moderate intensity corresponds to exercise below lactate threshold, when aerobic metabolism is the predominant source of energy and a physiological steady state can be maintained. The expected affective response in this range of intensity is one of pleasure, with little variation between individuals. Ekkekakis and colleagues (2005) believed the influence of cognitive factors would play a small part in driving affect in this range of intensity. It is hypothesized that activity in this domain is adaptive, and thus there may be some mechanism that 'rewards' the action by increasing or maintaining pleasure (Ekkekakis et al., 2005).

Heavy exercise, the second range of intensity of concern, is that which encompasses the lactate threshold to the maximal work rate at which lactate can be stabilized (Ekkekakis et al., 2005). Physical activity in this range cannot be maintained indefinitely, but it is possible to work at this intensity for a period of time. The inter-individual variability is high, as cognitive factors have a very strong influence in this domain. Goal achievement, self-efficacy, and personality characteristics will drive affect during exercise at this intensity.

The third and final domain is termed severe intensity. This range begins when lactate can no longer be stabilized and continues to maximal exercise capacity. Exercise at severe intensity relies heavily on the limited anaerobic metabolism to meet energy needs. Physical activity at this work rate cannot be maintained without depleting energy stores and threatening the body. Interoceptive cues (physiological responses to exercise) are believed to drive affect down during exercise in the severe intensity range. Ekkekakis and colleagues (2005) believe that affective responses act as a mechanism through which the body protects itself from dangers associated with prolonged exposure to high-intensity exercise (e.g. muscles going into rigor) for self-preservation and is responsible for regulating the human ability to work in this domain.

Ekkekakis and his colleagues (2005) suggested that intensities which induce a homogenous response reflect primarily subcortical mechanisms and involve relatively simple sensory cues (Ekkekakis, 2003), explaining for the apparent lack of cognitive mediation. This occurs both at the moderate and severe intensities discussed earlier. Physical activity at a moderate intensity is believed to be adaptive, while activity in the severe domain is maladaptive. The variability in affective responses in the heavy domain of intensity reflects primarily cortical mechanisms, thus the strong influence of cognitive factors. Physical activity in this range may not be consistently adaptive nor maladaptive (Ekkekakis et al, 2005).

As was intended, the dual-mode model has stimulated continuing research examining the relationship between exercise and affect. Studies have begun to investigate in-task affective responses based on the exercise intensity's relationship to the individual's VT. One way to test the dual-mode model is to assess affect during incremental exercise tests. Using this method, two groups of 30 healthy, young men and women showed a consistent pattern in affective responses during two different incremental treadmill exercise protocols (Ekkekakis, Hall & Petruzzello 2004). The authors noted a surge of displeasure once the intensity increased to VT, which was used as an index of the transition from aerobic metabolism to an increased input from anaerobic energy stores.

Several studies have examined the differences in affective responses to exercise above and below VT. One such study had 12 sedentary males complete three 20-minute exercise trials (Parfitt, Rose & Burgess, 2006). One trial was conducted above-LT (at 4 mmol/l), one below-LT (at 2 mmol/l), while the intensity of one trial was self-selected. Lactate levels did not significantly change over the 20-minute exercise periods. Affective response was less positive during the above-LT condition in comparison with the other two conditions. A great amount of variability in affective responses was seen in the below-LT condition with 42% either remaining unaltered or declining. The above-LT condition induced a more homogenous response, 83% reported declines in affect.

Rose and Parfitt (2007) conducted a similar study but used a sedentary female (n=19) sample and included an at-LT condition. The intensities for the different conditions were based on an incremental blood lactate test. At-LT was defined as when lactate breakpoint occurred, the intensity used for below-LT represented two minutes before lactate began to increase, and the intensity for above-LT represented when the second lactate breakpoint occurred. Defining intensities in this regard allowed a more individualized protocol, as opposed to choosing an arbitrary level of blood lactate. Again, affect was least positive during the above-LT condition. Affective responses in the at-LT and below-LT conditions did not differ. Both conditions displayed high variability as well, with the vast majority reporting a decline in affect during the above-LT condition.

A study by Lind, Ekkekakis & Vizou (2008) demonstrated that a minor increase above self-selected intensity pushed the workload above VT, resulting in a decline in affective response. Twenty-five sedentary women completed two 20-minute sessions of exercise, the initial bout at a self-selected intensity while the follow-up session speed was increased by 10% of the self-selected. Participants were allowed to adjust the intensity of the initial exercise session as desired at 5, 10 and 15 minutes. The intensity chosen was ~98% VT while the exercise intensity which was imposed reached ~115% VT. Affect did not change significantly during the self-selected intensity bout; however, affect continuously declined during the imposed intensity condition and was significantly decreased at minutes 5 and 15.

The results of a recent study suggest that exercise below VT might induce variability in affect rather than a homogenous response of pleasure. Ekkekakis, Hall and Petruzzello (2008) had 30 healthy, active participants (16 men) completed three exercise trials (20% below-VT, at-VT and 10% above-VT) in a randomized, counterbalanced order. While affective valence did not significantly decrease in the below- or at-VT conditions, there was a significant decline in affect during the above-VT exercise session as 80% of the sample reported reduced pleasure. Interestingly, 43% reported a decline in affect during the below-VT condition. The dual-mode model would hypothesize that exercise at this intensity would have produced a mostly homogenous increase in affective valence.

Markowitz and Arent (2010) demonstrated that exercise conducted just 5% above-LT can worsen affect in both sedentary and active individuals compared with exercise 5% below-LT and at-LT. Differing from most of the literature testing the dual-mode model, this study utilized the Activation Deactivation Adjective Checklist and State-Trait Anxiety Inventory to examine affect from a categorical rather than dimensional perspective. Despite this, the results show support for the dual-mode model.

Solomon's Opponent-process Theory of Acquired Motivation

While the dual-mode model provides a framework for the dose-response relationship of intensity and affect during exercise, Solomon's (1980) opponent-process theory provides a conceptual model for the affective responses following exercise. The displeasure often seen with exercise that occurs in either the heavy or severe domains of intensity is often reversed immediately following exercise. According to this Solomon's opponent-process theory, an unconditioned stimulus elicits what is called an a-process, which in turn triggers a b-process. The a-process carries with it a particular affective quality (pleasure or displeasure). The b-process "functions to oppose and suppress the affective or hedonic state initially generated by the onset of the a-process" (p. 699) and has a "relatively long latency, slow buildup, and slow delay" (p. 699). At the outset of the stimulus, the affective quality of the a-process dominates. When the categorical stimulus is removed, the a-process quickly subsides, resulting in the affective quality of the b process to be revealed. The a- and b-processes are put into a summing device that determines in which affective state the individual will be at any point in time.

With the presentation of high-intensity exercise (e.g. above VT) as the stimulus, Ekkekakis and colleagues (2005) argue that the a-process is driven by metabolic acidosis and therefore has a negative valence while the b-process is driven by the release of central opioids which have a positive valence. Solomon (1991) postulated that a “critical intensity” (p. 339) must be reached in order for the opponent-processes to be generated. Ekkekakis and colleagues (2005) suggest that this critical intensity during exercise seems to coincide with the LT and VT as it has been observed that the release of endogenous opioids occurs at these indices of exercise (Sgherza et al., 2002).

Chapter 3: Methods

Participants

Ten participants (5 male, 5 female) with a mean age of 21.6 ± 2.4 (range = 19-27) participated in the study. Mean V_{O2peak} was 39.9 ± 6.2 (range = 28.7-49.6). Nine out of ten participants reached nine or above on the CR-10 RPE scale during the maximal exercise test (mean = 9.5, range = 8-10). Nine out of ten participants reached 90% age-predicted maximum heart rate (mean = 188, low = 173, high = 204). Ten out of ten participants reached at least 1.10 RER (mean = 1.27, range = 1.14-1.41). VT occurred at a mean of 65.6% of participants' VO_{2peak} (range = 55-82). Mean peak power output was 232.5 W ± 61.1 (range = 160-325). Participants were low-risk and had no symptoms (cardiovascular, pulmonary, metabolic, or orthopedic) that would preclude safe participation in an exercise training program. Medical screens were conducted by a physician's assistant prior to the commencement of exercise.

Instruments

Following exercise, ratings of perceived enjoyment were measured by the 18-item Physical Activity Enjoyment Scale validated by Kendzierski and DeCarlo (1991). Each item is rated on a 7-point bipolar scale. Each item of the scale ranges from 1 to 7. Some items are reverse-scored. A representation of this scale can be found in Appendix A.

Affective valence was measured using the single-item, 11-point Feeling Scale (FS) (Hardy and Rejeski, 1989). The scale ranges from -5 to +5. Anchors are given at 0 (Neutral) and all odd integers, ranging from “Very Bad” at -5 to “Very Good” at +5. The FS allows the measure of affective response from a dimensional perspective. Because it is a single-item measure, it allows for a minimal burden on participants to respond as they exercise. A representation of this scale can be found in Appendix B.

Ratings of perceived exertion during the maximal exercise test were measured via the single-item, 11-point CR-10 scale (Borg, 1998). The scale ranges from 0 to 10. Anchors are given at every integer except 6, 8, and 9, ranging from “Rest” at 0 to “Maximal” at 10. A representation of this scale can be found in Appendix C.

Ratings of perceived enjoyment during exercise were measured via the single-item, 7-point Exercise Enjoyment Scale (ES) (Stanley, Williams & Cummings, 2009). The scale ranges from 1 to 7. Anchors are given at every integer, ranging from “Not at all” at 1 to “Extremely” at 7. Because it is a single-item measure, it allows for a minimal burden on participants to respond as they exercise. A representation of this scale can be found in Appendix D.

Equipment

All exercise was performed on an electronically-braked Lode cycle ergometer (Groningen, The Netherlands). All testing took place in a laboratory setting, allowing for environmental conditions to be the same for all participants. Heart rate was monitored using a Polar heart rate monitor (Polar, USA). Expired gases for a VO_{2peak} test were collected and analyzed using a Vacumed (Ventura, CA) metabolic cart. Height and weight of the participants was measured to the nearest 0.5 inch and 0.5 pound, respectively, on a Health' O Meter Professional scale. All data was collected and stored on an iPad 2. Statistical analyses were completed using SPSS 20.0.

Procedures

Participants completed six study visits. All exercise sessions were completed in the Health and Exercise Science Lab on the campus of the University of South Florida in Tampa, Florida. Participants were asked to refrain from ingesting caffeine and alcohol for the three hours prior to their visit and participating in strenuous exercise for the 24 hours prior to each session. They were asked to wear comfortable exercise clothes and sneakers or walking shoes for the exercise sessions.

First visit. Participants were given an informed consent document and were given time to ask any questions they had about the study. Once any questions were answered, the informed consent document was collected. Height and weight were measured and recorded. The participant completed a health history form that aided the physician in conducting the medical screening. The physician performed a physical exam to ensure the ability of the participant to take part in the study safely. The participant also received a form with pre-exercise instructions for future visits.

Second visit. The participant completed a ramp-style VO_{2peak} test on the cycle ergometer during the second visit. Upon arrival, the participant was given the iPad 2 with descriptions and examples of all of the measures which were to be used throughout the study. This served as a manipulation check and the participant was allowed to ask questions about any of the items to ensure understanding. Once completed, baseline heart rate and blood pressure were recorded.

The participant was then asked to move to the cycle ergometer and had the maximal exercise test explained to them in detail. The protocol was individualized according to standardized formulae for both men and women (Wasserman, Hansen, Sue, Casaburi & Whipp, 1999). Workload changes occurred every minute, and were ~15W for females and ~25W for males. The test was terminated when volitional exhaustion occurred or when the participant could not sustain 30 rpm. Expired O_2 and CO_2 concentration was analyzed using a Vacumed metabolic cart (Ventura, CA). VO_{2peak} was identified as the largest amount of oxygen consumed per minute during the test. VT was identified by visual inspection of ventilatory equivalents for O_2 and CO_2. Heart rate was monitored continuously throughout the test. Upon termination of the test the participant was allowed to cool down for as long as they liked. Once the participant left the cycle ergometer, they were asked to sit quietly for 10 minutes before a final heart rate and blood pressure were recorded.

Visits three through six. The final four visits consisted of the exercise sessions. The order of the sessions was counterbalanced. Two sessions of interval exercise and two sessions of continuous exercise were completed. All sessions were 20 minutes in length. Each 20-minute session was preceded by a two-minute warm-up and followed by a two-minute cool-down. Warm-ups were identical among all trials. Minute one of the warm-up was performed at 1/3 of the participant's prescribed exercise intensity for that session, minute two was performed at 2/3 of the prescribed intensity. The first minute of cool-down for the continuous trials was performed at 2/3 of the participant's prescribed exercise intensity for that session, minute two of the cool-down was performed at 1/3 of the prescribed intensity. Exercise for both interval sessions ended with recovery intervals at 10% of the exercise interval intensity for that session. Therefore, the cool-down for the interval sessions remained at the intensity of the recovery intervals. Both interval sessions consisted of ten one-minute exercise intervals interspersed with ten one-minute recovery intervals. One interval session had exercise intervals at 20% above VT (Interval-Severe) while the other had exercise intervals conducted at VT (Interval-Heavy). The intensity of one continuous session was at VT (Continuous-Heavy) while the other was 20% below VT (Continuous-Moderate).

Pre-exercise. At the outset of each experimental trial, baseline affect, heart rate, and blood pressure were recorded. The participant then had the exercise session to follow explained in detail. The participant was then asked to complete a pre-exercise survey on the iPad 2. This survey recorded the participant's current affect (FS). Baseline heart rate and blood pressure was then recorded. The participant was then asked to move to the cycle ergometer and commence the exercise session.

During exercise. Blood pressure was recorded during the warm-up and cool-down. Heart rate was recorded during the warm-up, cool-down, and every two minutes during the trial. During the two interval sessions, FS and enjoyment were recorded during the final fifteen seconds of every second exercise interval as well as every second recovery interval. These time-points occur at the end of minutes 3, 4, 7, 8, 11, 12, 15, 16, 19, and 20 of exercise. During the two continuous sessions, FS and enjoyment were recorded during the final fifteen seconds of minutes 3, 7, 11, 15, and 19 of exercise following the warm-up.

Post-exercise. Following the cool-down for each trial, the participant was asked to have a seat and complete a post-0 exercise survey on the iPad 2. The survey recorded the participant's current FS and the participant's perceived enjoyment of the session via the 18-item PACES. When the participant completed the post-0 survey, the iPad 2 was collected by a member of the study staff. These steps were repeated for the post-10 survey (identical to post-0) ten minutes after the exercise session was completed. Following the completion of the post-10 survey, a final blood pressure and heart rate were recorded.

Statistical Analyses

Data were analyzed using the Statistical Package for the Social Sciences (SPSS) 20.0. The criterion for significance was set at $p < 0.05$. A descriptive analysis of the sample was completed. A repeated measures analysis of variance (RMANOVA) was run to note whether there were differences in FS or enjoyment among the four conditions. Follow-up dependent t-tests were used to locate where the differences occurred.

Chapter 4: Results

Enjoyment

Perceived enjoyment was significantly greater at all five time-points during the exercise bout for Continuous-Moderate and Interval-Heavy than Continuous-Heavy ($p < 0.05$). Enjoyment during Interval-Severe was significantly greater ($p < 0.05$) than the Continuous-Heavy condition at the final time-point during exercise, and had large effect sizes toward significance during the second (ES = 0.67, $p > 0.10$), third (ES = 0.70, $p < 0.10$), and fourth (ES = 0.64, $p < 0.10$) in-task measurement of enjoyment. Means and standard deviations of enjoyment are highlighted in Table 1.

Post-0 enjoyment was significantly greater following the Continuous-Moderate ($p < 0.05$) and Interval-Heavy ($p < 0.05$) conditions than the Continuous-Heavy condition. Differences in enjoyment at post-10 for the Continuous-Moderate (ES = 0.60, $p < 0.10$) and Interval-Heavy (ES = 0.39, $p < 0.10$) compared to Continuous-Heavy trended toward significance. Post-0 and Post-10 enjoyment tended to be greater following the Interval-Severe compared to the Continuous-Heavy condition (ES= 0.44, $p > 0.10$; ES = 0.41, $p > 0.10$, respectively). H_{A1} stated that there would be differences among the four exercise trials. Due to the statistical differences between the conditions, we accept $H_{A1.}$

TABLE 4.1. Mean Ratings of Enjoyment with Standard Deviations

Time-point	Continuous-Heavy	Continuous-Moderate	Interval-Heavy	Interval-Severe
Exercise 1	3.3 ± 1.1	4.1 ± 1.0*	4.2 ± 1.1*	3.3 ± 1.1^
Recovery 1			4.6 ± 1.4	4.3 ± 1.1
Exercise 2	2.8 ± 0.9	3.9 ± 1.0*	4.2 ± 1.3*	3.5 ± 1.2
Recovery 2			4.5 ± 1.4	4.3 ± 0.8
Exercise 3	2.8 ± 1.0	3.8 ± 0.9*	3.8 ± 1.1*	3.6 ± 1.3
Recovery 3			4.2 ± 1.0	4.4 ± 0.8
Exercise 4	2.8 ± 0.9	3.7 ± 1.1*	3.8 ± 1.1*	3.5 ± 1.3
Recovery 4			4.5 ± 1.0	4.2 ± 1.0
Exercise 5	2.5 ± 1.1	3.9 ± 1.0*	4.1 ± 1.3*	3.6 ± 1.4*
Recovery 5			4.4 ± 0.8	4.2 ± 1.0
Post-0	85.6 ± 12.5	94.0 ± 11.1*	95.9 ± 16.8*	92.0 ± 16.9
Post-10	85.0 ± 16.1	90.8 ± 13.5	95.3 ± 18.3	91.4 ± 15.2

Exercise 1 – Recovery 5 were assessed using EES. Post-0 and Post-10 were assessed using PACES. Exercise 1-5 were assessed the final 15s of minutes 3, 7, 11, 15, and 19. Recovery 1-5 were assessed the final 30s of minutes 4, 8, 12, 16, and 20.
* denotes significantly different from Continuous-Heavy.
^ denotes significantly different from Continuous-Moderate.

Affective Valence

Affective responses among groups. In-task affect was significantly greater across all five time-points during the Continuous-Moderate ($p < 0.05$) and Interval-Heavy ($p < 0.05$) conditions than the Continuous-Heavy condition. Post-0 affect following the Continuous-Moderate condition was significantly greater compared with the Continuous-Heavy condition ($p < 0.05$). Post-10 affect following the Interval-Heavy condition was significantly greater compared with the Interval-Severe condition ($p < 0.05$). Pre-exercise affect was significantly greater in the Continuous-Moderate condition than the Continuous-Heavy condition ($p < 0.05$). The means and standard deviations for affective responses before, during, and after all exercise conditions are depicted in Table 2.

Affective responses within groups. Affect declined during all four conditions. However, at no time-points during or following exercise was the change in affect significant from pre-exercise assessments. During Continuous-Heavy, the decline in affect did elicit large effect sizes but did not reach significance at in-task time-points two ($ES = 0.55$, $p > 0.10$), three ($ES = 0.88$, $p > 0.10$), four ($ES = 0.60$, $p > 0.10$), and five ($ES = 0.52$, $p > 0.10$). A decline in affect was also observed during Continuous-Moderate at the final four time-points ($ES = 0.52$, $p > 0.10$; $ES = 0.53$, $p > 0.10$; $ES = 0.63$, $p > 0.10$; $ES = 0.70$, $p > 0.10$, respectively). The decline in affect during Interval-Heavy had large effect sizes but did not reach significance at time-points three ($ES = 0.62$, $p > 0.10$), four ($ES = 0.60$, $p > 0.10$), and five ($ES = 0.69$, $p = 0.10$). The decline in affect during the Interval-Severe had a large effect size but did not reach significance at the fifth and final time-point during exercise ($ES = 0.55$, $p > 0.10$). H_{A2} stated that there would be a steady decline in affect during the Interval-Severe condition. Due to the lack of statistical significance of the declines within that trial, we are forced to reject H_{A2}.

Affect assessed during recovery intervals was always higher than the immediately preceding exercise interval during both discontinuous bouts. However, none of these increases reached statistical significance and effect sizes were not large. H_{A3} stated that affect would increase back to baseline during the recovery intervals of the Interval-Severe condition. Due to the lack of a statistically significant increase from the exercise to recovery intervals, we reject H_{A3}.

TABLE 4.2. Mean Ratings of Affect with Standard Deviations

Time-point	Continuous-Heavy	Continuous-Moderate	Interval-Heavy	Interval-Severe
Pre1	2.1 ± 2.1	3.4 ± 1.6*	3.2 ± 1.4	3.1 ± 1.3
Pre2	2.2 ± 2.0	3.4 ± 1.6*	3.2 ± 1.4	2.6 ±1.4^
Exercise 1	1.6 ± 1.2	2.9 ± 1.2*	2.9 ± 1.4*	2.0 ± 1.2^#
Recovery 1			3.5 ± 1.5	2.7 ± 1.1
Exercise 2	1.3 ± 1.3	2.7 ± 1.1*	2.9 ± 1.5*	2.0 ± 1.5
Recovery 2			3.2 ± 1.4	2.4 ± 1.2
Exercise 3	0.8 ± 1.2	2.5 ± 1.8*	2.3 ± 1.5*	2.2 ± 1.8*
Recovery 3			2.7 ± 1.2	2.6 ± 1.4
Exercise 4	1.1 ± 1.7	2.0 ± 2.2*	2.3 ± 1.6*	1.8 ± 2.0
Recovery 4			2.7 ± 1.3	2.3 ± 1.6
Exercise 5	1.1 ± 2.2	2.0 ± 2.4*	2.0 ± 2.1*	1.6 ± 2.2
Recovery 5			2.2 ± 1.8	2.0 ± 1.3
Post-0	2.0 ± 2.2	3.2 ± 1.2*	2.9 ± 1.5	2.3 ± 1.6
Post-10	2.7 ± 1.3	2.6 ± 1.6	3.4 ± 1.4	2.5 ± 1.4#

Exercise time-points 1-5 were assessed the final 15s of minutes 3, 7, 11, 15, and 19.
Recovery time-points 1-5 were assessed the final 30s of minutes 4, 8, 12, 16, and 20.
* denotes significantly different from Continuous-Heavy.
^ denotes significantly different from Continuous-Moderate.
# denotes significantly different from Interval-Heavy.

Chapter 5: Discussion

Interval training has been highlighted in exercise physiology research recently as a possible time-efficient (Gibala, 2007) and more enjoyable (Bartlett et al., 2011) alternative to traditional continuous exercise. However, no research has been done investigating the perceptual responses to interval training which may impact the adherence to such exercise. This experiment was designed to assess affect and enjoyment during and following continuous and interval-style exercise matched for duration. The intensities chosen were reflective of the three domains of the dual-mode model: moderate, heavy, and severe. This study represents an initial effort to extend the dual-mode model beyond continuous exercise to interval training.

Enjoyment

Both Continuous-Moderate and Interval-Heavy elicited significantly higher ratings of in-task enjoyment throughout the entire exercise session than Continuous-Heavy. The work completed during Continuous-Heavy was greater than both Continuous-Moderate and Interval-Heavy, but it is interesting to note that as early as the first assessment during exercise (3:00 into exercise) the differences in enjoyment were significant and persisted to the end of exercise. Participants may have enjoyed Continuous-Moderate more than Continuous-Heavy due to the lower intensity and perception that the Continuous-Moderate was easier. The exercise intensity during Interval-Heavy was constantly fluctuating between the same intensity as Continuous-Heavy and light recoveries (10% of exercise intensity). These light recoveries may have allowed participants to enjoy the exercise more for a couple of reasons. They may have allowed for recovery metabolically so that increased lactate did not create a discomfort during exercise as may have happened during Continuous-Heavy. Alternating workloads throughout a session may also be perceived as less monotonous than exercising at a single intensity for a similar duration.

Enjoyment during Interval-Severe was consistently higher than Continuous-Heavy, but only reached significance at the final exercise time-point (19:00). Since the effect sizes were large, particularly towards the end of exercise, this was probably due to inadequate power. At the first assessment during exercise, enjoyment was the same between the two trials. But a difference began to appear four minutes later at the second assessment (7:00 into exercise) and continued to the end of exercise. Again, more work was completed during Continuous-Heavy, but the exercise intervals performed during Interval-Severe were performed at higher intensity which approximated 90% of peak power elicited during the maximal exercise test. Again, it is difficult to definitively state why enjoyment was higher when performing intervals, but one possibility is that the variety of performing high-intensity work interspersed with low-intensity recoveries rids the workout of the possible monotony that may be associated with exercising continuously for the same period of time at an unchanging intensity. This supposed 'novelty' of interval training contributing to higher ratings of enjoyment may lose its potency if the participant regularly performs interval training. No research to date exists regarding this possibility.

There were almost no significant differences in enjoyment assessed during exercise among Continuous-Moderate, Interval-Heavy, and Interval-Severe. Enjoyment was significantly greater at the first assessment during Interval-Heavy than Interval-Severe, but all other time-points were not different between these two trials. No significant differences existed between Continuous-Moderate and Interval-Severe. Enjoyment assessed at the first time-point of Interval-Severe was the lowest recorded during that trial. It could be that the initial few intervals of high intensity were sharp interruptions to the homeostasis of the bodily environment, and were thus less enjoyable.

Mirroring the in-task assessments, post-0 enjoyment was greater following Continuous-Moderate and Interval-Heavy compared with Continuous-Heavy. Enjoyment at post-10 was slightly reduced after Continuous-Moderate and Interval-Heavy, and the significance was lost between those two trials and Interval-Heavy. The effect sizes were still relatively large, and thus the loss of significance was most likely due to a lack of power. Enjoyment assessed following Interval-Severe was higher (although not significantly) than Continuous-Heavy as well, but not different from the other two trials., Bartlett et al. (2011) found similar results using running as a modality. In that study, ratings of perceived enjoyment after exercise were higher following interval running compared with continuous running. The two protocols were matched for average intensity, duration, and total work completed. There were differences between the interval protocol used by Bartlett et al. (2011) and the one utilized in the present study. The duration (non-inclusive of warm-up and cool-down) of their protocol was 36 minutes, 16 minutes longer than in the present study. Our study used 10 x 1-minute design, while Bartlett et al. (2011) used a 6 x 3-minute design. The overall results for enjoyment in this study indicate that continuous exercise well below the VT and interval training at VT and well above VT produce more enjoyment than continuous exercise proximal to VT.

Affect

In-task affect. The dual-mode model proposes that exercise at an intensity above VT will induce negative changes in affect. It has been suggested that exercising at such high intensities will reduce the likelihood of exercise adherence, as people will pursue what gives them pleasure and avoid what brings displeasure (Ekkekakis 2003). The most notable finding in this study is that in-task affect was significantly greater during Continuous-Moderate and Interval-Heavy compared with Continuous-Heavy at all time-points assessed. This is in contrast with Rose and Parfitt (2007) who did not find a difference in the affective response of 19 sedentary women between exercise trials performed at lactate threshold and below lactate threshold. It is interesting to note that breaking up the 20 minutes of exercise at VT into 60-second exercise and recovery intervals kept affect significantly higher, even in the early stages of exercise.

Affect at the first in-task assessment of Interval-Severe was significantly lower than Continuous-Moderate and Interval-Heavy. The reason for this may be similar to the reasons given earlier in the discussion of enjoyment regarding the same trials and exercise time-point. The extreme increase from the warm-up to the first few exercise intervals above VT may be responsible for this initial lower affect. These differences washed out during the rest of the exercise session.

Affect assessed during the third time point (11:00 into exercise) of Interval-Severe was significantly higher compared with Continuous-Heavy. All other time-points measured in-task were also higher during Interval-Severe, but did not reach significance. Considering the large effect sizes, it is possible that this was also due to a lack of power. This would be a notable finding, because the dual-mode model predicts that exercise above VT causes a homogenous decline in affect, whereas an intensity that approximates VT would elicit inter-individual variability. When examining continuous exercise sessions [one above lactate threshold (4 mmol/l) and one below lactate threshold (2mmol/l)], Parfitt, Rose & Burgess (2006) found that the above lactate threshold trial yielded significantly lower affect. Results from a study by Ekkekakis, Hall & Petruzello (2008) showed that continuous exercise 10% above VT induced a significant decline in affect as early as the sixth minute of exercise. However, we found that when exercise above VT is performed in 60-second intervals, affect is not significantly lower even when compared to exercise below VT, but this could be due to a lack of power. In the current study, continuous exercise at VT produced a greater (although not significant at all time-points) decline in affect, while performing intervals well above VT ‘preserved’ affect throughout exercise.

Post-exercise affect. Exercise generally elicits an increase in post-exercise affect back to baseline values or higher (Parfitt, Rose & Burgess, 2006; Ekkekakis, Hall & Petruzello, 2008). However, because affect did not significantly decline from baseline during exercise in the present study, no increase took place from in-task to post-task.

Despite this, each trial did have an increase in affect from the end of exercise to post-exercise. This is also in contrast to a study by Markowitz & Arent (2010) which demonstrated that participants who completed 20 minutes of exercise at 5% above lactate threshold needed 30 minutes of recovery to have affect recover to baseline. Our study suggests that performing intervals as high as 20% above VT does not negatively impact post-exercise affect.

Continuous-Moderate produced a significantly higher post-0 affect than Continuous-Heavy. This finding goes against what the opponent-process theory of affect (Solomon, 1980) would predict. The model would suggest that since the intensity of the stimulus in Continuous-Heavy was stronger or higher than that of Continuous-Moderate, the associated rebound in affect once the stimulus was removed would be greater following Continuous-Heavy. This difference was no longer significant at post-10. A similar instance occurred at post-10 between the two interval trials. Affect did not increase following Interval-Severe compared with Interval-Heavy as would be expected based on Solomon's (1980) opponent-process theory of affect.

Conclusions

The primary findings of this study were two-fold: 1) that Continuous-Moderate and Interval-Heavy were enjoyed more than Continuous-Heavy and 2) affect was greater during Continuous-Moderate and Interval-Heavy than Continuous-Heavy. The results of this study help to lay the foundation for future investigations regarding perceptual responses during interval training, provide an initial test of the dual-mode model utilizing interval training, and compare perceptual responses to various interval and continuous exercise protocols matched for duration.

Differences between enjoyment and affect during Interval-Severe and Continuous-Heavy may reach significance with the addition of participants. Such results would provide support for the idea that utilizing interval training to perform bouts of exercise well above VT may preserve affect despite the high intensity. This, coupled with greater enjoyment (Bartlett, 2011) during interval-style training may lead to increased adherence to exercise (Williams et al., 2008). Future acute studies may wish to manipulate the variables that make up interval training (e.g. exercise interval length, exercise interval intensity, recovery length, recovery intensity) to create more optimal protocols in an attempt to increase adherence while maintaining positive physiological adaptations. Training studies would allow researchers to see how repeated exposure to high-intensity workouts impact participants' affect and enjoyment of such exercise. Finally, this study utilized a sample of healthy, college-age adults. Future studies should use samples that reflect the targets of typical physical activity interventions.

Chapter 6: References Cited

Astorino, TA, Phillips, RP, Roberson, DW, Jurancich, M, Lewis, R, McCarthy, K & Trost, E. (2011). Adaptations to high-intensity training are independent of gender. European Journal of Applied Physiology, 111, 1279-1286.

Babraj, J.A., Vollaard, N.B.J., Keast, C., Guppy, F.M., Cottrell, G. & Timmons, J.A. (2009). Extremely short duration high intensity interval training substantially improves insulin action in young health males. BMC Endocrine Disorders, 9(3), doi: 10.1186/1472-6823/9/3

Bartlett, J.D., Close, G.L., MacLaren, D.P.M., Gregson, W., Drust, B. & Morton, J.P. (2011). High-intensity interval running is perceived to be more enjoyable than moderate-intensity continuous exercise: implications for exercise adherence. Journal of Sport Sciences, 29(6), 547-553.

Borg, G. (1998). *Borg's Perceived Exertion and Pain Scales*. Champaign, IL: Human Kinetics.

Burgomaster, K.A., Hughes, S.C., Heigenhauser, J.F., Bradwell, S.N. & Gibala, M.J. (2005). Six sessions of sprint interval training increases muscle oxidative potential and cycle endurance capacity in humans. Journal of Applied Physiology, 98, 1985-1990.

Burgomaster, K.A., Heigenhauser, G.J.F. & Gibala, M.J. (2006) Effect of short-term sprint interval training on human skeletal muscle carbohydrate metabolism during exercise and time-trial performance. Journal of Applied Physiology, 100, 2041-2047.

Burgomaster, K.A., Cermak, N.M., Phillips, S.M., Benton, C.R., Bonen, A. & Gibala, M.J. (2007). Divergent response of metabolite transport proteins in human skeletal muscle after sprint interval training and detraining. American Journal of Physiology- Regulatory, Integrative, and Comparative Physiology, 292, 1970-1976.

Burgomaster, K.A., Howarth, K.R., Phillips, S.M., Rakobowchuk, M., MacDonald, M.J., McGee, S.L., & Gibala, M.J. (2008). Similar metabolic adaptations during exercise after low volume sprint interval and traditional endurance training in humans. Journal of Physiology, 586(1), 151-160.

Coyle, E.F. (2005). Very intense exercise-training is extremely potent and time efficient: a reminder. Journal of Applied Physiology, 98, 1983-1984. Doi:10.1152/japplphysiol.00215.2005

Ekkekakis, P. & Petruzzello, S.J. (1999). Acute aerobic exercise and affect. Sports Medicine, 5, 337-374.

Ekkekakis, P. (2003). Pleasure and displeasure from the body: perspectives from exercise. Cognition and Emotion, 17(2), 213-239.

Ekkekakis, P., Hall, E.E. & Petruzzello, S.J. (2004). Practical markers of the transition from aerobic to anaerobic metabolism during exercise: rationale and a case for affect-based exercise prescription. Preventive Medicine, 38, 149-159.

Ekkekakis, P., Hall, E.A. & Petruzzello, S.J. (2005). Variation and homogeneity in affective responses to physical activity of varying intensities: an alternative perspective on dose-response based on evolutionary considerations. Journal of Sports Sciences, 23(5), 477-500.

Ekkekakis, P., Hall, E.E. & Petruzzello, S.J. (2008). The relationship between exercise intensity and affective responses demystified: to crack the 40-year-old nut, replace the 40-year-old nutcracker! Annals of Behavioral Medicine 35, 136-149.

Gibala, M.J. (2007). High-intensity interval training: a time-efficient strategy for health promotion? Current Sports Medicine Reports, 6, 211-213.

Gibala, M.J., Little, J.P., van Essen, M., Wilkin, G.P., Burgomaster, K.A., Safdar, A., Raha, S., & Tarnopolsky, M.A. (2006). Short-term sprint interval versus traditional endurance training: similar initial adaptations in human skeletal muscle and exercise performance. Journal of Physiology, 575(3), 901-911.

Gibala, M.J., McGee, S.L., Garnham, A.P., Howlett, K.F., Snow, R.J. & Hargreaves, M. (2008). Brief intense interval exercise activates AMPK and p38 MAPK signaling and increases the expression of PGC-1α in human skeletal muscle. Journal of Applied Physiology, 106, 929-934.

Hawley, J.A. & Gibala, M.J. (2009). Exercise intensity and insulin sensitivity: how low can you go? Diabetologia, 52, 1709-1713. Doi: 10.1007/s00125-009-1425-5

Hazell, T.J., MacPherson, R.E.K., Gravell, B.M. & Lemon, P.W.R. (2010). 10 or 30-s sprint interval training bouts enhance both aerobic and anaerobic performance. European Journal of Applied Physiology, 110, 153-160.

Hood, MS, Little, JP, Tarnopolsky, MA, Myslik, F & Gibala, MJ. (2011). Low-volume interval training improves muscle oxidative capacity in sedentary adults. Medicine & Science in Sports & Exercise, 43(10), 1849-1856.

Kilpatrick, M., Kraemer, R., Bartholomew, J., Acevedo, E., Jarreau, D. (2007). Affective responses to exercise are dependent on intensity rather than total work. Medicine & Science in Sports & Exercise, 39(8), 1417-1422.

Little, J.P., Gillen J.B., Percival, M., Safdar, A., Tarnopolsky, M.A., Punthakee, Z., Jung, M.E. & Gibala, M.J. (in press). Low-volume high-intensity interval training reduces hyperglycemia and increases muscle mitochondrial capacity in patients with type 2 diabetes. Journal of Applied Physiology. doi:10.1152/japplphysiol.00921.2011

Little, J.P., Safdar, A., Wilkin, G.P., Tarnopolsky, M.A. & Gibala, M.J. (2010). A practical model of low-volume high-intensity interval training induces mitochondrial biogenesis in human skeletal muscle: potential mechanisms. Journal of Physiology, 588(6), 1011-1022.

MacDougall, J.D., Hicks, A.L., MacDonald, J.R., McKelvie, R.S., Green, H.J. & Smith, K.M. (1998). Muscle performance and enzymatic adaptations to sprint interval training. Journal of Applied Physiology, 84, 2138-2142.

Markowitz, S.M. & Arent, S.M. (2010). The exercise and affect relationship: evidence for the dual-mode model and a modified opponent process theory. Journal of Sport & Exercise Psychology, 32, 711-730.

Niklas, P., Li, W., Jens, W., Nichail, T. & Kent, S. (2010). Mitochondrial gene expression in elite cyclists: effects of high-intensity interval exercise. European Journal of Applied Physiology, 110, 597-606.

Parfitt, G., Rose, E.A. & Burgess, W.M. (2006). The psychological and physiological responses of sedentary individuals to prescribed and preferred intensity exercise. British Journal of health Psychology, 11, 39-53.

Parra, J., Cadefau, J.A., Rodas, G., Amigo, N. & Cusso, R. (2000). The distribution of rest periods affects performance and adaptations of energy metabolism induced by high-intensity training in human muscle. Acta Physiologica Scandinavica, 169, 157-165.

Psilander,N., Wang, L., Westergren, J., Tonkonogi, M. & Sahlin, K. (2010). Mitochondrial gene expression in elite cyclists: effects of high-intensity interval exercise. European Journal of Applied Physiology, 110, 597-606.

Rakobowchuk, M., Tanguay, S., Burgomaster, K.A., Howarth, K.R., Gibala, M.J. & MacDonald, M.J. (2008). Sprint interval and traditional endurance training induce similar improvements in peripheral arterial stiffness and flow-mediated dilation in healthy humans. American Journal of Physiology – Regulatory, Integrative and Comparative Physiology, 295, 236-242.

Richards, J.C., Johnson, T.K., Kuzma, J.N., Lonac, M.C., Schweder, M.M., Voyles, W.F. et al. (2010). Short-term sprint interval training increases insulin sensitivity in healthy adults but does not affect the thermogenic response to beta-adrenergic stimulation. Journal of Physiology, 588(15), 2961-2972.

Rodas, G., Ventura, J.L., Cadefau, J.A., Cusso, R. & Parra, J. (2000). A short training programme for the rapid improvement of both aerobic and anaerobic metabolism. European Journal of Applied Physiology, 82, 480-486.

Rose, E.A. & Parfitt, G. (2007). A Quantitative analysis and qualitative explanation of the individual differences in affective responses to prescribed and self-selected exercise intensities. Journal of Sport & Exercise Psychology, 29, 281-309.

Sgherza, A.L., Axen, K., Fain, R., Hoffman, R.S., Dunbar, C.C. & Haas, F. (2002). Effect of naloxone on perceived exertion and exercise capacity during maximal cycle ergometry. Journal of Applied Physiology, 93, 2023-2028.

Solomon, R.L. (1980). The opponent-process theory of acquired motivation. American Psychologist, 35(8), 691-712.

Solomon, R.L. (1991). Acquired motivation and affective opponent-processes. In J. Madden (Ed.), Neurobiology of learning, emotion, and affect (pp. 307-347). New York : Raven.

Trilk, JL, Singhal, A, Bigelman, KA & Cureton, KJ. (2011). Effect of sprint interval training on circulatory function during exercise in sedentary, overweight/obese women. European Journal of Applied Physiology, 111, 1591-1597.

Trost, S.G., Owen, N., Bauman, A.E., Sallis J.F. & Brown, W. (2002). Correlates of adults' participation in physical activity: review and update. Medicine & Science in Sports & Exercise, 34(12), 1996-2001.

Wasserman, K, Hansen, JE, Sue, DY, Casaburi, R & Whipp, BJ. (1999). *Principles of Exercise Testing and Interpretation* (3rd ed.). Baltimore, MD: Lippincott Williams & Wilkins.

Welch, A.S., Hulley A. & Beauchamp, M. (2010). Affect and self-efficacy responses during moderate-intensity exercise among low-active women: the effect of cognitive appraisal. Journal of Sport & Exercise Psychology, 32, 154-175.

Whyte, L.J., Gill, J.M.R. & Cathcart, A.J. (2010). Effect of 2 weeks of sprint interval training on health-related outcomes in sedentary overweight/obese men. Metabolism Clinical and Experimental, 59, 1421-1428.

Williams, D.M. (2008). Exercise, affect, and adherence: an integrated model and a case for self-paced exercise. Journal of Sport and Exercise Psychology, 30, 471-496.

Williams, D.M., Dunsiger, S., Ciccolo, J.T., Lewis, B.A., Albrecht, A.E. & Marcus, B.H. (2008). Acute affective response to a moderate-intensity exercise stimulus predicts physical activity participation 6 and 12 months later. Psychology of Sport and Exercise, 9, 231-245.

Appendices

Appendix A: Physical Activity Enjoyment Scale
Used to assess enjoyment following exercise

Instructions: Please rate how you feel at this moment about the exercise you have been doing by circling the number that seems most appropriate.

1	I enjoy it	1 2 3 4 5 6 7	I hate it
2	I feel bored	1 2 3 4 5 6 7	I feel interested
3	I dislike it	1 2 3 4 5 6 7	I like it
4	I find it pleasurable	1 2 3 4 5 6 7	I find it unpleasurable
5	I am very absorbed in this activity	1 2 3 4 5 6 7	I am not at all absorbed in this activity
6	It's no fun at all	1 2 3 4 5 6 7	It's a lot of fun
7	I find it energizing	1 2 3 4 5 6 7	I find it tiring
8	It makes me depressed	1 2 3 4 5 6 7	It makes me happy
9	It's very pleasant	1 2 3 4 5 6 7	It's very unpleasant
10	I feel good physically while doing it	1 2 3 4 5 6 7	I feel bad physically while doing it
11	It's very invigorating	1 2 3 4 5 6 7	It's not at all invigorating
12	I am very frustrated by it	1 2 3 4 5 6 7	I am not at all frustrated by it
13	It's very gratifying	1 2 3 4 5 6 7	It's not at all gratifying
14	It's very exhilarating	1 2 3 4 5 6 7	It's not all exhilarating
15	It's not at all stimulating	1 2 3 4 5 6 7	It's very stimulating
16	It gives me a strong sense of accomplishment	1 2 3 4 5 6 7	It does not give me a strong sense of accomplishment
17	It's very refreshing	1 2 3 4 5 6 7	It's not at all refreshing
18	I felt as though I would rather be doing something else	1 2 3 4 5 6 7	I felt as though there was nothing else I would rather be doing

Appendix B: Feeling Scale
Used to assess affect at all assessment points

Instructions: Please rate how you currently feel.

+5	Very Good
+4	
+3	Good
+2	
+1	Slightly Good
0	Neutral
-1	Slightly Bad
-2	
-3	Bad
-4	
-5	Very Bad

Appendix C: CR10 RPE Scale
Used to assess exertion during the maximal exercise test

Instructions: During the exercise bout we want you to pay close attention to how hard you feel the exercise work rate is. This feeling should reflect your total amount of exertion and fatigue, combining all sensations and feelings of physical stress, effort, and fatigue. Don't concern yourself with any one factor, such as leg pain, shortness of breath or exercise intensity, but try to concentrate on your total inner feeling of exertion. Try not to underestimate or overestimate your feeling of exertion; be as accurate as you can.

0	Rest
1	Very, very easy
2	Easy
3	Moderate
4	Somewhat hard
5	Hard
6	
7	Very Hard
8	
9	
10	Maximal

Appendix D: Exercise Enjoyment Scale
Used to assess enjoyment during exercise

Instructions: Use the following scale to indicate how much you are enjoying this exercise session.

1: Not at all
2: Very little
3: Slightly
4: Moderately
5: Quite a bit
6: Very much
7: Extremely