THE ACUTE EFFECTS OF ARM ERGOMETRY ON AFFECT

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Abstract

The primary purpose of this study was to test the predictions of the Dual-mode theory using arm ergometry as the exercise modality. It was hypothesized that changes in affect during exercise would be greater in high (105% GET) and low (80% GET) intensity exercise conditions than in a control condition, while differences in affect would be observed between exercise conditions. In addition, it was predicted that during recovery, there would be no differences in affect between the exercise conditions. Study participants were 24 physically active men. A within-subjects design was used. Affect was measured using the Activation-Deactivation Adjective Check List (Thayer, 1986) and the State Anxiety Inventory (Spielberger et al., 1970). Cognitive (i.e., self-efficacy, enjoyment) and physiological (i.e., heart rate, pain, perceived exertion) mediators of the exercise-affect relationship were also examined. Results showed that during exercise, changes in affect were greater in the exercise conditions than the control condition, and affective valence in the exercise conditions declined relative to the control condition. In partial support of the Dual-mode theory, self-efficacy mediated the relationship between below GET exercise and affect, whereas pain mediated the relationship between above GET exercise and affect. During recovery, arousal was higher in the exercise conditions compared to control, affective valence was less positive compared to control, and state anxiety did not differ across conditions. Finally, there were no significant differences between the two exercise conditions on any of the affect measures. These findings highlight the importance of exercise intensity to the affective benefits of exercise.

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LITERATURE REVIEW

While physical activity can indirectly improve well-being by preventing disease and lowering the risk of premature death, there is a growing body of literature examining the direct influence physical activity can have on mental health (Fox, 1999). Indeed, it has been suggested that accumulated acute bouts of exercise can have long-term benefits on some of the more enduring aspects of psychological well-being that are problematic such as anxiety and depression (Thayer, 2001). The potential for exercise to aid in the treatment of psychological well-being is of fundamental importance given that poor mental health is second only to cardiovascular conditions in the number of disability adjusted life years (i.e., a measure that expresses years of life lost to premature death and years lived with a disability of specified severity and duration; Murray & Lopez, 1996).

Overview of the effects of exercise on affect

In general, participation in a single bout of aerobic exercise (e.g., running, cycling) has a positive effect on psychological well-being. In a review of more than 80 studies examining the acute effects of exercise on mood states, Yeung (1996) reported that a vast majority (> 85%) found some degree of improved mood following exercise (i.e., results were either positive or mixed). In addition, these findings were independent of how mood was measured, the type of exercise performed, as well as the exercise durations and intensities employed across studies.

In a meta-analysis of 158 studies examining the relationship between acute aerobic exercise and positive activated affect (i.e., feelings associated with energy and pleasantness), an effect size (*ES*) of .47 was found, indicating that this type of exercise is associated with a moderate increase in these kinds of sensations (Reed & Ones, 2006).

The meta-analysis also showed that there were several moderators of this relationship. For instance, low levels of exercise intensity (15-39% VO_2 max) were almost twice as effective in improving positive activated affect post-exercise than either moderate (40-59% VO_2 max) or high intensity exercise (60-80% VO_2 max; *ESs* = .57, .35, and .31 respectively). In addition, the effects were greatest in the first couple of minutes after exercise (*ES* = .61), with progressive declines thereafter (*ESs* = .43 - .10).

While Reed and Ones' (2006) meta-analysis examined the effects of acute aerobic exercise on positive psychological states, other studies have examined the effects of acute exercise on negative psychological states (i.e., state anxiety). In a meta-analysis of 104 studies, acute and aerobic exercise were associated with small reductions in state anxiety (*ESs* = .23 and .26 respectively; Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991). Moderator analyses revealed that there were no significant differences in anxiety reduction based on exercise intensity (i.e., 40-59, 60-69, 70-79 or > 80% HR max or VO_2 max), the type of anxiety measure employed, or the time anxiety was measured post-exercise (i.e., 0-5, 5, 10, 20, or > 20 mins).

Although previous research findings provide good evidence that acute aerobic exercise improves affect, additional study in this domain is required. More specifically, the discovery of a reliable dose-response relationship between exercise intensity and affective responses would provide a fundamental criterion for establishing causality (Dishman, 1995). In a review that examined the dose-response relationship between acute aerobic exercise and affect, Ekkekakis and Petruzzello (1999) found that in a majority of studies, there was no evidence that the intensity of exercise influenced affective responses. These authors did however, suggest that a potential reason for the inability to discover a reliable dose-response relationship may be due to several methodological limitations in the existing literature. Accordingly, they offered several suggestions for carrying out future work in the area in order to address these obstacles. Some of these considerations have been raised by other researchers as well (e.g., Yeung, 1996). In the following sections, these issues will be briefly discussed in turn.

Considerations for conducting exercise-affect research

The definition of affect. In order to assess the effects of exercise on psychological well-being, it is important to differentiate between the conceptualizations of psychological states. There has been a tendency in the existing literature to use the terms emotion, mood and affect all to refer to the same phenomenon (Ekkekakis & Petruzzello, 2000). While these terms are interrelated, they represent distinct constructs. Emotions require cognitive appraisal of an experience and their causes can usually be identified. In other words, emotions follow mental processing that results in a particular meaning attached to an event. For example, public speaking, upon appraisal, may induce fear. Moods, on the other hand, usually last for longer periods than emotions, are less intense than emotions, and their causes cannot always be determined (e.g., irritability). Finally, basic affect is a more general conceptualization than emotions or moods (e.g., a good-bad feeling) and is thought to be evolutionarily more primitive as it does not require cognitive appraisal of an experience or event and thus, can be formed through "hard-wired" mechanisms (Ekkekakis & Petruzzello, 2000). Inconsistent use of terminology in the exercise-affect literature may well result in misleading, or difficulty in comparing, research findings in this domain.

The measurement of affect. When the measurement of exercise-related affect started to gain research attention in the early to mid 1970s, in most studies, selection of the measures was not guided by the outcomes of interest, but rather by what measures were available or popular for use with non-clinical samples (e.g., the Profile Of Mood States; McNair, Lorr, & Droppleman, 1971), without any prior evaluations as to their psychometrics in the context of exercise (Ekkekakis & Petruzzello, 2000). As a way of potentially resolving these issues, the development of "exercise-specific" measures of affect followed in the early 1990s (e.g., the Exercise-induced Feeling Inventory; Gauvin & Rejeski, 1993; The Subjective Exercise Experiences Scale; McAuley & Courneya, 1994). While intuitively appealing, the most glaring problem with construction of such measures was the absence of systematic evidence to suggest that the affective experience is uniquely transformed in the context of exercise (Ekkekakis & Petruzzello, 2000). In addition, the development of these measures predominantly relied on studies involving young, healthy individuals, which limits their generalizability beyond such groups (Ekkekakis & Petruzzello, 2000). Furthermore, there is a potential for bias when exercise-specific measures (which are constructed to tap the stimulus properties of exercise) are used to assess responses to non-exercise control conditions (e.g., participants involved in quiet reading).

Another consideration for the measurement of affect is whether to use a dimensional or categorical model. From a dimensional perspective, affective states are considered to be inter-related and thus, their relationships can be modelled with as few as two dimensions (e.g., Russell, 1980). For example, one dimension could be low activation-high activation (i.e., arousal), and the other unpleasantness-pleasantness (i.e., affective valence), which can be mapped onto a circumplex (see Figure 1). Dimensional models offer a broad, theoretically unrestricted scope, while representing a comprehensive affective space (Ekkekakis & Petruzzello, 1999, 2000). Categorical models on the other hand, are more specific, offering finer detail of psychological meanings (i.e., affective states are organized into discrete categories thought to resemble prototypical exemplars such as sadness or happiness). Therefore, the decision to choose one model over the other depends on whether the researcher is interested in basic affect (dimensional) or distinct emotions (categorical; Ekkekakis & Petruzzello, 2000).

The timing of measurement. A substantial proportion of the studies of exercise-related affect have examined responses before and after an acute bout of exercise (Ekkekakis & Petruzzello, 1999). Unfortunately, with such an approach, no information is gained on the affective responses that may take place during exercise. Therefore, comprehensive and adequate assessments of the complex relationship between exercise and affect over time cannot occur, which hinders theory development, testing and modification. Indeed, studies have shown that affective responses during a bout of physical activity can be quite dynamic in nature (e.g., Hall, Ekkekakis, & Petruzzello, 2002) such that affective changes from pre-to-post exercise are not linear. For example, feelings of pleasure may increase or go unchanged during exercise only until the intensity becomes strenuous, with a significant decline thereafter. Therefore, research in this area should aim to assess affect at one or more points during exercise in order to develop a clearer picture of the entire range of possible responses in the context of exercise.

Standardization of exercise intensities. The majority of investigations of the dose-response relationship between exercise and affect have used percentages of maximal heart rate or oxygen uptake to define levels of exercise intensity (Hall et al., 2002). This decision was supposedly based on the notion that a percentage of maximal effort represented a similar metabolic requirement across individuals. For example, 70% maximal oxygen uptake would be just as metabolically "taxing" for regular exercisers as it would be for sedentary individuals. However, some researchers have suggested that the selection of various levels of intensity within such dose-response studies has been made without reason or justification (e.g., what are the conceptual distinctions between 40%, 60%, 80% of VO_2 max, and 30%, 50%, 70% of VO_2 max?). In addition, percentages of these markers do not take into account the relative contributions of aerobic and anaerobic metabolism. For instance, at 75% VO_2 max, fit individuals may use aerobic resources, whereas unfit individuals may use anaerobic resources (Ekkekakis & Acevedo, 2006). Therefore, percentages of maximal heart rate or oxygen consumption do not appear to be an appropriate means of standardizing intensity.

A suitable solution to this problem would be to define intensity levels relative to certain metabolic markers, such as the transition from using aerobic resources to anaerobic supplementation (i.e., the ventilatory gas exchange threshold; GET). GET is considered an indirect, but non-invasive index of the transition from aerobic to anaerobic metabolism (Lind, Joens-Matre, & Ekkekakis, 2005). Given that these metabolic landmarks have been linked to significant differences in affective responses to exercise (e.g., Acevedo, Kraemer, Haltom, & Tryniecki, 2003), standardizing intensities based on GET makes sound methodological sense.

Lack of theory. Another area of concern is the limited use of theory in studies examining the relationship between physical activity and affect (most have been descriptive in nature; Ekkekakis & Petruzzello, 1999). One model that has been used to explain the exercise intensity-affect relationship is the inverted-U hypothesis. This hypothesis suggests that moderately vigorous exercise is the optimal intensity for positive affective change, whereas low intensity is ineffective and high intensity is experienced as aversive. Unfortunately, this model does not account for research that has shown positive affective change in short-bouts of low intensity exercise such as walking (e.g., Ekkekakis, Hall, Van Landuyt, & Petruzzello, 2000; Thayer, 1987). In addition, for exercise performed at moderate intensity, some research has found that individuals may experience either progressive improvement in affect or progressive deterioration (Van Landuyt, Ekkekakis, Hall, & Petruzzello, 2000).

As demonstrated by the preceding review, there are several problems with current conceptualizations of the dose-response relationship between exercise and affect. Therefore, in order to improve future study in this area, researchers may need to question traditional views and methodologies, while considering theory modification and development.

The Dual-Mode Theory

Based on the notion that existing theories (e.g., the inverted-U hypothesis) were unable to adequately explain the results of several studies (e.g., those showing that low intensity exercises were capable of producing states of positive affect), Ekkekakis (2003) developed the Dual-mode theory. The primary goal of this theory is directed toward stimulating new research into the relationship between exercise and affect. A central tenet of the theory is that physical activity must be examined from an evolutionary and adaptational standpoint. In other words, the Dual-mode theory views physical activity in terms of its role in ensuring survival, while providing a means for growth and development. Specifically, the theory stipulates that: (a) physical activity has been a vital ingredient in helping to form human evolution, (b) affective responses are evolved psychological mechanisms that have been selected for their ability to promote and maintain the health of the organism, (c) affective responses are dependent on a system involving several levels of control (i.e., evolutionarily primitive pathways at the bottom to evolutionarily recent pathways at the top), and (d) more primitive levels of affective control will show less interindividual variability than those which are evolutionarily recent, which are mostly formed by the development histories (e.g., past experience with physical activity).

Based on these assumptions, the theory proposes that both cognitive processes (e.g., self-efficacy) and interoceptive cues associated with exercise-induced physiological changes (e.g., muscle fatigue) are responsible for affective responses to exercise. In addition, the relative importance of these factors shifts as a function of exercise intensity (Ekkekakis, 2003). That is to say, cognitive processes are posited to be more important for determining affective responses to low-to-heavy activities (i.e., below or at the aerobic-anaerobic transition), while interoceptive cues are expected to take precedence for determining affective responses when the intensity of physical activity becomes more strenuous (i.e., exceeds the aerobic-anaerobic transition). Thus, arousal is believed to increase as a function of exercise intensity due to the limited plasticity of pathways carrying interoceptive information to the affective centers of the brain. On the other hand, affective valence is believed to vary from person to person, due to the reliance on cognitive factors, to the point when the aerobic-anaerobic transition is reached

(Ekkekakis, 2003). Consequently, exercise poses a threat to homeostasis, the balance shifts toward dominance of physiological factors, and valence declines thereafter. Therefore, homogeneity in affective valence across individuals is posited to exist during low and high intensities (positive responses and negative responses respectively), while inter-individual variability is thought to exist at mid-range intensities.

Due to its recent development, there have been relatively few systematic studies testing the tenets of the Dual-mode theory. In the following sections, these studies are reviewed. As affective responses can be quite different during exercise compared to recovery from exercise (Ekkekakis & Petruzzello, 1999), the literature review is organized according to these time points. The final section of this review outlines findings related to the cognitive and physiological variables proposed to correlate with affective responses.

Affective changes during exercise. In one study (Bixby, Spalding, & Hatfield, 2001), affect was measured in 27 university students following 30 minutes of continuous exercise at two different intensities, 75% of GET (low-intensity), and 100% of GET (high-intensity). Results showed that there were between-condition differences in affective responses. Specifically, the low-intensity condition led to improvements in affective valence (i.e., greater pleasure), whereas the high-intensity condition led to a decline in affective valence. In another study with participants exercising at 80% of GET (low-intensity) and 110% of GET (high-intensity) for 15 minutes, Ekkekakis, Hall and Petruzzello (2008) discovered that while there was a non significant decline in affective valence over the bout in the low-intensity condition, there was a much larger decline in the high-intensity group which reached significance as early as minute 6, and grew increasingly larger until the end of the bout.

Similarly, Hall et al. (2002) found declines in affective valence during an incremental treadmill test. However, it was only once the participants exceeded GET that significant declines in affective valence occurred. Together, these findings provide support for the Dual-mode theory, suggesting that not only is the affective response to exercise likely to change during exercise, but also GET (the point at which an individual switches from aerobic metabolism to anaerobic supplementation) seems to be the point at which there is a significant decline in affective valence.

To determine if the aforementioned findings were due to differences in total work rather than differences in intensity, Kilpatrick and colleagues (Kilpatrick, Kraemer, Bartholomew, Acevedo, & Jarreau, 2007) compared the affective responses of two bouts of cycle ergometry that were equal in total caloric expenditure, but different in intensity and duration. The two bouts were a low-intensity condition (30 minute cycling bout at 85% of GET) and a high-intensity condition (24 minute cycling bout at 105% of GET). Results indicated that although both conditions led to similar increases in arousal, only the high-intensity condition led to a significant decline in affective valence (even though the duration of the bout was less than the low intensity condition). These results suggest that exercise intensity, but not total workload, determines the affective valence response and therefore, provides support for the basic tenets of the Dual-mode theory. That is, exercise intensities that exceed GET are perceived as aversive due to a disruption in homeostasis, whereas lower intensities are more likely to be adaptive and pleasant.

Affective changes after exercise. Of the abovementioned studies, Bixby et al. (2001), Ekkekakis et al. (2008) and Kilpatrick et al. (2007) also examined affective responses between exercise conditions post-exercise (i.e., during recovery). All of these studies showed that the differences found in affective responses between conditions during exercise were no longer evident over the recovery period. More specifically, affective valence and arousal in the Kilpatrick et al. and Ekkekakis et al. studies were the same after lower and higher exercise conditions at 15 minutes and 20 minutes respectively. In the Bixby et al. study, affective valence was the same between conditions at 10, 20, and 30 minutes into recovery (arousal was not assessed at these time points). These results are consistent with other studies examining affect post-exercise between conditions standardized relative to GET (e.g., Bixby & Lochbaum, 2006) as well as studies comparing moderate and high intensities based on percentages of oxygen uptake reserve (i.e., 40-59% and 60-85% respectively; Reed & Ones, 2006). Such findings suggest that when comparing exercise conditions during recovery periods, there does not seem to be a difference in affective valence or arousal between intensities below GET and just above GET for up to 30 minutes post-exercise.

Cognitive and physiological correlates of affective valence. In a study assessing affective valence every minute during an incremental treadmill test until participants reached exhaustion, Ekkekakis, Hall, and Petruzzello (1999) found that self-efficacy was responsible for almost all (80-100%) of the total accounted variance in affective valence for exercise performed below GET. Furthermore, participants' respiratory exchange ratio was responsible for most (65-80%) of the total accounted variance in affective valence for exercise performed above GET. The finding that physiological variables (e.g., heart rate, blood lactate) show increasingly negative correlations with affective valence as exercise intensity increases is consistent with other work in this area (e.g., Acevedo, Rinehardt, & Kraemer, 1994). However, the relationship between cognitive variables (e.g., self-efficacy) and affective valence has been less clear. Some studies have shown a relationship between self-efficacy and affect at moderate intensities (e.g., Tate, Petruzzello, & Lox, 1995) while others have shown this relationship at light and maximal intensities, but not at moderate intensities (e.g., McAuley, Blissmer, Katula, & Duncan, 2000). However, these differences may be due to the previously described methodological limitations in the existing literature, as well as the age and fitness level of the participants included in these studies.

Taking these latter points into consideration, the Dual-mode theory accounts for the research findings indicating that physiological variables show a stronger relationship with affective valence once the aerobic-anaerobic transition has been surpassed (e.g., Acevedo et al., 2003) with affect becoming increasingly more negative as intensity increases. In addition, the theory also accounts for the findings that cognitive variables show a stronger, positive correlation with measures of affective valence when the intensity of physical activity is in close proximity to the aerobic-anaerobic transition, and that this relationship becomes progressively weaker once this metabolic marker has been exceeded (Ekkekakis et al., 1999).

Other considerations

Non-dimensional measures of psychological states. While the studies presented thus far have provided important information toward understanding the dose-response relationship between exercise and basic affect (i.e., arousal and valence), how might other measures of psychological well-being (i.e., those not couched in a dimensional framework, such as state anxiety) respond to comparable assessment procedures? Not unlike some measures of basic affect (i.e., arousal), state anxiety seems to change during an exercise bout as a function of intensity. For example, one study assessed the effects of cycling at 55% VO_2 max, 70% VO_2 max, or a non-exercise control condition on state anxiety in 20 regularly active university students (Tate & Petruzzello, 1995). Results indicated that during a 30 minute exercise period, state anxiety was greatest in the 70% VO_2 max condition, followed by the 55% VO_2 max and control conditions respectively. Therefore, it appears that during exercise, state anxiety shares a similar pattern with some qualities of basic affect, namely arousal.

During recovery, state anxiety may also have a pattern of response akin to measures of basic affect. A meta-analysis conducted by Petruzzello et al. (1991) showed that anxiety reduction post-exercise was not significantly different based on the intensity of exercise for up to 30 minutes into recovery. More recent investigations including exercise intensities that may approximate below and at/just above GET (i.e., 50-60% and 75-80% VO_2 max respectively) have shown similar results up to 60 minutes into recovery (Cox, Thomas, & Davis, 2000) and beyond (Cox, Thomas, Hinton, & Donahue, 2004).

Differences in affect between exercise and control conditions. The Dual-mode theory has been instrumental in establishing a new framework for examining the dose-response relationship between exercise and affect in an acute context. However, other pertinent questions concerning the association between exercise and affect remain, warranting further investigation. For instance, how might changes in affect based on intensities relative to GET compare to a non-exercise control group (i.e., participants involved in quiet reading)?

In a study of physically active university students, Van Landuyt et al. (2000) compared affective responses between cycling for 30 minutes at 60% estimated VO_2 max and 30 minutes of quiet rest (i.e., participants sat quietly reading magazines). Results revealed that during recovery (10 and 20 minutes post-reading or post-exercise), arousal in the exercise condition was significantly greater than the control condition. Similarly, Tate and Petruzzello (1995) found higher levels of arousal between exercise conditions (i.e., 55% VO_2 max and 70% VO_2 max) and a control condition up to 30 minutes post-task. These results suggest that feelings of arousal are higher after exercise (i.e., at 55-70% VO_2 max) than a non-exercise control condition, and that this difference can last up to 30 minutes.

The Van Landuyt et al. (2000) and Tate and Petruzzello (1995) studies also examined affective valence during the recovery period. In the Van Landuyt et al. study, affective valence was significantly higher (i.e., more positive) in the 60% VO_2 max exercise condition compared to the control condition at 10 and 20 minutes into recovery, as assessed by the Feeling Scale (Hardy & Rejeski, 1989). However, when assessing affective valence with the Tense Arousal scale of the Activation-Deactivation Adjective Checklist (Thayer, 1986, 1989), the exercise condition was significantly higher (i.e., less positive) than the control condition at 10 but not 20 minutes post-test.

In contrast, Tate and Petruzzello (1995) found that tense arousal was similar between exercise and control conditions over the recovery period (i.e., to 30 minutes). However, tense arousal was assessed using a 5-item scale as opposed to the 10-item scale used by Van Landuyt et al. (2000). Unlike the 5-item Tense Arousal scale, the 10-item scale includes measures related to calmness (e.g., quiet, at-rest, still). This difference may result in the 10-item version being more susceptible to changes in tense arousal during exercise and thus, produces higher tense arousal scores. In addition, the authors noted that perhaps the participants did not perceive either the 55% or 70% VO_2 max exercise bout to be overly demanding, so they may not have reached a high enough level of energy expenditure to elicit changes in tense arousal. Taken together, these results suggest that, unlike arousal, affective valence may not differ greatly during recovery from a non-exercise control condition, and that if a difference does exist, it is likely to be short-lived (i.e., 20 minutes).

Again, when looking at the acute effects of exercise on state anxiety, there are some similarities to studies of basic affect. In their meta-analysis examining the effects of acute exercise on state anxiety, Petruzzello et al. (1991) concluded that other anxiety-reducing methods (e.g., relaxation, quiet rest) were as effective as exercise up to 30 minutes into recovery. These results may imply that a control group involved in quiet reading would exhibit similar levels of state anxiety as an exercise condition up to 30 minutes into recovery. In a recent study that compared the effects of exercise intensities of 60% VO_2 max, 80% VO_2 max (which the authors note may approximate below and above GET respectively) and a quiet reading control condition on state anxiety, Cox et al. (2004) discovered that there was no effect of condition during recovery until 30 minutes after exercise. At this point, only the 80% VO_2 max condition had significantly lower anxiety than the control condition. The same result was found 60 minutes after exercise. Only at 90 minutes were both exercise conditions significantly lower in anxiety than the control condition. It is worth mentioning that in the control condition, participants sat quietly on a treadmill for 33 minutes reading back issues of two selected magazines while connected to a metabolic cart. This circumstance could have been more mentally stressful than the exercise bouts. During recovery the participants were asked to spend an additional 90 minutes engaged in the same activity (albeit without connection to a metabolic cart). Spending 90 minutes in a laboratory after a half-hour of exercise is likely to have different effects on state anxiety than 90 minutes resting in a laboratory after a half-hour session of reading (Cox et al.).

This study assessed anxiety at 5, 30, 60 and 90 minutes into recovery, leaving open the possibility that high intensity exercise conditions could significantly differ from control conditions between 5 and 30 minutes. However, other studies imply otherwise. After participants exercised at 70-80% HR max, Raglin, Turner, and Eksten (1993) found that state anxiety was not significantly different from baseline at 20 minutes into recovery. Moreover, Bahrke and Morgan (1978) found that at a similar exercise intensity, state anxiety was not significantly different from a control condition in which participants read at 10 minutes into recovery.

Nevertheless, this is not to say that state anxiety does not differ between exercise and control groups during recovery. Rather, in what has come to be known as "the delayed anxiolytic effect of exercise", a period of 15-30 minutes may need to pass following exercise before a decrease in state anxiety is found (Raglin et al., 1993; Cox et al., 2004). If the intensities of exercise are set at the higher end of the intensity spectrum, this delay may be considerably longer (Raglin & Wilson, 1996).

When comparing affective responses between exercise and control conditions during exercise, the patterns are somewhat different. Typically, exercise groups exhibit increased feelings of arousal, while control groups show small declines in arousal (Reed & Ones, 2006). On the other hand, affective valence does not seem to show much difference between exercise and control conditions when exercise intensities are set between approximately 55-70% VO_2 max/below the GET (e.g., Tate & Petruzzello, 1995, Van Landuyt et al., 2000). Given the marked decline in affective valence at intensities that exceed GET (e.g. Ekkekakis et al., 2008), it is likely that affective valence in a non-exercise control group would be greater than in an exercise condition working at an intensity that is above GET.

In summary, it generally appears that during exercise, affect and state anxiety are dependent on intensity (i.e., exceeding GET leads to a decline in valence/further increase in state anxiety and arousal). During recovery, affect/state anxiety are similar across exercise bout intensities, up to approximately 30 minutes. In addition, when compared to a control condition, exercise conditions lead to greater arousal and anxiety during activity. During recovery, state anxiety is similar between exercise and control conditions up to 30 minutes, affective valence may be more positive in exercise conditions up to 20 minutes, while arousal seems to be the most enduring, remaining significantly higher in exercise conditions up to at least 30 minutes.

The Present Study

To date, affective responses to acute exercise have focused primarily on a limited number of aerobic modalities (i.e., cycling and running). While this topic has started to receive research attention in other forms of acute exercise such as resistance training (e.g., Arent, Landers, Matt, & Etnier, 2005; Arent, Alderman, Short, & Landers, 2007), other forms of aerobic activity remain inadequately examined. At present, no published studies have examined affective responses to single, acute bouts of arm ergometry. The lack of data on responses to arm ergometry is disappointing given that important information could be obtained for those who use such equipment on a regular basis for health benefits (i.e., people living with mobility disability such as lower limb amputation or spinal cord injury).

Therefore, the primary purpose of this study was to test the predictions of the Dual-mode theory using arm ergometry as the exercise mode. As a majority of the studies examining affective responses to varying intensities relative to GET have not included a non-exercise control condition, the second purpose was to compare affective responses across lower intensity, higher intensity and control conditions. Due to the theory's postulates regarding cognitive and physiological correlates of affective responses, the third purpose of this study was to examine cognitive and physiological variables as possible mediators of affective responses. Finally, as affective responses have been shown to vary over the course of lower body aerobic exercise bouts, affect was measured before, during and after exercise in order determine if any changes occur over the course of bouts of arm ergometry.

For the in-task phase of the exercise bout (i.e., baseline to minute 15), it was hypothesized that (1) changes in affect will be larger in the exercise conditions compared to the control condition, (2) changes in affective valence and state anxiety in the 80% GET condition will be more positive than in the 105% GET condition (i.e., less tense arousal and anxiety), while changes in arousal will be similar between the exercise conditions, and (3) the effects of exercise on affective responses will be mediated by cognitive factors (i.e., self-efficacy, enjoyment) for the 80% GET condition, and by physiological factors (i.e., heart rate, perceived exertion, pain) for the 105% GET condition.

For the recovery phase, it was hypothesized that (4) consistent with previous literature showing no difference between 5 and 30 minutes, there will not be significant differences in state anxiety between conditions at any point during the recovery period, (5) arousal will be higher in the exercise conditions than in the control condition during the entire recovery phase (i.e., to minute 45), (6) affective valence in the exercise conditions will be significantly different from the control condition at 5, 10 and 20 minutes into recovery, but will not be significantly different from the control condition at 30 and 45 minutes into recovery, and (7) there will not be a significant difference in any of the affect measures between the 80% GET condition and 105% GET condition during the 5 to 45 minute recovery period.

Method

Participants

Participants were recruited from McMaster University. Advertisements providing information about the project were placed around campus and posted on the university's website. Twenty-four male undergraduate and graduate students (M_{age} = 22.50, SD = 3.38) volunteered to participate in the study. The project was approved by the McMaster University Research Ethics Board, and all participants provided informed consent prior to their involvement in the study. Inclusion criteria required participants to be physically active at a moderate to heavy intensity at least 3 days per week, and have little to no experience using an arm ergometer. Physically active men were included because (a) most studies examining the acute effects of above and below GET exercise on affect have used samples with these attributes, and (b) we wanted to ensure that the participants would be able to complete the exercise tasks without any untoward physical or psychological effect (e.g., distress). In general, participants had good cardiovascular fitness ($M_{\text{VO2peak arm ergometer}} = 26.21$, $SD = 4.49$). The overall means and standard deviations for the participant characteristics are displayed in Table 1.

Measures: Outcome variables

Affective Valence & Arousal. The Activation-Deactivation Adjective Checklist (Thayer, 1986, 1989) is a 20-item dimensional measure that was used to assess both affective valence and arousal. The Activation-Deactivation Adjective Check List consists of two bipolar dimensions, energetic arousal (i.e., arousal) and tense arousal (i.e., affective valence). Energetic arousal refers to feelings that can range from energy to feelings of tiredness. Tense arousal refers to feelings that can range from subjective tension to calmness. Participants responded to each item by indicating how they felt *at this moment* by circling the appropriate response on the rating scale. Each item was rated on a 4-point scale: (1 = *definitely do not feel*, 2 = *cannot decide*, 3 = *feel slightly*, and 4 = *definitely feel*). The Activation-Deactivation Adjective Check List can be scored either in terms of the bipolar dimensions (i.e., energetic arousal and tense arousal, 10-items each), or in terms of four unipolar scales (i.e., Energy, Tiredness, Tension, and Calmness, 5-items each). For this study, the Activation-Deactivation Adjective Check List was scored according to the bipolar dimensions in order to draw comparisons with studies that have used the Feeling Scale (Hardy & Rejeski, 1989) and the Felt Arousal Scale (Svebak &

Murgatroyd, 1985). The Activation-Deactivation Adjective Check List is a valid and reliable measure (Thayer, 1978, 1986).

Anxiety. The 20-item version of the State Anxiety Inventory (Spielberger, Gorsuch, & Lushene, 1970), which is a categorical measure, was used in order to assess state anxiety. Participants were asked to rate how they felt *right now, that is, at this moment* by circling the appropriate response beside each item. Each item was rated on a 4-point scale: (1 = *not at all*, 2 = *somewhat*, 3 = *moderately so*, and 4 = *very much so).* The scale is scored by reverse-scoring the positive items (e.g., I feel at ease) and then summing the scores for all items. The 20-item measure has proven to be a valid and reliable measure (Spielberger, et al., 1970).

Measures: Potential Mediators of the Relationship Between Acute Aerobic Exercise and Affect

Pain. One item from the Brief Pain Inventory (Cleeland, 1991) was used to measure pain. Participants responded to the item "Please rate your upper body pain by circling the one number that tells how much pain you have right now" with ratings ranging from 0 = *no pain*, to 10 = *pain as bad as you can imagine.*

Physical Effort. The Category-Ratio (CR-10) Rating of Perceived Exertion (Borg, 1982) scale was used to measure feelings of physical effort. The CR-10 is an 11-point single-item scale ranging from 0 = *nothing at all*, to 10 = *very, very strong (almost max).* A meta-analysis by Chen, Fan, and Moe (2002) showed that the CR-10 is a valid measure of exercise intensity in healthy individuals.

Heart Rate. Heart rate was assessed by placing a heart rate monitor around each participant's chest (i.e., a telemetry monitor; Polar Electro, Woodbury, NY).

Self-efficacy. Self-efficacy for completing an exercise bout of a particular intensity was assessed by a task-specific measure. Participants were asked about the belief in their ability to continue exercising for incremental 2-min periods at the same intensity as their upcoming bout. In order to provide a basis for their efficacy appraisals, participants performed a familiarization protocol in which they performed a 1-minute bout of arm ergometry at the same intensity as the forthcoming bout (i.e., 80% GET, 105% GET). For the control condition, participants performed a 1-minute bout of arm ergometry at an intensity that was set very low (i.e., 20 watts). Eight items were used, ranging from "I believe I am able to continue for 2 min" to "I believe I am able to continue for 16 min". For each item, participants were asked to rate their confidence on a 100-point scale consisting of 10-point increments ranging from 0% = *not at all confident*, to 100% = *very confident*. An average of the eight item scores were used as the participants' self-efficacy score. Previous use of this scale has indicated acceptable internal consistency in healthy volunteers participating in 15-min treadmill runs of varying intensity (i.e., Cronbach's alpha = 0.92; Hall, Ekkekakis, & Petruzzello, 2005).

Enjoyment. The Physical Activity Enjoyment Scale (Kendzierski & DeCarlo, 1991) was used to measure enjoyment. The PACES is an 18-item questionnaire which asks participants to "rate how you feel at the moment about the physical activity you have been doing" on a 7-point scale. Prior to completing the scale, participants performed the same familiarization protocol used before completing the self-efficacy measure. Some exemplars of the items on the PACES are: 1 = *I enjoy it*, to 7 = *I hate it*, and 1 = *it's very pleasant*, to 7 = *it's very unpleasant*. Total scores are calculated by summing all items (reverse scoring negative items) and can range from 18 to 126. The PACES has been shown to be a valid and reliable measure of physical activity enjoyment (Kendzierski & DeCarlo, 1991). For a complete list of all the study questionnaires, see Appendix B.

Study design and Rationale

A within-subjects study design was used. Therefore, each participant took part in two exercise sessions of different intensities (20% below and 5% above their GET) as well as a control condition. There are two fundamental advantages of the within-subjects design: (a) increased statistical power and (b) reduction in error variance associated with individual differences. Much of the error variance in a between-subjects design is due to the fact that, even though participants are randomly assigned to groups, the two groups may differ due to individual difference factors. With a within-subject design, the conditions are always exactly equivalent with respect to individual difference variables. A disadvantage of the within-subjects design is the risk of carryover effects (i.e., participation in one condition may effect performance in other conditions). However, given that each experimental condition was randomly assigned and occurred on separate days, carryover effects like fatigue or practice are not likely to confound the results.

In total, each participant took part in four sessions (i.e., a peak oxygen uptake assessment, a control condition, and two exercise conditions). The intensities of the two exercise conditions (i.e., 20% below the GET and 5% above the GET) were selected based on previous research examining affective responses to cycling and treadmill exercises that lasted at least 15 minutes, and used 20% or 15% below the GET as the lower intensity, and 5% or 10% above the GET as the higher intensity (e.g., Ekkekakis, Hall, & Petruzzello, 2001; Hall et al., 2005; Kilpatrick et al., 2007). The above GET condition was set at 5% for this study as pilot testing in our laboratory revealed that arm ergometry at this intensity for 15 minutes represented a considerable challenge and thus, 10% above GET may have been to be too strenuous an intensity to maintain for the same duration.

Participants exercised at each intensity for 15 minutes. This duration was chosen based on (a) previous studies that have shown affective benefits with exercise bouts of this duration (e.g., Ekkekakis et al., 2000), and (b) previous research findings that 15 and 30 minute bouts of exercise have similar affective benefits (e.g., Daley & Welch, 2004). The first three assessment time points after the exercise (i.e., 5, 10, and 20 minutes into recovery) were chosen taking into consideration previous studies with similar protocols (i.e., Hall et al., 2002; Bixby et al., 2001). The rationale for measuring affect beyond 20 minutes (i.e., 30 and 45 minutes into recovery) was that studies have found further changes in affect when assessments are made at later time points (e.g., Bartholomew, Morrison, & Ciccolo, 2005; Cox et al., 2000). The assessment time points made during exercise (i.e., 5 and 10 minutes) were chosen based on the perception that the multiple measurement time points employed in other studies (e.g., every minute of the exercise bout; Hall et al., 2002) coupled with multi-item questionnaires (e.g. the Activation-Deactivation Adjective Check List) might annoy the participants and disrupt the cognitive and physiological processes that may cause affective changes.

Procedure

At the baseline testing session, consent was obtained, each participant's height and weight were measured, and his date of birth was recorded. Subsequently, participants underwent a progressive exercise test on an arm ergometer (Monark 881, Sweden) to determine their peak oxygen uptake (VO_2 peak). The participant sat in front of the arm ergometer, which was bolted to an adjustable table. The height of the table was adjusted such that the handle of the ergometer was aligned with the participant's shoulder when at its highest point (i.e., 90 degrees from horizontal). In addition, each participant was asked to move his chair close enough to the table such that there was a slight bend in his elbow when the ergometer handle was at the furthest point from his body (i.e., parallel to the table). This procedure ensured that the angle of cranking was the same for all participants.

The testing protocol was the same for all participants with the exception of their starting workload (i.e., watts), which was based on the participant's weight. These workloads were established according to the work of Washburn and Seals (1983) who assessed the effectiveness of different VO_2 peak protocols in healthy active men that were not experienced in arm ergometry. In total, there were four different starting workloads (i.e., 59-67 kg = 25 watts, 68-75 kg = 30 watts, 76-83 kg = 35 watts, 84-91 kg = 40 watts). The workload was increased 10 watts every 2 minutes for the first 6 minutes of the test, and then 10 watts every minute for the remainder of the test. The procedure was terminated when participants could no longer maintain a cadence of 50 rpm. The arm ergometer was equipped with a digital readout for rpm. A metronome was also used to assist participants in maintaining the desired cadence. All participants "maxed out" between 8 and 14 minutes.

Expired gases were collected during the test using a Medisoft metabolic cart (Medisoft, Ergocard: Cardio Respiratory Instrumentation) for measurements of oxygen (O_2) uptake and carbon dioxide (CO_2) output. GETs were calculated using the V-slope method (Beaver, Wasserman, & Whipp, 1986). This method consists of plotting CO_2

production over O_2 utilization and identifying a breakpoint in the slope of the relationship between these two variables. The level of exercise intensity corresponding to this breakpoint is considered to be GET. The calculated values from the software of the metabolic cart were also examined by visual inspection for accuracy. Each participant's heart rate was also measured during the procedure using a heart rate monitor. The test took approximately 20 minutes to complete.

Participants were also scheduled for three more experimental sessions, which occurred on separate days. For each session, participants were allocated to 1 of 3 conditions (i.e., low intensity exercise, high intensity exercise, or control) the order of which was assigned using a random numbers table. Two of the sessions consisted of completing a 15 minute bout on the arm ergometer, one session at 20% below their GET (low intensity) and one at 5% above their GET (high intensity). The third session involved quiet reading of magazines (i.e., “Men’s Health” and “Sports Illustrated”). Prior to, during, and after each session, participants completed the study measures. The Activation-Deactivation Adjective Check List and State Anxiety Inventory were administered at all timepoints (i.e., baseline, 5 and 10 minutes in-task, immediately following the end of the bout/15th minute, and 5, 10, 20, 30 and 45 minutes into recovery). Pain and perceived exertion were measured at baseline, 5 and 10 minutes in-task, and immediately following the 15th minute. Self-efficacy and physical activity enjoyment were assessed after the familiarization protocol, and immediately following the 15th minute (see Table 2). During the exercise bouts, the investigator asked participants to verbalize their responses to the questionnaires, which were placed on the table beside them, so that they did not have to stop exercising to give their response. For the control condition (i.e., quiet reading) all questionnaires were completed by the participants, and those refering to feeling *during physical activity* (e.g., the Physical Activity Enjoyment Scale) were modified to simply read *during this activity*.

Each experimental session took 60 minutes to complete (i.e., 15 minutes in-task, and 45 minutes for the recovery). Upon completion of the final experimental session, participants were thanked for their time, debriefed, and given a copy of their VO_2 peak assessment results. Each participant was paid $40 in total for his time (i.e., $10 after each testing session).

Analytic Approach

Area under the psychological response curve, adjusted for baseline scores (DAUC), was calculated to assess changes in affect in-task. This approach was utilized as there was considerable variability in the time it took participants to complete the questionnaires at the assessment points. Some participants completed the questionnaires within 1 minute, while others exceeded 2 minutes. As a result, assessment time-points in-task lost some meaning (i.e., it may not be a fair comparison to assess changes in affect occurring at the pre-specified time-points as not all questionnaires were completed within the same time frame).

A general linear model (GLM) repeated measures analysis of variance (ANOVA) was used to compare DAUC across the 3 conditions. Post-hoc comparisons were adjusted with the Bonferroni correction.

Linear regression was used to determine if changes in cognitive variables (e.g., self-efficacy) mediated the relationship between exercise and changes in affect in the 80% GET condition, and to determine if changes in physiological variables (e.g., pain) mediated the relationship between exercise and changes in affect in the 105% GET condition. The variables used in the regression model were based on the recommendations put forward by Judd, Kenny and McClelland (2001) for testing for mediation in a within-subjects design (details reported below under "*Test for Mediation*").

Finally, a 3 x 5 (condition x time) GLM repeated measures ANOVA on raw affect scores was used to assess changes in affect during the recovery period. The degrees of freedom were adjusted with Greenhouse-Geisser epsilon when the sphericity assumption was violated. Significant effects were followed up with Bonferroni corrected paired t-tests to compare affect scores between conditions at each recovery time-point.

Results

Scale Psychometrics

Cronbach's alpha statistics for the multi-item scales are presented in Table 3. Of note, some of the Tense Arousal scales had alpha levels below the conventional level of acceptability ($\alpha \geq .70$). However, an alpha level below .70 does not necessarily mean that the measure is inadequate, and levels as low as .63 (the lowest in the present study) can still be acceptable (Schmitt, 1996).

Psychological Responses In-Task as a Function of Condition

There was a significant effect of condition on state anxiety, $F(2, 46) = 18.57$, $p < .01$. Consistent with hypotheses 1 and 2, pairwise comparisons revealed a significant difference between all conditions with the 105% GET condition exhibiting the largest increase in state anxiety, followed by the 80% GET condition (all *ps* < .05, see Table 4 and Figure 2).

As predicted for arousal, changes in the exercise conditions were significantly larger than the control condition $F(2, 46) = 57.53$, $p < .01$, but were not significantly different from each other, $p > .10$ (see Table 4 and Figure 3).

There was a significant effect of condition on affective valence, $F(2, 46) = 161.00$, $p < .01$. Also as predicted, pairwise comparisons revealed a significant difference between all conditions with the 105% GET condition exhibiting the largest increase in tense arousal, followed by the 80% GET condition (all *ps* < .01, see Table 4 and Figure 4).

Before testing for mediation, three of Baron and Kenny's (1986) criteria for mediation had to be met (i.e., the independent variable should be significantly related to the dependent variable, the independent variable should be significantly related to the mediator, and the mediator should be significantly related to the dependent variable; the ABC conditions specified in Figure 5). As noted above, there was a significant effect of condition (independent variable) on measures of affect (dependent variable). What follows are tests of the remaining criteria for mediation.

Differences in Change Scores of the Potential Mediators as a Function of Condition

Before comparing changes in the mediators over the course of the exercise bout, GLM repeated measures ANOVAs were conducted to assess whether baseline values for each mediator were significantly different across conditions. Pairwise comparisons revealed no significant differences across conditions with the exception of self-efficacy (i.e., control self-efficacy was significantly higher than self-efficacy for both exercise conditions, $p < .05$). However, in the control condition, participants were asked about their self-efficacy to perform very low intensity exercise (i.e., 20 watts) and therefore, the difference between self-efficacy in the control and exercise conditions was expected.

In-task changes in the cognitive mediators (i.e., self-efficacy and physical activity enjoyment) were compared across conditions using a GLM repeated measures ANOVA on the change scores. There was a significant effect of condition on both self-efficacy and physical activity enjoyment change scores $F(2, 46) = 7.21, p < .01$, $F(2, 46) = 5.22, p < .01$. Pairwise comparisons revealed that for self- efficacy, the exercise conditions exhibited significantly greater change than the control condition, but not from each other. For physical activity enjoyment, the only significant difference was between the 80% GET condition and the control condition such that enjoyment increased in the 80% GET condition and decreased in the control condition (see Table 5).

In-task changes in the physiological mediators (i.e., heart rate, pain, and perceived exertion) were compared across conditions using a GLM repeated measures ANOVA on the change scores. There was a significant effect of condition on heart rate $F(2, 46) = 83.12, p < .01$, pain $F(2, 46) = 65.56, p < .01$, and perceived exertion $F(2, 46) = 112.68, p < .01$. Pairwise comparisons revealed that for each of these variables, all conditions were significantly different from each other, with the 80% GET condition scoring higher than control, and the 105% GET condition scoring higher than the 80% GET condition (see Table 5).

Relationships between the mediators and psychological responses for the exercise conditions

In order to determine if changes in the cognitive mediators were related to changes in affect during the 80% GET condition and if changes in physiological mediators were related to changes in affect during the 105% GET condition, Pearson correlation coefficients were calculated. These correlations are displayed in Table 6. For descriptive purposes only, the full correlational matrix is included (i.e., cognitive mediators in the above GET condition, and physiological mediators in the below GET condition). Self-efficacy and state anxiety were significantly related in the 80% GET condition. Pain and energetic arousal were significantly related in the 105% GET condition. No other correlations were significant. As such, only these variables were included in the final regression model testing for mediation.

Models meeting the requirements for meditation testing

Of all possible mediational models, two models met the preliminary conditions (as specified by Baron & Kenny, 1986) for mediation. Model 1 consisted of the 80% GET condition, with self-efficacy as the mediator and state-anxiety as the outcome (see Figure 6). Model 2 consisted of the 105% GET condition, with pain as the mediator and energetic arousal as the outcome (see Figure 7). Therefore, only these mediational models were tested.

Test for mediation

In order to test for mediation, the recommendations of Judd et al. (2001) for testing mediation in a within-subjects design were implemented. The traditional statistical procedures for mediation testing (e.g., Baron & Kenny, 1986) are appropriate for circumstances where an individual participant receives only one "treatment". However, these procedures have not been systematically examined in cases where an individual participant may experience more than one treatment condition (i.e., a repeated measures design). The within-subject case calls for attention toward certain issues that are not typically addressed in a between-subjects case (Judd et al.).

The within-subject design test for mediation involves 4 steps. The first step is to calculate the difference in the scores of the mediator of interest (i.e., mediator difference) between the conditions of interest (e.g., difference in self-efficacy change scores between the control and 80% GET conditions). The next step is to calculate the sum of the mediator scores (i.e., mediator sum, such as the sum of self-efficacy change scores between the control and 80% GET conditions). The third step requires the computation of the difference in scores of the outcome variable of interest between the conditions of interest (i.e., outcome difference, such as the difference in state anxiety change between the control and 80% GET conditions). The fourth and final step consists of regressing the outcome difference on both the mediator sum and mediator difference. Assuming that there is an overall treatment effect on the outcome, if the mediator difference predicts the outcome difference, mediation is indicated.

In model 1, we tested the hypothesis that self-efficacy mediates the effects of below GET exercise (i.e., 80% GET) on state anxiety. In order to test this assumption, in line with the steps outlined above, the difference in self-efficacy change scores between the control and 80% GET conditions were calculated, the sum of the self-efficacy change scores between the control and 80% GET conditions were calculated, and the difference in changes in state anxiety (DAUC) between the control and 80% GET conditions were calculated. The control condition was used for comparison to the 80% GET condition instead of the 105% GET condition because the Dual-mode theory predicts that cognitive variables (e.g. self-efficacy) will only act as mediators in the below GET condition. Once these variables were calculated, a linear regression model was computed.

The summed score of self-efficacy and the difference score in self-efficacy were entered into the regression model and accounted for 20% of the variance in differences in state anxiety. However, only self-efficacy difference was a significant predictor $\beta = -.52$, $p < .05$ (see Table 7). This result indicates that self-efficacy mediated the effects of below GET exercise on state anxiety.

In model 2, it was expected that pain would mediate the effects of above GET exercise (i.e., 105% GET) on energetic arousal. In order to test this hypothesis, in line with the steps outlined above, the difference in pain change scores between the control and 105% GET conditions were calculated, the sum of the pain change scores between the control and 105% GET conditions were calculated, and the difference in changes in energetic arousal (DAUC) between the control and 105% GET conditions were calculated. The control condition was used for comparison to the 105% GET condition instead of the 80% GET condition because the Dual-mode theory predicts that physiological variables (e.g. pain) will only act as mediators in the above GET condition. Once these variables were calculated, a linear regression model was computed.

The summed score of pain and the difference score in pain were entered into the regression model and accounted for 14% of the variance in difference scores for energetic arousal. However, only pain difference was a significant predictor $\beta = -.44$, $p < .05$ (see Table 8). This result indicates that pain mediated the effects of above GET exercise on energetic arousal.

Psychological Responses During Recovery as a Function of Condition

As hypothesized, there was not a significant effect of condition on state anxiety over the recovery period $F(2, 46) = 2.34, p > .10$. In addition, there was not a significant effect of time $F(4, 92) = .53, p > .10$, or a significant condition x time interaction $F(8, 184) = 1.52, p > .10$.

For energetic arousal, there was a significant effect of condition over the recovery period $F(2, 46) = 14.98, p < .01$. In addition, there was a significant effect of time $F(4, 92) = 26.60, p < .01$, and a significant condition x time interaction $F(8, 184) = 6.85, p < .01$. Post-hoc analysis of the interaction using paired t-tests revealed that, as hypothesized, arousal scores in the exercise conditions were significantly higher than the control condition at 5 minutes into recovery $t_{80\%GET}(23) = -5.70$, $t_{105\%GET}(23) = -5.79$, $ps < .01$, 10 minutes into recovery $t_{80\%GET}(23) = -4.08$, $t_{105\%GET}(23) = -5.06$, $ps < .01$, 20 minutes into recovery $t_{80\%GET}(23) = -3.23$, $t_{105\%GET}(23) = -2.83$, $ps < .01$, and 30 minutes into recovery $t_{80\%GET}(23) = -3.35$, $p < .01$, $t_{105\%GET}(23) = -2.76$, $p < .05$. However, contrary to prediction, by 45 minutes into recovery, only the 105% GET condition had significantly higher arousal than the control condition $t(23) = -2.72, p < .05$. (see Table 9 and Figure 4)

For tense arousal, there was a significant effect of condition over the recovery period $F(2, 46) = 7.90, p < .01$. In addition, there was a significant effect of time $F(4, 92) = 26.24, p < .01$, and a significant condition x time interaction $F(8, 184) = 7.64, p < .01$. Post-hoc analysis of the interaction using paired t-tests revealed that, as predicted, tense arousal scores in the exercise conditions were significantly different than the control condition at 5 minutes into recovery $t_{80\%GET}(23) = -4.95$, $t_{105\%GET}(23) = -4.59$, $ps < .01$, and 10 minutes into recovery $t_{80\%GET}(23) = -2.31, p < .05$, $t_{105\%GET}(23) = -10.46, p < .01$. However, contrary to the hypothesis no significant differences were found between conditions after 10 minutes into recovery (all *ps* > .05, see Table 9 and Figure 5).

Finally, as hypothesized, state anxiety, energetic arousal and tense arousal were not significantly different between exercise conditions at any of the recovery time-points (all *ps* > .05, see Table 9).

Discussion

The primary purpose of this study was to test the predictions of the Dual-mode theory using arm ergometry as the exercise modality. Results showed that during 15 minutes of arm ergometry, changes in affect were greater in the exercise conditions than the control condition, and affective valence in the exercise conditions declined relative to the control condition (this effect being more pronounced in the above GET condition). In partial support of the Dual-mode theory, a cognitive variable (i.e., self-efficacy) mediated the relationship between below GET exercise and affect, whereas a physiological variable (i.e., pain) mediated the relationship between above GET exercise and affect. During recovery, arousal was higher in the exercise conditions compared to control, affective valence was less positive compared to control, while state anxiety did not differ across conditions. Finally, there were no significant differences between the two exercise conditions on any of the affect measures. As the study predictions differed between in-task and recovery periods, the results will be discussed separately according to these time points.

Affective responses in-task

Hypothesis 1. The hypothesis that changes in affect would be larger in the exercise conditions than the control condition was supported. This finding is consistent with previous literature (Tate & Petruzzello, 1995; Van Landuyt et al., 2000), suggesting that arm ergometry and lower body exercises (e.g., running, cycling) have similar effects on affect relative to a control condition. The findings also support the notion that exercise-related changes in affect may be contingent upon a balance between energy stores and expenditure (Rowland, 1998). As exercise intensity increases, physiological changes in the body (e.g., cardiovascular) respond in an effort to restore this balance. In line with the assumptions of the Dual-mode theory, as interoceptive information becomes stronger with intensity, homeostasis becomes more difficult to maintain and thus, the body signals that energy stores are diminishing through a decline in affective valence (Cabanac, 1971; Ekkekakis, 2003).

It is perhaps not surprising that during exercise, state anxiety changed in a similar manner to affective valence and arousal. The State Anxiety Inventory contains several of the same items as tense arousal (e.g., jittery, calm, tense), as well as other items that likely tap in to feelings of arousal (e.g., at ease, rested, relaxed). In this vein, some researchers have suggested that increases in state anxiety during exercise may be due to exercise-induced activation or effort-related tension rather than increases in anxiety per se (Ekkekakis & Petruzzello, 1999; Ekkekakis, Hall, & Petruzzello, 1999b, Rejeski, Hardy, & Shaw, 1991). Still, other researchers contend that the State Anxiety Inventory is assessing a construct different from tension (Landers, Arent, Rogers, He, & Lochbaum, 2002). Results from the current investigation suggest that increases in anxiety during exercise may be due in part to effort related tension (see Figure 3 & 8).

Hypothesis 2. The hypothesis that changes in affective valence and state anxiety in the 80% GET condition would be more positive than in the 105% GET condition, while changes in arousal would be similar between the exercise conditions in-task was also supported. Our findings using arm ergometry exercise is consistent with previous literature focused on lower body exercise, that has shown state anxiety to increase during exercise as a function of intensity (e.g., Tate & Petruzzello, 1995). The results are also in line with findings that affective valence shows a greater decline while exercising above GET (e.g., Bixby & Lochbaum, 2006; Ekkekakis et al., 2008; Kilpatrick et al., 2007). This would suggest that arm ergometry has similar effects on affective valence and state anxiety as lower body exercise.

The finding that arousal was the same between the above and below GET exercise conditions is consistent with some previous findings (i.e., Kilpatrick et al., 2007), but not with others (i.e., Ekkekakis et al., 2008). While both of these previous studies examined arousal using the Felt Arousal Scale, total caloric expenditure in the above and below GET conditions was controlled in the Kilpatrick et al. study. Thus, even though exercising in the above GET condition was more strenuous, it was for a shorter duration. The equality in expenditure between conditions may have resulted in equivalent perceptions of arousal. In contrast, the Ekkekakis et al. study kept the exercise bouts constant in terms of duration (as did our study), and yielded significant differences in arousal between the above and below GET exercise conditions. The difference between our findings and those of Ekkekakis et al. may be due to differences in the arousal measures employed. In the present study, arousal was assessed using the Energetic Arousal scale. In the Ekkekakis et al. study, arousal was measured by the Felt Arousal Scale, which asks participants to rate how aroused they feel (1 = low arousal to 6 = high arousal). The Energetic Arousal scale, on the other hand, uses a series of adjectives to measure arousal (e.g., wide-awake, active), and allows for two choices in the affirmative, "definitely feel" or "slightly feel". Therefore, regardless of choice, there is only a 1-point difference between them when scoring the scale. However, the Felt Arousal Scale has six different levels/choices of arousal, perhaps making it more sensitive to changes in arousal than the Energetic Arousal scale.

The abovementioned findings suggest that exceeding GET results in a greater decline in affective valence and increase in anxiety, while feelings of arousal are similar whether exercising on an arm ergometer at 80% GET or 105% GET. While there was a decline in affective valence in the 80% GET condition in the current study, participants' scores were still indicative of calmness (see Figure 5). Only the 105% GET group experienced tension during exercise, a state which lasted a majority of the 15 minute bout. Consistent with the tenets of the Dual-mode theory, exceeding GET during arm ergometry leads to increased arousal and a decline in affective valence.

Hypothesis 3. The prediction that the effects of exercise on affective responses will be mediated by cognitive factors for the 80% GET intensity, and by physiological factors for the 105% GET intensity received partial support. Starting with the 80% GET intensity, self-efficacy was found to be a mediator, but physical activity enjoyment was not. The finding that self-efficacy mediated the relationship between below GET arm ergometry and measures of affect is consistent with previous literature in lower body exercise (i.e., Ekkekakis et al., 1999), and suggests that increased feelings of mastery and accomplishment are notable contributors to the effects of acute exercise on affect (McAuley, Talbot, & Martinez, 1999). The finding that enjoyment did not emerge as a mediator is inconsistent with previous research (e.g., Motl, Berger, & Leuschen, 2000). Enjoyment may not have emerged as a mediator in our study because the change in enjoyment over the exercise bout was relatively small. In addition, the relatively low variability in enjoyment change scores makes it difficult to detect significant correlations with the measures of affect.

Next, examining the 105% GET intensity condition, pain was found to be a mediator, but heart rate and physical effort (i.e., Rating of Perceived Exertion) were not. Of note, when asked to rate their level of pain during the exercise bouts, participants clarified that what they were experiencing would be more accurately described as "discomfort from effort" than pain. This discomfort, such as a burning sensation in the arms while cranking, may alert the body that resources are diminishing and thus, results in a negative affective response in order to prevent further disruption in homeostasis (Cabanac, 1971; Ekkekakis, 2003). While pain has not been systematically investigated in the present context (i.e., in an acute aerobic exercise setting with intensities standardized relative to GET), research have shown that changes in pain can influence changes in affect in people with spinal cord injury doing lower body exercise (Martin Ginis & Latimer, 2007).

Heart rate may not have emerged as a mediator in the 105% GET condition because arm ergometry at this intensity may not induce as great a change in heart rate as lower body exercise (e.g., average maximum heart rate while running at 10% above GET

= 186 bpm, and running at GET = 180 bpm; Acevedo et al., 2003) . Indeed, the average heart rate increase from baseline in the current study was less than 35 bpm, resulting in an average maximum heart rate of 128 bpm. As a result, heart rate may not have disrupted the participants' homeostasis enough to influence affect. While perceived exertion did increase substantially (i.e., 5.92 units), some participants may have been focusing on feelings of exertion related to their arms, rather than an overall sensation of bodily physical stress. The combined feelings of physical stress may not have been strong enough to influence affect. These explanations also account for the relatively smaller correlations between heart rate, perceived exertion, and affect at high intensities observed in our study compared to other studies (e.g., Acevedo et al., 1994; Hardy & Rejeski, 1989). Bearing the above limitations in mind (i.e., low variability in enjoyment, relatively low heart rate), our findings using arm ergometry as the exercise mode provide partial support for the basic predictions of the Dual-mode theory. In addition, as previous research in this area has been correlational in nature, our study is the first to demonstrate cognitive and physiological variables as mediators of the relationship between acute aerobic exercise and affect.

Affective responses during recovery

Hypothesis 4. As predicted, there were no significant differences in state anxiety between conditions during the recovery. While several studies have not found a difference between exercising and quiet rest on state anxiety during recovery periods up to 30 minutes (e.g., Bahrke & Morgan, 1978; Focht & Hasenblaus, 2001; Petruzzello et al., 1991), at further periods into recovery (e.g., 60 and 90 minutes), differences have materialized (e.g., Cox et al., 2004). As our study assessed affective responses to 45 minutes into recovery, it is quite possible that anxiety may have changed beyond this time point, resulting in differences between exercise and control conditions. Indeed, it may take 15-30 minutes for a reduction in state anxiety to develop after exercise (Raglin et al., 1993; Cox et al., 2004), and if the intensities of exercise are in the higher range, this delay could be longer (Raglin & Wilson, 1996). It is worth mentioning that the average anxiety score across all conditions at baseline in our study was low (i.e., 31.93, see Appendix C). As the State Anxiety Inventory scores can range from 20 (lowest possible level of anxiety) to 80 (highest possible level of anxiety), participants were not very anxious prior to each experimental condition. Therefore, floor effects may be another reason why state anxiety did not differ between conditions during recovery. In other words, as anxiety scores were low at baseline, there would not be much room for improvement during the recovery period.

Hypothesis 5. The hypothesis that arousal would be higher in the exercise conditions than in the control condition during the entire recovery phase, received partial support. While the above GET condition differed from the control condition during the entire recovery period, the below GET condition differed from the control condition for only 4 of the 5 recovery timepoints (i.e., no significant differences at minute 45). In general, our findings using arm ergometry are consistent with previous work in lower body exercise, which has found arousal in exercise conditions to be higher than control conditions for 20 minutes (Van Landuyt et al., 2000) to 30 minutes post-exercise (Tate & Petruzzello, 1995). The slightly different pattern of results in the present study for the above and below GET conditions may be a function of the in-task differences in arousal between the exercise conditions. Although not significantly different, the 80% GET condition was slightly less aroused/activated during exercise than the 105% GET condition. Thus, a return to baseline levels of arousal (and below) could be expected to occur earlier for the 80% GET condition than the 105% GET condition during recovery.

Hypothesis 6. The prediction that affective valence in the exercise conditions would be significantly different from the control condition at 5, 10 and 20 minutes into recovery, but would not be significantly different from the control condition at 30 and 45 minutes into recovery, was partially supported. Specifically, the differences in affective valence between the exercise conditions and the control condition persisted only for 10 minutes. These findings are consistent with some previous research (Van Landuyt et al., 2000) but not with others (Tate & Petruzzello, 1995). A possible reason for this disparity is the way in which affective valence was measured. Although Tate and Petruzzello (1995) also assessed affective valence with the Tense Arousal scale, only the tension items were included. In the context of exercise, the calmness items may be more susceptible to change than the tension items (see Figure 8 and 9). Consequently, when only tension is measured during recovery, tense arousal in an exercise condition may be no different from tense arousal in a control condition.

Hypothesis 7. The final hypothesis, that there would not be a significant difference in any of the affect measures between the 80% GET and 105% GET conditions during recovery was supported. This finding with upper body exercise (i.e., arm ergometry) is consistent with previous literature using lower body exercise (e.g., Bixby & Lochbaum, 2006; Cox et al., 2004; Ekkekakis et al., 2008; Kilpatrick et al. 2007; Petruzzello & Landers, 1991). Our results suggest that any between-condition effects on affect would likely have dissipated by 5 minutes. As the first assessment time point during recovery was at 5 minutes, participants had an opportunity to "cool down" before their first recovery period affective assessment. As a result, the physiological activation which had occurred during exercise was no longer evident (i.e., heart rate had, on average, declined to levels below baseline).

Limitations

Over the course of conducting this study, some limitations became apparent and warrant mention. First, although all trials (i.e., conditions) were completed on separate days in order to avoid fatigue effects, for some individuals, the trials were completed on consecutive days, while for others the trials took place over the course of 1 month. Ideally, we would have preferred to keep the amount of time between testing sessions constant, but logistically, this was not feasible. It is possible that those individuals who completed the trials on consecutive days were more fatigued than those who did not have this schedule. Such an occurrence might cause further decreases in affective valence during exercise due to a greater disruption in homeostasis. Second, while participants were asked not to exercise on the days of testing, no instructions were given regarding diet and rest (e.g., refrain from consuming caffeine and alcohol, make an effort to obtain 8 hours of sleep the night prior to testing). These are variables that have been controlled in other studies (e.g., Bixby & Lochbaum, 2006) due to their potential influence on affect (e.g., poor sleep/diet resulting in lower levels of energy). Not controlling for these factors in the present study may have caused differences in affective responses for reasons other than condition assignment. Third, while all attempts were made to control the environment of the laboratory, adjacent labs were also conducting testing which involved maximal resistance and aerobic training protocols. This testing occasionally resulted in a considerable amount of noise, which could have distracted the participants in the current study from noticing any cognitive and/or physiological processes that may influence affective responses. Finally, low Cronbach's alpha levels (i.e., $\alpha < .70$) were found for some of the tense arousal measures. As such, the related results for tense arousal should be interpreted with caution.

Future directions

Future study of affective responses to exercise would benefit from considering several issues. First, replicating this study in individuals who use arm ergometers on a regular basis (e.g., individuals with spinal cord injury), and who may have lower levels of cardiovascular fitness, would be worthwhile. As affective responses have shown to be influenced by the physical fitness of participants (Bixby & Lochbaum, 2006; Gauvin, Rejeski, Norris, & Lutes, 1997), examination of such responses in these populations would provide useful information about the influence of physical fitness on affective responses while exercising on an arm ergometer. Second, it may be meaningful to assess in-task affect using a combination of the Activation-Deactivation Adjective Check List, the Feeling Scale, and the Felt Arousal Scale. Studies that have used the Activation-Deactivation Adjective Check List in conjunction with the Feeling Scale and Felt Arousal Scale have not used the Activation-Deactivation Adjective Check List during exercise (likely due to the longer administration time of this measure). However, as these measures are meant to capture arousal and affective valence within a circumplex structure, including all of these measures in the same study would provide a more comprehensive assessment of basic affective responses to acute exercise. Third, it would be informative from both a theoretical and applied perspective to examine cognitive variables as potential mediators in an above GET condition, and physiological variables in a below GET condition (these potential mediators were not examined in the present study as only the tenets of the Dual-mode theory were tested). Finally, and perhaps most importantly, future studies should assess whether intensity-dependent differences in affective responses make a difference to exercise adherence, in the first few weeks and over the long run. This is an area of study that has been proposed for some time (e.g., Morgan, 1977), but has still not received sufficient attention (Dishman, 2003).

Conclusions

The results of the present study have important theoretical and applied implications. From a theoretical standpoint, support was provided for the use of the Dual-mode theory as a methodological framework for investigations of the exercise and affect relationship in dose-response studies. From a practical perspective, exercising above GET was shown to elicit declines in affective valence, which may ultimately reduce motivation for exercise and decrease adherence. Taken together, our findings speak to the importance of self-monitoring and self-regulating exercise intensity to maximize the affective benefits of exercise.

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Table 1

Participant (N=24) Characteristics

Variable	*M*	*SD*	*Min*	*Max*
Age	22.50	3.38	18.00	29.00
Height (cm)	179.96	5.61	170.00	195.00
Weight (kg)	76.38	12.99	52.00	100.00
VO_2 peak (ml/kg)	26.21	4.49	19.40	37.80
VO_2 peak (L/min)	2.00	.44	1.11	2.63
GET (W)	58.54	11.75	30.00	75.00
80% GET (W)	46.83**	9.40	24.00	60.00
105% GET (W)	61.47**	12.33	31.50	78.75

Note. W = Watts; GET = Gas Exchange Threshold.

**t-test, $p < .01$.

Table 2

Questionnaire Administration by Time-point

Baseline	FP	5 min	10 min	15 min	5 post	10 post	20 post	30 post	45 post
ADACL	SE	ADACL	ADACL	ADACL	ADACL	ADACL	ADACL	ADACL	ADACL
SAI	PACES	SAI	SAI	SAI	SAI	SAI	SAI	SAI	SAI
BPI		BPI	BPI	BPI					
RPE		RPE	RPE	RPE					
				SE					
				PACES					

Note. FP = Familiarity Protocol; ADACL = Activation Deactivation Adjective Checklist; SAI = State Anxiety Inventory; BPI = Brief Pain Inventory; RPE = Rating of Perceived Exertion; SE = Self-efficacy; PACES = Physical Activity Enjoyment Scale.

Table 3

Scale Psychometrics

Scale	α		α		α
Energetic Arousal					
Control (Baseline)	0.73	80% GET (Baseline)	0.84	105% GET (Baseline)	0.79
Control (5)	0.76	80% GET (5)	0.79	105% GET (5)	0.79
Control (10)	0.70	80% GET (10)	0.78	105% GET (10)	0.83
Control (15)	0.79	80% GET (15)	0.82	105% GET (15)	0.80
Control (5R)	0.83	80% GET (5R)	0.87	105% GET (5R)	0.79
Control (10R)	0.80	80% GET (10R)	0.88	105% GET (10R)	0.80
Control (20R)	0.81	80% GET (20R)	0.87	105% GET (20R)	0.80
Control (30R)	0.81	80% GET (30R)	0.88	105% GET (30R)	0.81
Control (45R)	0.80	80% GET (45R)	0.87	105% GET (45R)	0.83
Tense Arousal					
Control (Baseline)	0.80	80% GET (Baseline)	0.66	105% GET (Baseline)	0.78
Control (5)	0.79	80% GET (5)	0.65	105% GET (5)	0.63
Control (10)	0.76	80% GET (10)	0.75	105% GET (10)	0.65
Control (15)	0.79	80% GET (15)	0.68	105% GET (15)	0.68
Control (5R)	0.80	80% GET (5R)	0.71	105% GET (5R)	0.68
Control (10R)	0.76	80% GET (10R)	0.71	105% GET (10R)	0.69
Control (20R)	0.73	80% GET (20R)	0.75	105% GET (Baseline)	0.71
Control (30R)	0.69	80% GET (30R)	0.71	105% GET (5R)	0.69
Control (45R)	0.77	80% GET (45R)	0.63	105% GET (45R)	0.66

State Anxiety Inventory					
Control (Baseline)	0.89	80% GET (Baseline)	0.89	105% GET (Baseline)	0.92
Control (5)	0.87	80% GET (5)	0.89	105% GET (5)	0.92
Control (10)	0.87	80% GET (10)	0.87	105% GET (10)	0.91
Control (15)	0.89	80% GET (15)	0.85	105% GET (15)	0.91
Control (5R)	0.90	80% GET (5R)	0.87	105% GET (5R)	0.92
Control (10R)	0.88	80% GET (10R)	0.89	105% GET (10R)	0.91
Control (20R)	0.93	80% GET (20R)	0.91	105% GET (Baseline)	0.91
Control (30R)	0.91	80% GET (30R)	0.90	105% GET (5R)	0.89
Control (45R)	0.92	80% GET (45R)	0.91	105% GET (45R)	0.87
Self-efficacy					
Control (Baseline)	0.88	80% GET (Baseline)	0.94	105% GET (Baseline)	0.93
Control (15min)	0.86	80% GET (15min)	0.87	105% GET (15min)	0.95
Physical Activity Enjoyment Scale					
Control (Baseline)	0.94	80% GET (Baseline)	0.93	105% GET (Baseline)	0.94
Control (15min)	0.94	80% GET (15min)	0.95	105% GET (15min)	0.95

Note. R = Minutes into recovery; GET = Gas Exchange Threshold.

Table 4

DAUC of Psychological Responses (M ± SD) *for the Control and Exercise Conditions*

	Control	80% GET	105% GET
State Anxiety			
Baseline-15min	140.00 ± 41.67	174.69 ± 59.11^{a*b**}	221.15 ± 77.07^{a**}
Energetic Arousal			
Baseline-15min	92.60 ± 41.07	173.23 ± 46.46^{a**}	190.94 ± 29.73^{a**}
Tense Arousal			
Baseline-15min	59.06 ± 15.67	146.25 ± 28.47^{a**b**}	175.63 ± 38.02^{a**}

Note. DAUC = Delta Area Under the Curve; GET = Gas Exchange Threshold.

[a] Significant difference compared to control. [b] Significant difference compared to 105% GET.

*$p < .05$. **$p < .01$.

Table 5

Change Scores for the Potential Mediators (M ± SD) *for the Control and Exercise Conditions*

	Control	80% GET	105% GET
Self-efficacy	.32 ± .62	1.60 ± 1.71[a**]	1.40 ± 1.54[a*]
Enjoyment	-4.92 ± 11.95	4.46 ± 10.84[a*]	2.21 ± 10.33
Heart rate	-14.58 ± 8.72	24.5 ± 14.98[a**b**]	34.88 ± 19.37[a**]
Pain	-.17 ± .48	2.21 ± 1.74[a**b**]	4.42 ± 2.10[a**]
Perceived exertion	-.13 ± .37	3.69 ± 2.03[a**b**]	5.92 ± 2.03[a**]

Note. GET = Gas Exchange Threshold.

[a] Significant difference compared to control. [b] Significant difference compared to 105% GET.

*$p < .05$. **$p < .01$.

Table 6

Correlations between Affect Scores (DAUC) and Change Scores of the Potential Mediators

80% GET	State Anxiety	Energetic Arousal	Tense Arousal
Self-efficacy	-.44*	.11	.21
Enjoyment	-.06	-.26	.27
Heart rate	.08	.02	-.43
Pain	.38	.20	.13
Perceived exertion	.37	-.10	-.19
105% GET			
Self-efficacy	-.11	.08	-.31
Enjoyment	-.09	.05	-.12
Heart rate	.20	-.07	-.05
Pain	.17	-.56**	.03
Perceived exertion	.23	-.30	.23

Note. DAUC = Delta Area Under the Curve.

*$p < .05$. **$p < .01$.

Table 7

Linear Model Testing Changes in Self-efficacy as a Mediator of Changes in State Anxiety

Variable	*Adj.* R^2	β	t	p
Self-efficacy 1		.06	.31	.76
Self-efficacy 2	.20	-.52	-2.80	.01

Note. Adj. R^2 = Adjusted R-squared; Self-efficacy 1 = sum of self-efficacy in the control and 80% GET; Self-efficacy 2 = difference in self-efficacy between control and 80% GET conditions; The dependent variable was the difference in state anxiety between the control and 80% GET conditions.

Table 8

Linear Model Testing Changes in Pain as a Mediator of Changes in Energetic Arousal

Variable	*Adj.* R^2	β	t	p
Pain 1		.14	.73	.47
Pain 2	.14	-.44	-2.27	.03

Note. Adj. R^2 = Adjusted R-squared; Pain 1 = sum of pain in the control and 105% GET conditions; Pain 2 = difference in pain between control and 105% GET conditions; The dependent variable is the difference in changes in energetic arousal between the control and 105% GET conditions.

Table 9

Psychological Responses (M ± SD) *for Each Condition During the Recovery Period*

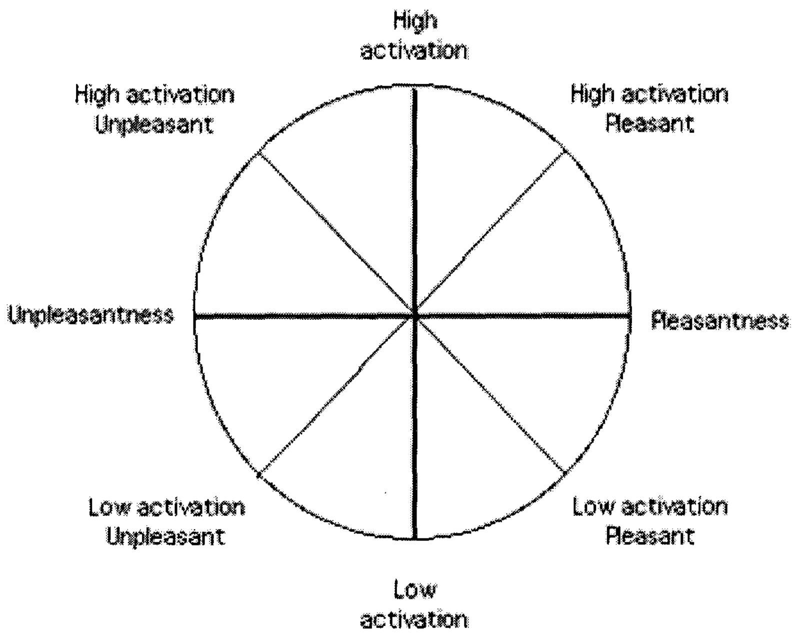
	Control	80% GET	105% GET
State Anxiety			
5mins	29.21 ± 6.98	28.50 ± 6.11	31.75 ± 8.86
10mins	29.29 ± 7.10	28.33 ± 6.87	30.79 ± 7.80
20mins	30.17 ± 9.05	28.21 ± 7.49	30.04 ± 7.15
30mins	29.67 ± 8.51	28.71 ± 7.79	29.92 ± 7.10
45mins	29.92 ± 8.46	28.04 ± 7.61	29.25 ± 6.65
Energetic Arousal			
5mins	22.21 ± 5.87	29.46 ± 6.59[a**]	30.33 ± 4.84[a**]
10mins	21.29 ± 5.45	26.08 ± 6.88[a**]	27.79 ± 5.47[a**]
20mins	20.25 ± 5.46	23.83 ± 6.84[a**]	23.67 ± 5.58[a**]
30mins	19.88 ± 5.70	23.25 ± 7.04[a**]	22.67 ± 5.58[a*]
45mins	19.96 ± 5.66	22.00 ± 6.99	22.75 ± 5.69[a*]
Tense Arousal			
5mins	15.33 ± 4.42	19.96 ± 4.42[a**]	20.75 ± 4.27[a**]
10mins	15.29 ± 4.22	17.21 ± 3.49[a*]	18.63 ± 3.83[a**]
20mins	15.29 ± 3.88	16.33 ± 4.19	16.21 ± 2.90
30mins	14.79 ± 3.36	15.50 ± 2.87	15.21 ± 3.01
45mins	15.04 ± 4.08	15.63 ± 3.44	16.00 ± 3.49

Note. GET = Gas Exchange Threshold.

[a] Significant difference compared to control. [b] Significant difference compared to 105% GET.

*$p < .05$. **$p < .01$.

Figure Captions



y axis = arousal
x axis = affective valence

Figure 1. A dimensional model of affect (the circumplex)

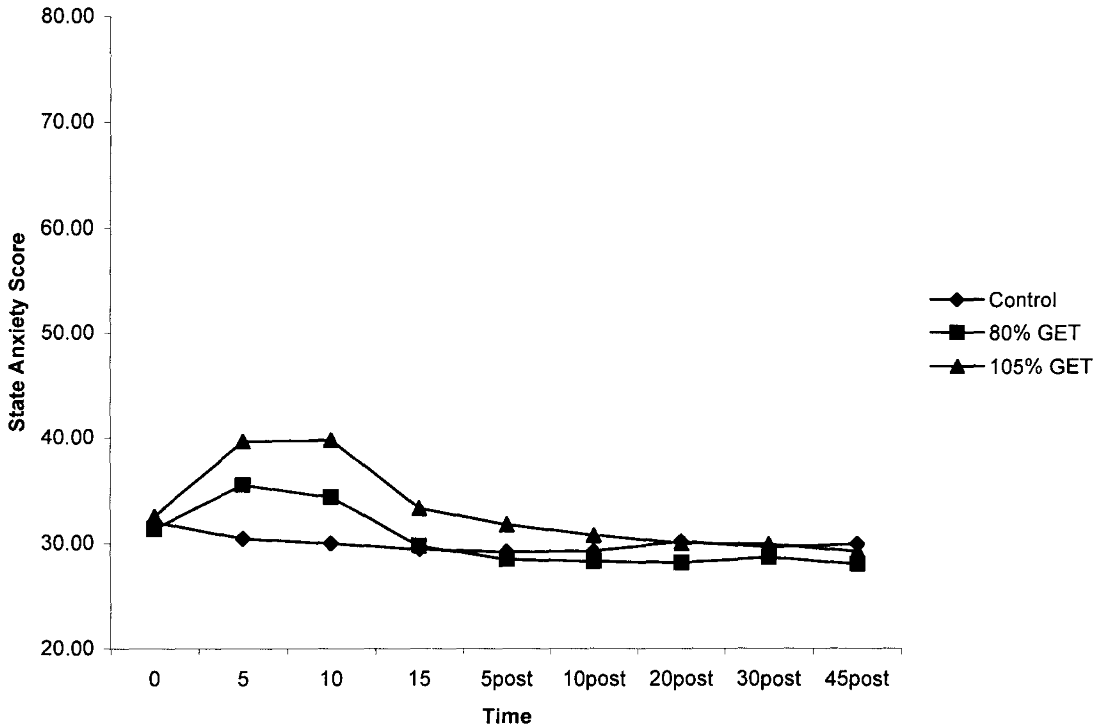


Figure 2. Changes in state anxiety in-task and during recovery

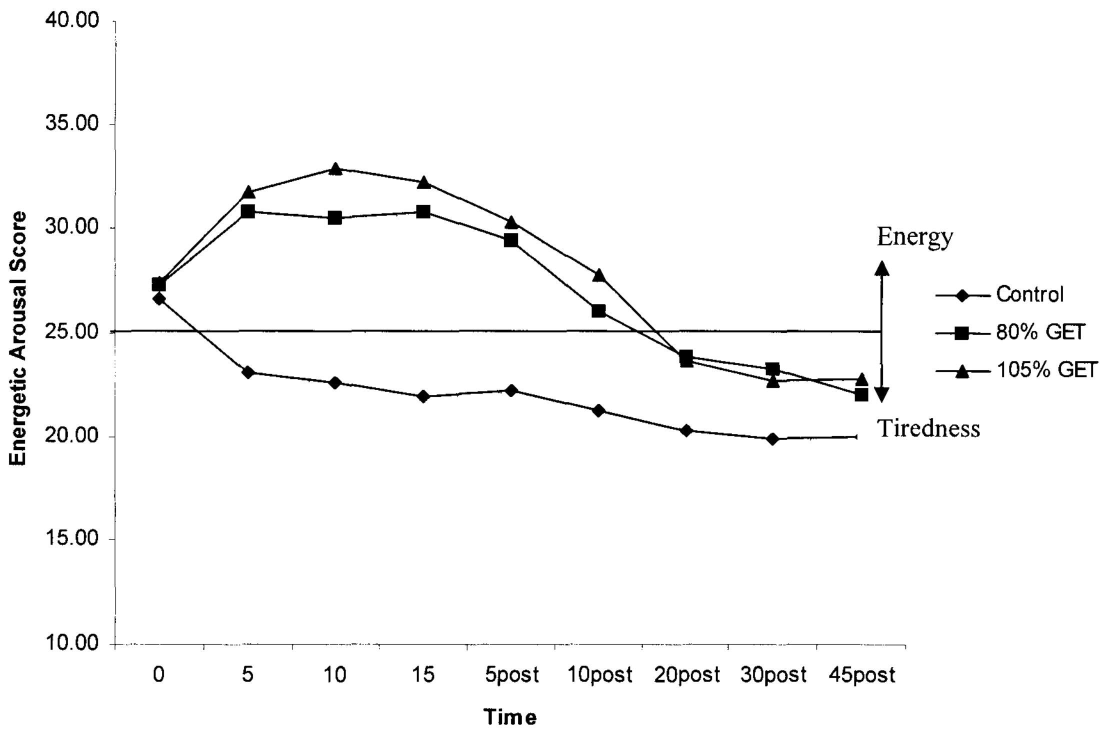


Figure 3. Changes in energetic arousal in-task and during recovery

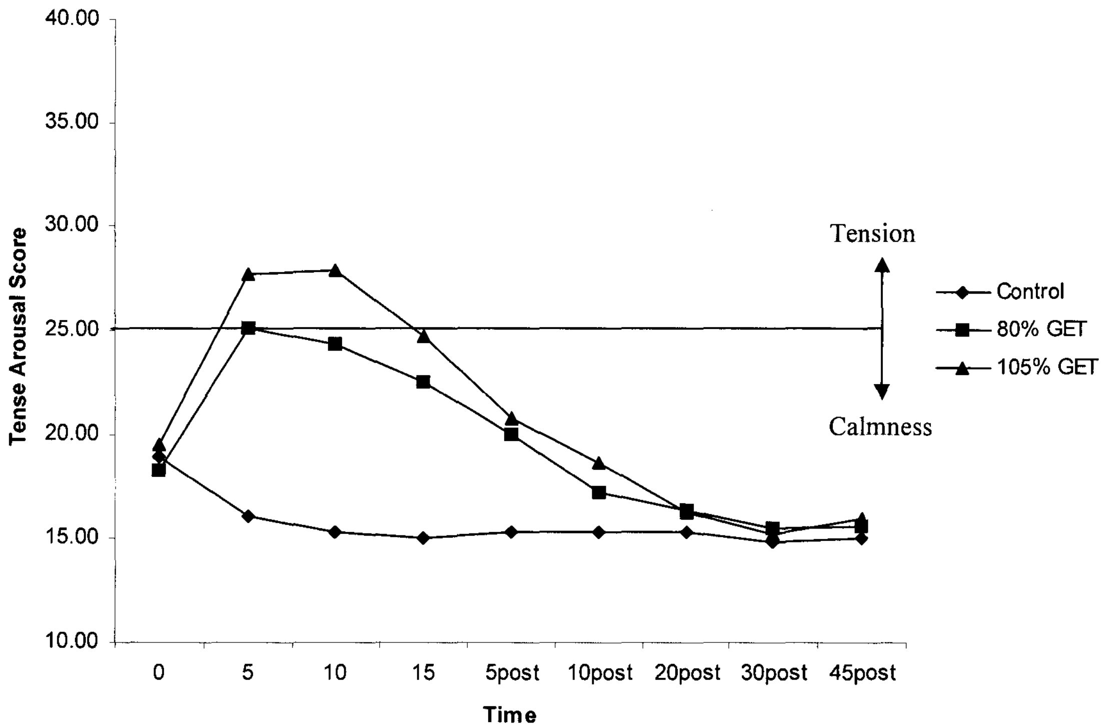


Figure 4. Changes in tense arousal in-task and during recovery

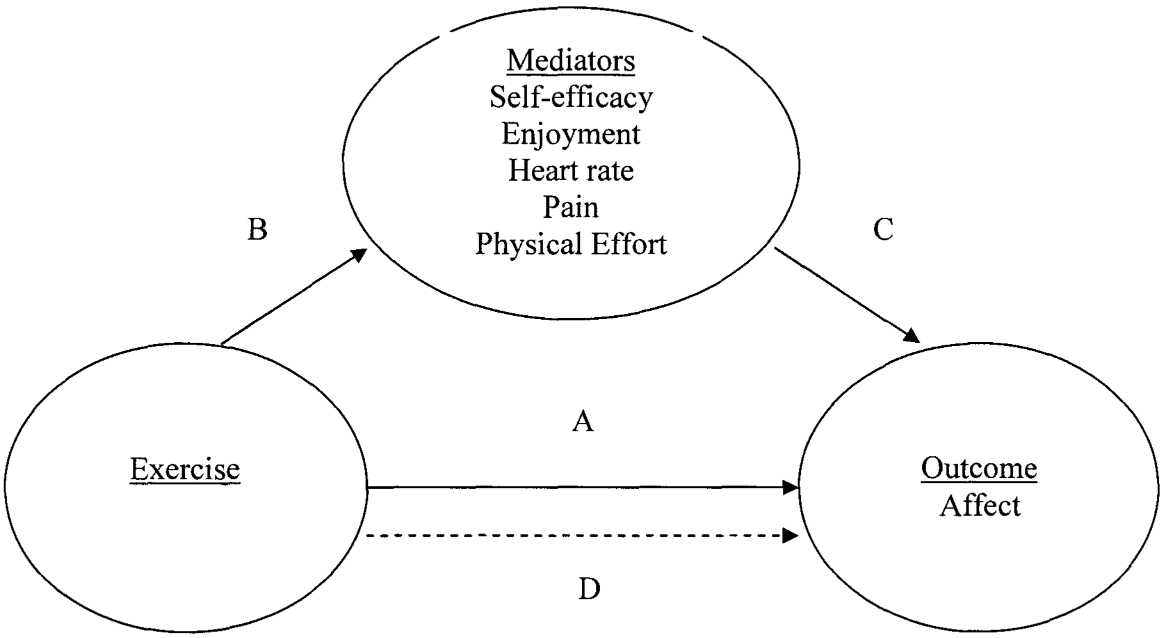


Figure 5. Conceptual model used for mediational analysis

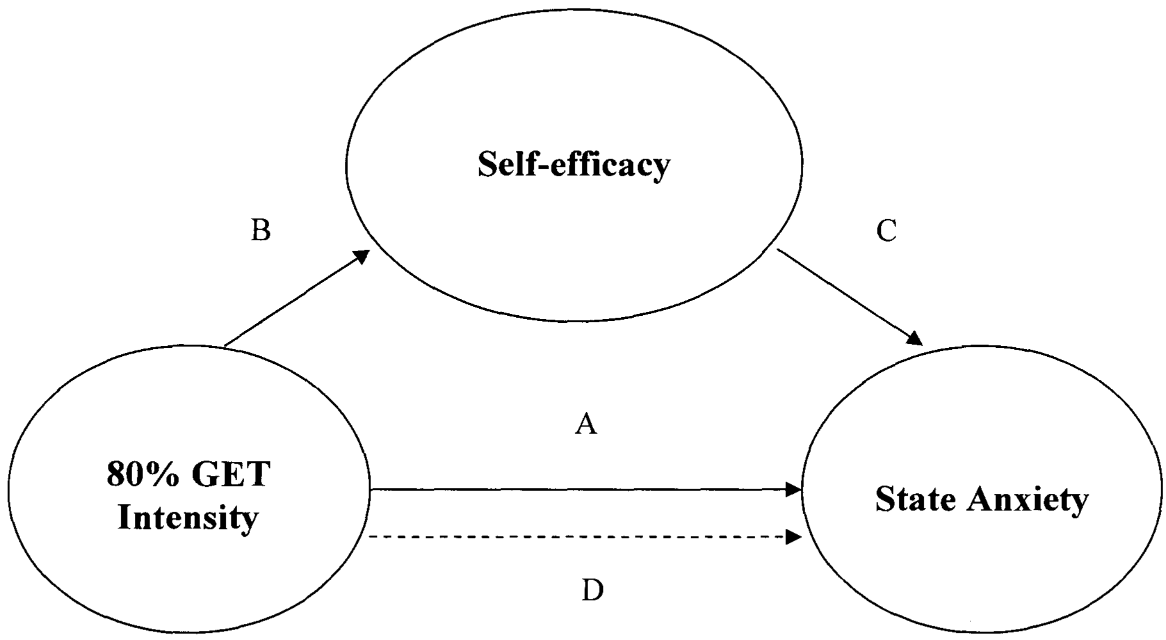


Figure 6. Changes in self-efficacy as a mediator of changes in state anxiety

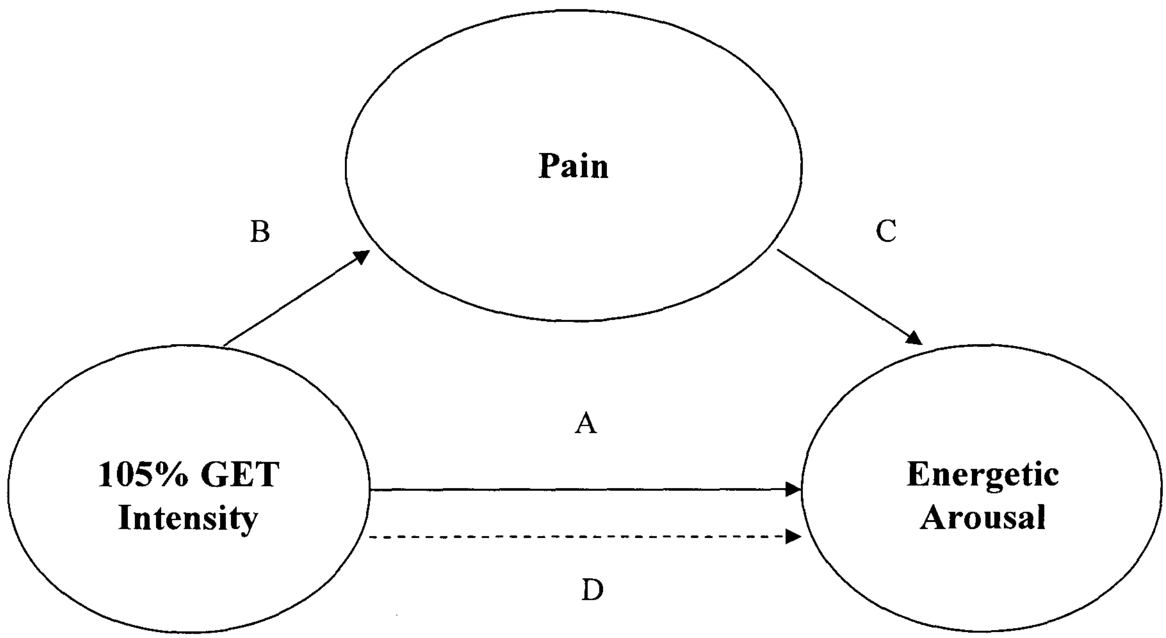


Figure 7. Changes in pain as a mediator of changes in energetic arousal

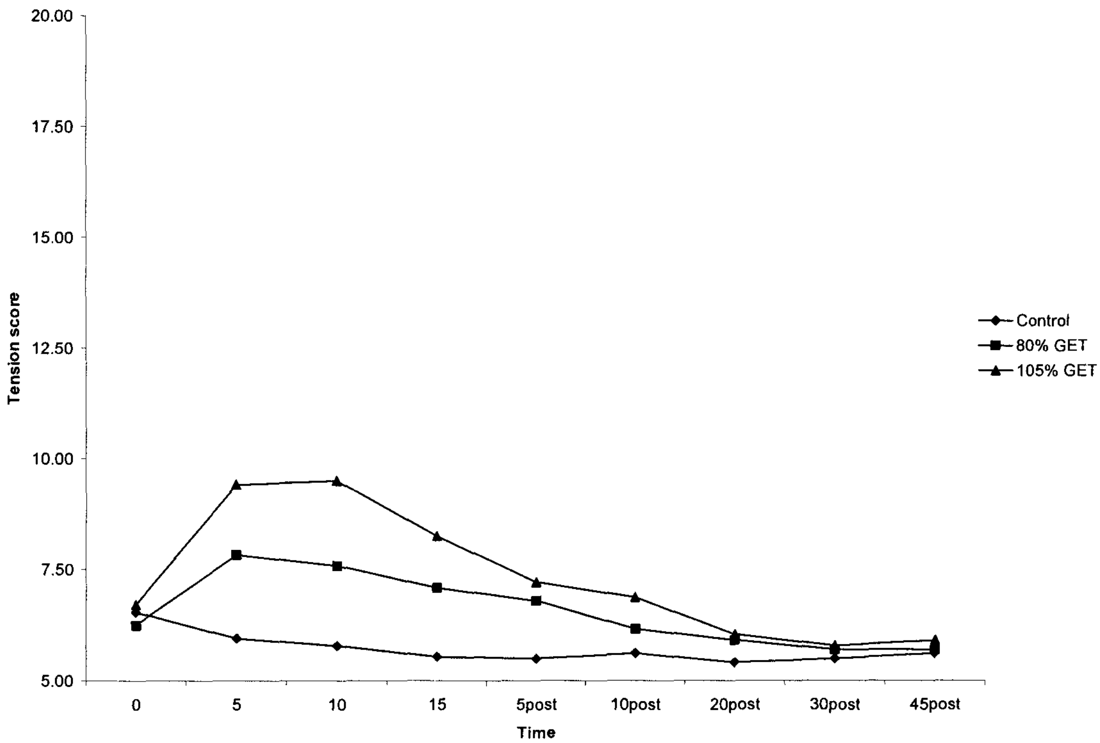


Figure 8. Changes in tension in-task and during recovery

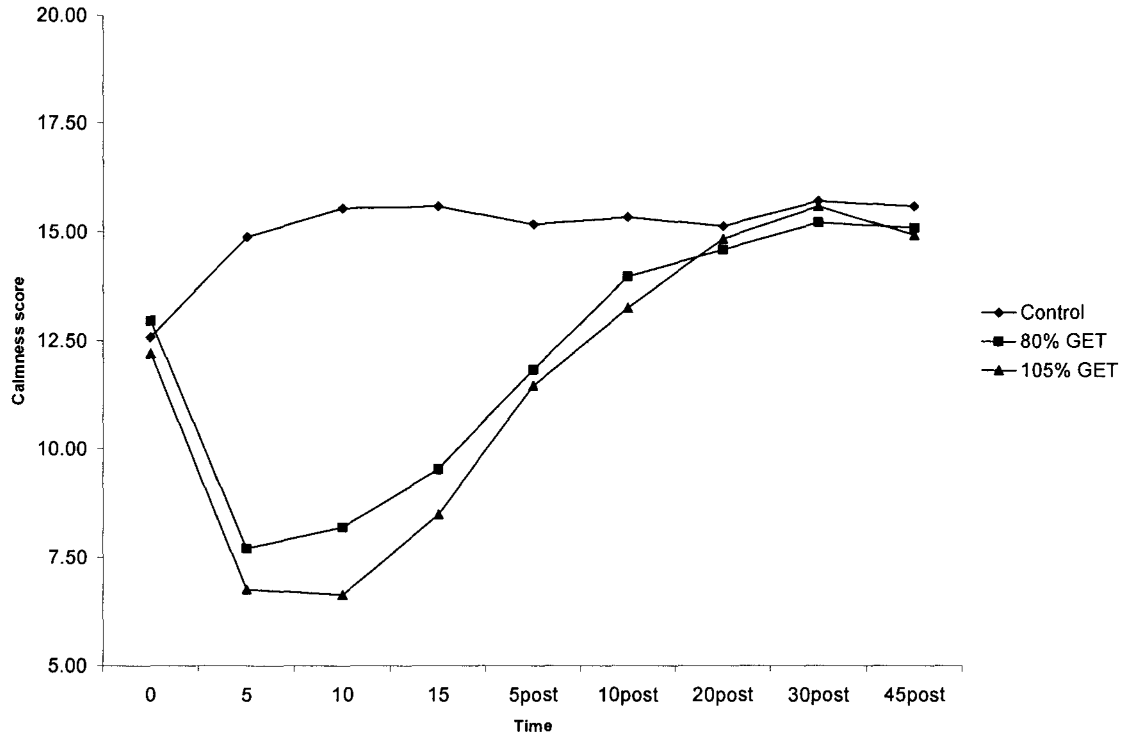


Figure 9. Changes in calmness in-task and during recovery

Appendix A

Participant Letter of Information and Informed Consent Letter

MCMASTER UNIVERSITY

INFORMATION LETTER / INFORMED CONSENT

The Acute Effects of Arm Ergometry on Affect

Principal Investigator: Dr. Kathleen Martin Ginis
Department of Kinesiology
McMaster University
Hamilton, Ontario, Canada
905-525-9140 ext. 23574

Student / Co-Investigator: Neil Barr (M.Sc. Candidate)
Department of Kinesiology
McMaster University
Hamilton, Ontario, Canada
905-525-9140 ext. 24694

WHY IS THIS RESEARCH BEING DONE?

We are interested in understanding the relationships between exercise and various kinds of mood. Given the numerous psychological and physical benefits associated with exercise, gaining a greater understanding of the effects of exercise on mood will serve to guide exercise promotion strategies. In other words, by determining the optimal intensity of exercise for improved mental-well being, physical activity could be prescribed in a manner conducive to maximizing enjoyment and thus, improve participation rates and enhance adherence.

WHAT IS THE PURPOSE OF THE STUDY?

The purpose of the study is to examine the effects of various intensities of physical activity on your thoughts and feelings regarding exercise.

WHAT WILL MY RESPONSIBILITIES BE IF I TAKE PART IN THIS STUDY?

In agreeing to participate in the study, you will attend the exercise facility at McMaster at an agreeable time at which point you will be asked to perform a VO_{2peak} test. This test involves cycling on a hand bike (arm ergometer) at progressively higher workloads while the amount of oxygen taken up by your body is determined from a mouthpiece connected to a gas analyzer. We will also monitor your heart rate from a strap placed around your chest. The test will last approximately 30 min.

You will also be scheduled for 3 more sessions in which you will complete 2 exercise bouts of 15 minutes each (at 2 different intensities) on one of the hand cycle machines in the rehabilitation centre, and 1 session involved in quiet reading. Prior to, during, and after each session you will be asked to complete several questionnaires about your thoughts and feelings. The total time required to complete the questionnaires for each exercise session will be about 15 minutes. We will also monitor your heart rate from a strap placed around your chest. Thus, your participation in the study is requested for 4 assessment time points that will take place over 4 visits to the rehabilitation centre. Each session will take approximately 45 minutes (i.e., a 15 minute exercise session followed by a 30 minute rest period). Completion of all questionnaires from beginning to end as well as the exercise sessions (including the VO_{2peak} test on day 1) requires a total time commitment of approximately 3 hours.

WHAT ARE THE POTENTIAL RISKS AND DISCOMFORTS?

There are no serious risks associated with taking part in this study. The potential risks and discomforts associated with the exercise testing procedures are similar to those associated with any form of heavy physical activity. These include but are not limited to: fatigue, fainting, abnormal blood pressure and irregular heart rhythm. Every effort will be made to minimize these potential risks by evaluation of preliminary information relating to your health and fitness and by careful observations during testing.

WHAT ARE THE POTENTIAL BENEFITS TO ME AND/OR SOCIETY?

You will receive a personalized fitness report after the first session. This will inform you of your current fitness level and can give you a reference point to which future fitness assessments can be compared. The findings from the study will be informative for researchers attempting to understand the associations between several intensities of aerobic activity and mood in arm ergometry. The findings may have implications for fostering motivation to start and maintain a physical activity program.
For participation in this study, you will receive $10 for each testing session. Therefore, a total of $40 will be paid to you over 4 testing sessions.

WHAT INFORMATION WILL BE KEPT PRIVATE?

Any information that is obtained during this study that can be identified with you will be kept private. This information will only be released with your permission or as required by law. Do not write your name on any part of the questionnaires. A randomized number assigned to you will be used to match surveys from each time point.

Any information obtained during the testing is private. This information will be kept in a locked filing cabinet in Dr. Martin Ginis' research laboratory for a period of five years and then will be destroyed. Only the primary investigators will have access to this information. Your identity will never be revealed in any reports of this study.

It is possible that a member of the McMaster Research Ethics Board may access your research data in order to monitor this study. You permit such access by signing this consent form.

CAN PARTICIPATION IN THE STUDY END EARLY?

If you decide to volunteer for this study, you are free to stop taking part at any time without consequences of any kind. You may choose to remove your data from the study at any time. You may also refuse to answer any questions you don't want to answer and still remain in the study. The researcher may remove you from this study if circumstances arise which warrant doing so (e.g., if you are having difficulty answering some of the questions). You may remove your consent and stop taking part in this study at any time without penalty.

You are not waiving any legal claims, rights or remedies because you are taking part in this research study. Data obtained from the study will be included in the analysis unless you indicate otherwise. If you indicate that you would like your data withdrawn from the study, it will not be included in the analysis and the data will be destroyed and deleted from the electronic datafile.

INFORMATION ABOUT STUDY RESULTS

Upon completion of the study, a report of the research findings will be available to you. You may contact the student investigator at any time after study completion if you wish to obtain this information.

IF I HAVE ANY QUESTIONS OR CONCERNS, WHOM CAN I CALL?

If you have any questions or concerns about the study now or later, please feel free to contact Neil Barr at 905-525-9140 ext. 24694 or Dr. Martin Ginis at 905-525-9140 ext. 23574.

This study has been reviewed and approved by the McMaster Research Ethics Board. If you have concerns or questions about your rights as a participant or about the way the study is conducted, you may contact:

McMaster Research Ethics Board Secretariat
Telephone: (905) 525-9140 ext. 23142
c/o Office of Research Services
E-mail: ethicsoffice@mcmaster.ca

CONSENT

I have read the information presented in the information letter about a study being conducted by Dr. Kathleen Martin Ginis and Neil Barr of McMaster University. I have had the opportunity to ask questions about my involvement in this study, and to receive any additional details I wanted to know about the study. I understand that I may withdraw from the study at any time, if I choose to do so, and I agree to participate in this study. I have been given a copy of this form.

____

Name of Participant

Appendix B

Study Questionnaires

B1: The Activation-Deactivation Adjective Checklist

B2: The State Anxiety Inventory

B3: The Brief Pain Inventory

B4: The Rating of Perceived Exertion (Category Ratio 10)

B5: Self-efficacy

B6: The Physical Activity Enjoyment Scale

B1: The Activation-Deactivation Adjective Checklist

relaxed **vv** v ? no	If you circle the double check (vv) it means that you definitely feel relaxed at the moment.
relaxed vv **v** ? no	If you circle the single check (v) it means that you feel slightly relaxed at the moment.
relaxed vv v **?** no	If you circled the question mark (?) it means that the word does not apply or you cannot decide if you feel relaxed at the moment.
relaxed vv v ? **no**	If you circled the (no) it means that you are definitely not relaxed at the moment.

Work rapidly, but please mark all the words. Your first reaction is best.

active vv v ? no	drowsy vv v ? no
placid vv v ? no	fearful vv v ? no
sleepy vv v ? no	lively vv v ? no
jittery vv v ? no	still vv v ? no
energetic vv v ? no	wide-awake vv v ? no
intense vv v ? no	clutched-up vv v ? no
calm vv v ? no	quiet vv v ? no
tired vv v ? no	full-of-pep vv v ? no
vigorous vv v ? no	tense vv v ? no
at-rest vv v ? no	wakeful vv v ? no

B2: The State Anxiety Inventory

A number of statements which people have used to describe themselves are given below. Read each statement and then use the rating scales to the right of each set of items to indicate how you feel right now, that is, at this moment. There are no right or wrong answers. Do not spend too much time on any one statement but give the answer that seems to describe your present feelings best. Work rapidly, but please mark all the statements. Your first reaction is best. This should only take a minute or two.

1	2	3	4
Not At All	Somewhat	Moderately So	Very Much So

1. I feel calm	1	2	3	4
2. I feel secure	1	2	3	4
3. I am tense	1	2	3	4
4. I am regretful	1	2	3	4
5. I feel at ease	1	2	3	4
6. I feel upset	1	2	3	4
7. I am presently worrying over possible misfortunes	1	2	3	4
8. I feel rested	1	2	3	4
9. I feel anxious	1	2	3	4
10. I feel comfortable	1	2	3	4
11. I feel self-confident	1	2	3	4
12. I feel nervous	1	2	3	4
13. I am jittery	1	2	3	4
14. I feel "high strung"	1	2	3	4
15. I am relaxed	1	2	3	4
16. I feel content	1	2	3	4
17. I am worried	1	2	3	4

18. I feel overexcited and rattled	1	2	3	4
19. I feel joyful	1	2	3	4
20. I feel pleasant	1	2	3	4

B3: The Brief Pain Inventory

Please rate your upper body pain by circling the one number that tells how much pain you have right now.

0	1	2	3	4	5	6	7	8	9	10
No pain										Pain as bad as you can imagine

B4: The Rating of Perceived Exertion (Category Ratio 10)

While doing physical activity, we want you to rate your perception of exertion. This feeling should reflect how heavy and strenuous the exercise feels to you, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any one factor such as leg pain or shortness of breath, but try to focus on your total feeling of exertion.

Look at the rating scale below while you are engaging in an activity; it ranges from 0 to 11, where 0 means "nothing at all" and 11 means "maximal exertion." Choose the number from below that best describes your level of exertion.

Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Your own feeling of effort and exertion is important, not how it compares to other people's. Look at the scales and the expressions and then give a number.

0	Nothing at all
0.5	Very, very weak
1	Very weak
2	Weak
3	Moderate
4	Somewhat strong
5	Strong
6	
7	Very strong
8	
9	
10	Very, very strong
11	Maximal exertion

B5: Self-efficacy

Please complete the following questions by circling the responses that indicates your level of confidence.

I believe I am able to continue exercising for 2 minutes at this intensity

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident Very confident

I believe I am able to continue exercising for 4 minutes at this intensity

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident Very confident

I believe I am able to continue exercising for 6 minutes at this intensity

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident Very confident

I believe I am able to continue exercising for 8 minutes at this intensity

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident Very confident

I believe I am able to continue exercising for 10 minutes at this intensity

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident Very confident

I believe I am able to continue exercising for 12 minutes at this intensity

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident Very confident

I believe I am able to continue exercising for 14 minutes at this intensity

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%
Not at all confident Very confident

I believe I am able to continue exercising for 16 minutes at this intensity

0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Not at all confident										Very confident

B6: The Physical Activity Enjoyment Scale

Please rate how you feel *at the moment* about the physical activity you have been doing.

*	I enjoy it	1	2	3	4	5	6	7	I hate it
	I feel bored	1	2	3	4	5	6	7	I feel interested
	I dislike it	1	2	3	4	5	6	7	I like it
*	I find it pleasurable	1	2	3	4	5	6	7	I find it unpleasurable
*	I am very absorbed in this activity	1	2	3	4	5	6	7	I am not at all absorbed in this activity
	It's no fun at all	1	2	3	4	5	6	7	It's a lot of fun
*	I find it energizing	1	2	3	4	5	6	7	I find it tiring
	It makes me depressed	1	2	3	4	5	6	7	It makes me happy
*	It's very pleasant	1	2	3	4	5	6	7	It's very unpleasant
*	I feel good physically while doing it	1	2	3	4	5	6	7	I feel bad physically while doing it
*	It's very invigorating	1	2	3	4	5	6	7	It's not at all invigorating
	I am very frustrated by it	1	2	3	4	5	6	7	I am not at all frustrated by it
*	It's very gratifying	1	2	3	4	5	6	7	It's not at all gratifying
*	It's very exhilarating	1	2	3	4	5	6	7	It's not at all exhilarating
	It's not at all stimulating	1	2	3	4	5	6	7	It's very stimulating
*	It gives me a strong sense of accomplishment	1	2	3	4	5	6	7	It does not give me any sense of accomplishment at all
*	It's very refreshing	1	2	3	4	5	6	7	It's not at all refreshing
	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 C

Mean Psychological Responses (M ± SD) For All Experimental Conditions

	Control	80% GET	105% GET
State Anxiety			
Pre	31.96 ± (8.02)	31.33 ± (7.49)	32.50 ± (9.43)
5	30.46 ± (6.66)	35.46 ± (7.86)	39.63 ± (9.46)
10	30.00 ± (6.51)	34.29 ± (6.93)	39.75 ± (9.44)
15	29.46 ± (6.87)	29.75 ± (5.99)	33.25 ± (9.22)
5-P	29.21 ± (6.99)	28.50 ± (6.11)	31.75 ± (8.86)
10-P	29.29 ± (7.10)	28.33 ± (6.87)	30.79 ± (7.80)
20-P	30.17 ± (9.05)	28.21 ± (7.49)	30.04 ± (7.15)
30-P	29.67 ± (8.51)	28.71 ± (7.79)	29.92 ± (7.10)
45-P	29.92 ± (8.46)	28.04 ± (7.61)	29.25 ± (6.65)
Energy			
Pre	10.58 ± (3.50)	11.29 ± (4.24)	11.08 ± (3.65)
5	8.21 ± (2.87)	13.88 ± (2.46)	14.58 ± (2.59)
10	7.79 ± (2.92)	13.92 ± (2.81)	15.42 ± (2.22)
15	7.38 ± (2.43)	13.96 ± (2.91)	14.63 ± (2.41)
5-P	7.58 ± (3.11)	12.79 ± (3.79)	13.25 ± (3.22)
10-P	7.08 ± (2.81)	10.00 ± (3.49)	11.25 ± (3.48)
20-P	6.63 ± (2.46)	8.92 ± (3.05)	8.71 ± (3.14)
30-P	6.96 ± (2.88)	8.46 ± (3.32)	7.92 ± (3.24)
45-P	7.00 ± (2.73)	7.92 ± (2.96)	7.96 ± (2.91)

	Control	80% GET	105% GET
Tiredness			
Pre	8.96 ± (3.72)	8.96 ± (3.11)	8.67 ± (2.81)
5	10.08 ± (4.28)	8.13 ± (3.15)	7.88 ± (1.68)
10	10.17 ± (4.03)	8.42 ± (3.24)	7.54 ± (1.69)
15	10.46 ± (4.27)	8.17 ± (3.41)	7.46 ± (1.86)
5-P	10.38 ± (4.33)	8.33 ± (3.73)	7.92 ± (2.54)
10-P	10.79 ± (4.26)	8.92 ± (4.32)	8.46 ± (3.09)
20-P	11.38 ± (4.21)	10.92 ± (2.48)	10.38 ± (2.06)
30-P	12.08 ± (4.44)	10.21 ± (4.82)	10.25 ± (3.91)
45-P	12.04 ± (4.52)	10.92 ± (4.84)	10.21 ± (3.84)
Tension			
Pre	6.54 ± (2.70)	6.25 ± (1.92)	6.71 ± (2.79)
5	5.96 ± (2.07)	7.83 ± (2.57)	9.42 ± (3.00)
10	5.79 ± (1.38)	7.58 ± (2.24)	9.50 ± (3.18)
15	5.54 ± (0.83)	7.08 ± (2.45)	8.25 ± (3.17)
5-P	5.50 ± (1.14)	6.79 ± (2.45)	7.21 ± (2.86)
10-P	5.63 ± (1.53)	6.17 ± (1.83)	6.88 ± (2.61)
20-P	5.42 ± (0.83)	5.92 ± (1.35)	6.04 ± (1.85)
30-P	5.50 ± (1.02)	5.71 ± (1.16)	5.79 ± (1.44)
45-P	5.63 ± (1.50)	5.71 ± (1.20)	5.92 ± (1.64)

	Control	80% GET	105% GET
Calmness			
Pre	12.58 ± (3.31)	12.96 ± (2.65)	12.21 ± (3.30)
5	14.88 ± (3.29)	7.71 ± (2.99)	6.75 ± (2.03)
10	15.54 ± (1.84)	8.21 ± (3.19)	6.63 ± (2.04)
15	15.58 ± (2.47)	9.54 ± (2.95)	8.50 ± (2.69)
5-P	15.17 ± (3.58)	11.83 ± (3.14)	11.46 ± (2.64)
10-P	15.33 ± (3.58)	13.96 ± (2.85)	13.25 ± (2.56)
20-P	15.13 ± (3.48)	14.58 ± (3.69)	14.83 ± (2.14)
30-P	15.71 ± (2.90)	15.21 ± (2.90)	15.58 ± (2.43)
45-P	15.58 ± (3.44)	15.08 ± (3.17)	14.92 ± (2.87)

Note. P = Post-exercise; GET = Gas Exchange Threshold.