

THE EXERCISE AND MOOD RELATION:
TESTING THE DUAL-MODE MODEL AND SELF-SELECTED SPEEDS

by

SARAH MELINDA MARKOWITZ

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ABSTRACT OF THE DISSERTATION

The Exercise and Mood Relation:

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By SARAH MELINDA MARKOWITZ

Dissertation Director:
G. Terence Wilson, Ph.D.

Evidence indicates that exercise improves mood, but not enough is known about the level of exertion required for optimum mood benefit. The present study examined the nature of the relation between exertion level and mood improvement in the theoretical context of the dual-mode hypothesis and opponent-process theory by testing mood changes in highly active and sedentary college-age participants in both assigned and self-selected conditions. As expected, exercise produced in-task arousal, and post-task mood improvement. As predicted by the dual-mode hypothesis and opponent-process theory, at low levels of exertion, in-task and post-task mood improvement was observed, and at high levels of exertion, in-task mood worsened, but post-task mood improved. Participants chose speeds close to 5% below lactate threshold. Theoretical and practical implications of these findings are discussed.

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Introduction

In the past fifteen years, there has been a rapid increase in high quality evidence that exercise is beneficial for both physical and mental health, yet very few Americans regularly engage in physical activity ("Healthy people 2010", 2000; Dubbert, 2002; Landers & Arent, 2001). One explanation for this problem is that exercise is physically and mentally aversive, and therefore people do not like to do it. There is, however, a substantial body of evidence that even a single bout of exercise improves post-exercise mood (Yeung, 1996). What is not known, though, is what dose of exercise is needed to produce optimal mood improvement in different individuals. Although there is some evidence that exercise-induced mood contributes to adherence to exercise (McAuley, Jerome, Elavsky, Marquez, & Ramsey, 2003), it remains to be determined if in-task increases in negative mood may account for the apparent paradox in which mood improvement follows exercise, yet poor adherence to exercise regimens is widely observed. If we could determine the optimum level of exertion for mood improvement in different individuals, this could be useful in promoting adherence to exercise routines among the general public, as well as helping clinicians recommend the most effective exercise treatment for patients with low mood. It is also scientifically important that this work be done in a theoretical context, or it will be impossible to refine recommendations in a consistent way as more evidence is gathered.

The physical benefits of exercise are numerous. Regular physical activity can reduce substantially the risk of developing or dying from heart disease, diabetes, colon cancer, and high blood pressure (U.S. Department of Health and Human Services, 1996). In addition to the physical benefits of exercise, there is substantial evidence that exercise

has a beneficial effect on mental health in both healthy and depressed individuals. Healthy subjects assigned to a ten-week program of moderate exercise improved their scores for tension-anxiety and confusion on the Profiles of Mood States (POMS), whereas those assigned to control conditions did not (Moses, Steptoe, Mathews, & Edwards, 1989). There is also evidence that regular exercise can prevent the onset of depression in persons who are at risk. Roth and Holmes (1987) identified college students with a high number of negative life events in the past year and randomly assigned them to exercise, relaxation training, or wait-list control conditions. Those in the exercise condition improved their scores on the Beck Depression Inventory (BDI) more than others within the first five weeks. Although statistically significant differences between those in the exercise and other conditions were not apparent at the end of the intervention or at follow-up, this may have been due to a floor effect of BDI score, and those in the exercise condition continued to improve (Roth & Holmes, 1987).

Meta-analysis has indicated that exercise is an effective treatment for depression, with an average benefit of .53 to .72 standard deviation improvement on measures of depression (Craft & Landers, 1998; Landers & Arent, 2001; North, McCullagh, & Tran, 1990). There is also evidence that exercise has a beneficial effect on anxiety. Recent reviews and meta-analyses show that the effect size of exercise on anxiety reduction is small to moderate, ranging from .15 to .56, with consistent results for state, trait and psychophysiological measures of anxiety in both clinical and non-clinical populations (Arent, Rogers, & Landers, 2001; Landers & Arent, 2001). Despite the benefits of exercise on mood, few mental health care professionals discuss exercise with patients,

leading experts to consider it an under-utilized intervention in mental health care (Callaghan, 2004).

Despite the benefits of exercise for physical and mental health, 40% of American adults engage in no leisure time physical activity whatsoever, and only 15% engage in the government recommended 30 minutes or more of moderate physical activity five or more days per week ("Healthy people 2010", 2000). Furthermore, among those who begin an exercise program, 50% drop out within six to twelve months (Dishman & Buckworth, 1997). This is a major public health problem. Exercise plays a significant role in preventing coronary heart disease (CHD), the leading cause of death and disability in the United States ("Healthy People 2010", 2000). It is crucial that we improve our understanding of people's motivation and ability to exercise. One facet of this is the subjective enjoyment or displeasure of exercise participation. Maybe there is something aversive about the experience of exercise for at least some people, even if mood improves upon exercise completion. Perhaps, if the mood effects of exercise were better understood, health care providers could capitalize on these effects by making better recommendations which would help people adhere to exercise regimens for both physical health and mood improvement, which would be an important public health contribution. Already, researchers have suggested that adherence to exercise programs might be improved among obese individuals by changing the emphasis from "should" to "want" by emphasizing the positives of exercise, based on the positive psychology model (Berger, 2004). Before we can make prescriptive use of the mood benefits of exercise to improve adherence, though, it is essential that we identify the moderators and mechanisms of the relation between exercise and mood to appropriately and accurately advise patients of the

optimal routine for them (North et al., 1990; O'Neal, Dunn, & Martinsen, 2000; Yeung, 1996).

Before further consideration of the issue of the effects of exercise on mood, it is important to understand what is meant by the term “mood.” When considering this question, some researchers have discussed “affect” or “affective states” as opposed to mood states. Ekkekakis and Petruzzello (2002) have argued for the circumplex model of affect in regard to exercise, in which affect is represented by valence (pleasure-displeasure) and activation (high-low), and affective states are combinations of these dimensions. Thayer (1989), on the other hand, defines mood as two dimensions of arousal: energy (v. tiredness) and tension (v. calmness). Optimal mood, in this case, would be states of high energy and low tension (energetic-calm), as opposed to the most negative mood state of low energy and high tension (tired-tense) (Thayer, 1989). Both affect and mood are valid and similar terms in the context of exercise. Affect is a more general concept, and mood is slightly more specific. Because of its increased specificity, the term mood will be used here.

In addition to the evidence that chronic exercise improves mood, there is also a substantial literature on mood improvement from a single bout of exercise. In an important review of the mood effects of acute exercise, Yeung (1996) noted that the vast majority of studies examining this phenomenon showed positive mood effects from exercise, while only a handful showed negative or no change in mood from exercise. Many of those that did not find mood benefit did not consider mood a primary outcome variable, usually because they were more interested in the psychophysiological response to cognitive stress following exercise (Yeung, 1996). Though most of this work has been

done in healthy participants, there is also evidence that a single bout of exercise improves mood in patients with Major Depressive Disorder (MDD) (Bartholomew, Morrison, & Ciccolo, 2005). Though reviewers have consistently found support for the relation between exercise and mood improvement, experts have called for further research to elucidate the mechanisms of this association, particularly within a theoretical framework (North et al., 1990; O'Neal et al., 2000; Yeung, 1996).

Researchers have considered the possibility of a dose-response relationship between exercise and mood improvement in the effort to determine optimal exertion level. Ekkekakis and Petruzzello's (1999) review of the literature on dose-response relation between exercise and mood concluded that this question is still unresolved, due to methodological and theoretical limitations of many studies. The prevailing notion that an inverted U-shaped curve exists, such that moderate exercise produces the most mood improvement, is based largely on intuition, with little theoretical or empirical support. Many studies have only examined two levels of exertion or duration, making it impossible to establish the inverted U-shaped curve. Furthermore, many studies have not taken into account individual differences, like fitness, and how these may affect the dose-response relationship (Ekkekakis & Petruzzello, 1999). Researchers have suggested that finding a dose-response curve is not realistic, as affective responses to exercise are too variable between individuals, though a trend toward universality may emerge at especially adaptive or maladaptive levels of exertion (Ekkekakis, Hall, & Petruzzello, 2005a). One exception to this is a study examining the dose-response relationship of three levels of resistance training on affect in healthy, active college students, which found evidence for the inverted U-shaped curve (Arent, Landers, Matt, & Etnier, 2005). Some

studies have shown that exercise at a high intensity improves mood post-exercise more than at moderate or low intensity among active college-age individuals (Cox, Hinton, & Donahue, 2006; Cox, Thomas, Hinton, & Donahue, 2004; Ekkekakis, 2001; Tate, Petruzzello, & Lox, 1995). Ekkekakis (2001) also found, however, that in-task affective valence was least variable and worst in the most intense exercise condition. Another study found no post-exercise difference between moderate and high-intensity exercise in college students (Berger & Owen, 1998). Finally, this relation must be tested in different populations, as there is some evidence that high intensity exercise may have a negative effect on post-exercise mood in middle-aged women (Oweis, 2001), though it has also been found to have a positive effect on mood in active middle-aged women (Cox et al., 2006). The present study aims to contribute to the dose-response literature by testing the mood effects of exercise at three different assigned levels of exertion and one self-selected level among active and inactive college students.

In order to better understand the results of studies of the differential effects of exertion level on mood, it is essential to consider potential theoretical frameworks that may account for these results. It is also important to consider other moderators that may contribute to the findings. Two of the most important theories regarding the effects of exertion level on mood are the opponent-process theory and the dual-mode model.

Solomon's opponent-process theory provides one potential explanation (Solomon, 1980, 1991; Solomon & Corbit, 1974). Although not developed specifically to explain the exercise and mood relation, it has been recommended that work in this area be done in this theoretical framework (Solomon, 1991). Opponent-process theory posits that the primary affective response (*a* process) is aroused by a particular stimulus (e.g., increased

negative mood from high-intensity exercise from physiological arousal and catecholamine secretion). A secondary (*b*) process (e.g., pleasure upon cessation of exercise) with the opposite valence of the *a* process is generated whenever the input from the *a* process reaches a threshold level of stimulation. The *b* process has a long latency, increases slowly, and lasts a long time, and it is strengthened by use (Solomon & Corbit, 1974). In exercise, the *a* process is most accurately described as the sympathetic activation and parasympathetic withdrawal that occurs during exercise, and the *b* process is the parasympathetic rebound that occurs in response. In high intensity exercise, some of the physiological changes (e.g., body temperature, heart rate, cortisol release) may not cease immediately upon ending exercise, so that some *a* processes may continue for some amount of time after exercise, while other *b* processes begin, potentially producing a wash-out effect, in which the *a* and *b* processes overlap and offset one another to some degree.

Ekkekakis (2001) found that in-task mood was worst for exercisers at the highest intensity, but this same group also got the most mood benefit post-exercise, as opponent-process theory would predict. There is a large body of evidence that mood improves post-exercise, regardless of the valence of in-task affect. This is a robust finding, applicable across types of exercise, environments, participants, and mood measures (Ekkekakis, 2003). Opponent-process theory accounts for those in whom in-task mood is negative. For those in whom in-task mood is positive, and post-exercise mood remains positive, it is possible that they did not reach a sufficient mood threshold to activate a compensatory *b* process and that the mechanisms by which in-task mood improvement occurs are still functioning.

One problem in the current literature on exercise and mood is the timing of questionnaires to assess mood. Most studies measured mood immediately before and after exercise, and sometimes again after a rest or recovery period. When mood measures are taken in-task, there is evidence that mood worsens during exercise as intensity increases, and then improves upon exercise completion and continue to improve during quiet rest (Ekkekakis & Petruzzello, 1999; Hall, Ekkekakis, & Petruzzello, 2002). Those studies that have examined in-task mood have used extremely brief measures, such as the Feelings Scale (FS) and Felt Arousal Scale (FAS), each only a single item scale. These brief instruments assess affect (i.e., valence and strength of mood state), which is different than mood per se. It is therefore difficult to determine the time course of mood with such instruments, especially when trying to make comparisons with longer measures assessing mood pre- and post-task. One study assessed mood at five-minute intervals during 20 minutes treadmill running at a moderate level of exertion in a small sample of fit college students using the Subjective Exercise Experience Scale (SEES), and found that positive well-being increased in-task among those in whom it was low at baseline, and psychological distress decreased in-task among those in whom it was high at baseline, but both remained unchanged in those who were high in positive well-being and low in psychological distress, respectively, at baseline (Parfitt, Rose, & Markland, 2000). Because little is known about the in-task effects of exercise on mood it is critical that researchers examine changes in mood during exercise, at exercise completion, and after a rest phase to determine the total mood course of exercise. It is possible that there is negative effect on mood during exercise, especially at high intensities, which is adversely affecting adherence.

A more recent conceptualization of the exercise and mood relation is the dual-mode hypothesis, in which cognitive factors (like self-efficacy, attributions, and thoughts about the social environment) primarily determine mood at low to moderate levels of exercise intensity, and interoceptive cues from exercise-related physiological changes determine mood as exercise intensity approaches certain biological thresholds which threaten homeostasis. The two such thresholds that have received the most attention are the ventilatory threshold (VT) and the lactate threshold (LT). VT is the point at which pulmonary ventilation increases disproportionately with O₂ consumption during graded exercise (Ekkekakis, 2003; Gaesser & Poole, 1996). LT is the point at which lactate (an acid by-product of the metabolism of glucose) begins to accumulate in the bloodstream faster than it can be removed (Ekkekakis, 2000). Both of these thresholds mark the level at which the body can no longer maintain homeostasis, if exertion at this level continues. It makes sense that at levels of exertion above either LT or VT, the body would have cues encouraging the cessation of exercise, since this level of exertion is not sustainable for an extended period of time. According to the dual-mode model, we would expect improved mood in-task at low to moderate intensity levels for those with high self-efficacy (which would likely be most people, given the low intensity of the task). We would expect positive mood to remain post-exercise as cognitions related to self-efficacy, such as a feeling of mastery at having completed the exercise, would continue. Negative mood as a *b* process would not be a factor, as positive mood levels would not reach a threshold to initiate a *b* process. At levels of exertion beyond VT or LT, we would expect in-task mood to worsen due to physiological cues. We would also expect that the negative mood experienced during high intensity exercise would be followed by post-exercise positive

mood, as suggested by opponent-process theory. These theories together would account for in-task mood improvement at low to moderate intensity exercise with continued mood improvement post-exercise, in addition to the negative mood during high intensity exercise, followed by post-exercise positive mood, which may be delayed in high intensity exercise because of time to recovery from that initial *a* process.

There is good evidence supporting the dual-mode model in the context of opponent-process theory, including examples from animal models (Ekkekakis et al., 2005a). One study showed that among young, healthy participants, walking on a treadmill at increasing speed and gradient until volitional exhaustion, in-task mood remained constant until VT was reached, at which point it declined quadratically (Ekkekakis, Hall, & Petruzzello, 2004). It is possible that the VT is the level at which individuals begin to experience in-task displeasure from exercise. The fact that VT is extremely variable between individuals may explain some of the equivocal results regarding a dose-response relation between exercise and mood, as these studies used percent maximal oxygen uptake (VO₂ max) or percent maximum heart rate to determine exertion level (Yeung, 1996). Two studies have examined LT in the context of the dual-mode model, and they also found evidence in support of the model (Rose & Parfitt, 2007; Parfitt, Rose, & Burgess, 2006). Parfitt et al. found that when participants exercised above their LT, in-task mood was significantly worse than when exercising below LT, but post-task mood was not significantly different. Furthermore, when allowed to self-select intensity, participants chose to exercise near their individual LT (2006). Rose and Parfitt found similar in-task results, such that exercise above LT produced the worst in-

task affective response, and exercise below LT and at self-selected speeds produced the best in-task affective response, compared with exercise at LT (2007).

In addition to the theoretical framework of the dual-mode model and opponent-process theory, it is important to examine putative moderators that may explain why certain individuals experience more mood benefit than others from exercise. The dual-mode model posits that cognitive mechanisms, such as self-efficacy or expectancy, may influence the relation between exercise and mood improvement, particularly at lower levels of exertion (Ekkekakis, 2003; Ekkekakis & Petruzzello, 1999; North et al., 1990). There is some evidence that self-efficacy plays a role as a mediating variable in mood effects of exercise (Mihalko, McAuley, & Bane, 1996; McAuley & Courneya, 1992), and that it has a differential effect on mood improvement depending on exertion level (Blanchard, Rodgers, Courneya, & Spence, 2002; Treasure & Newbery, 1998; Ekkekakis, Hall, & Petruzzello, 1999). Another study, however, did not find that the relation between pre-exercise self-efficacy, in-task affect, and post-exercise self-efficacy increased with changes in intensity from 55% to 70% VO₂ max (Tate et al., 1995). An additional study found that self-efficacy levels were positively related to positive well-being and inversely related to fatigue regardless of length of exercise (Rudolph & Butki, 1998). It is difficult to compare these studies to determine under what conditions self-efficacy mediates the relation between intensity and mood, due to the different measures of intensity used. Overall, there appears to be some evidence that self-efficacy may be an important moderator, as people with different levels of self-efficacy achieve different levels of mood improvement, or mediator, as changes in self-efficacy predict changes in mood

improvement, in the relation between exercise and mood. How this factor changes in different intensities of exercise has yet to be fully explored.

In addition to examining self-efficacy as a potential mediator or moderator, researchers have also considered other factors that may moderate the relation between exertion and mood improvement. The activity and fitness level of participants is one moderator that has been examined frequently but with equivocal results (Ekkekakis & Petruzzello, 1999). Several studies have found no fitness effects on mood improvement for low or moderate intensity exercise (Felts & Vaccaro, 1988; Felts, Crouse, & Brunetz, 1988; Reed, Berger, Latin, & La Voie, 1998; Steptoe & Cox, 1988; Steptoe, Kearsley, & Walters, 1993). There is evidence, however, that fitness effects emerge at high intensity exercise, such that more fit individuals experience more mood benefit than unfit individuals (Blanchard, Rodgers, Spence, & Courneya, 2001; Boutcher, McAuley, & Courneya, 1997; Parfitt, Markland, & Holmes, 1994; Tieman, Peacock, Cureton, & Dishman, 2002). Reviewers have recommended that activity level be examined as a potential moderator of the exercise and mood relation, particularly for high-intensity exercise conditions (Ekkekakis & Petruzzello, 1999).

Evidence suggests that individuals vary widely in their preferences and tolerances for different levels of exercise intensity, even when intensity is measured in relative terms to their individual exercise capacity (Spelman, Pate, Macera, & Ward, 1993). It has also been suggested that perceived exertion is a more influential moderator of the relation between exercise and mood improvement than intensity or duration. Among a sample of college students assigned to exercise for 30 minutes on a treadmill, Rating of Perceived Exertion (RPE) had a significant effect on mood change, whereas VO₂ max scores did

not (Tuson, Sinyor, & Pelletier, 1995). It is possible that RPE correspond better with physiological thresholds, such as LT and VT, than with VO₂ max scores, although this has not been well established. High RPE could signal that the individual has begun exercising at a level too difficult to sustain. It would be important to know if individuals can accurately gauge their LT and VT through RPE, so that extensive laboratory testing would not be necessary beyond research purposes to determine optimal levels of exertion for mood improvement. It is also important to determine how individual preferences are related to RPE and the mood effects of exercise.

Calls for study of individual preferences have gone largely ignored, perhaps because of a lack of appropriate instrumentation to measure such differences. The recent publication of The Preference for and Tolerance of the Intensity of Exercise Questionnaire (PRETIE-Q) may be an important step in understanding this potential moderator (Ekkekakis, Hall, & Petruzzello, 2005b). The PRETIE-Q is based on a two-factor structure, such that exercise preference and exercise tolerance are measured separately. These two factors exhibited a correlation of .42 in the study of the test's structural validity (Ekkekakis, et al., 2005b). The two-factor structure of the PRETIE-Q exhibits a reasonable, but not close fit, due to the correlation of four pairs of items, and the test-retest reliability of the measure is appropriately high (Ekkekakis et al., 2005b). The PRETIE-Q measures preferences about exercise intensity and not other aspects of physical activity participation, and it has good construct validity, as evidenced by the fact that it predicts affective response at differing exercise intensities (Ekkekakis et al., 2005b).

In addition to preference and tolerance for exercise as measured by questionnaire, there has also been interest in the exertion level that individuals, both trained and untrained, select when allowed to choose their own speed on a treadmill or other apparatus. Researchers have hypothesized that individuals would prefer to exercise at a self-selected rather than assigned exertion level, and allowing individuals to select speed might therefore lead to improved adherence (Lind, Joens-Matre, & Ekkekakis, 2005). There has been concern, however, over whether inactive individuals would choose a speed sufficient to improve cardiovascular fitness. Among a sample of active college students, individuals chose to run on a treadmill at a speed between 50% and 85% of their VO₂ max, which adheres to the guidelines of the American College of Sports Medicine (Glass & Chvala, 2001). One study compared mood during 20 minutes of assigned treadmill running at 65% VO₂ max to self-selected speed among active undergraduates and found that individuals worked harder (average 71% VO₂ max) in the self-selected condition, but did not differ in RPE or mood improvement between assigned and selected speeds, suggesting that for active individuals, self-selected speed may lead to more physiological than psychological benefit (Parfitt et al., 2000). Among a sample of trained middle-aged runners, individuals selected a running speed that was not significantly different from their LT (Zamparo, Perini, Peano, & di Pompero, 2001). Among a sample of middle-aged sedentary female participants allowed to choose their own speed on a treadmill, researchers found that the selection averaged at individual VT, though with considerable variability (Lind et al., 2005). It is possible that individuals are able to recognize their biological threshold for the transition from aerobic to anaerobic activity and choose an exertion level that approximates this. One question that remains is whether

individuals select a level of exertion that maximizes the mood benefit of exercise, in addition to improving physical fitness.

Although there is good evidence that a single bout of exercise can improve acute mood, it is important that researchers continue to refine the search for the optimal exertion level of exercise for mood enhancement for the purpose of maximizing the mood benefit from exercise. It is also important to determine what individual differences may moderate exercise and mood enhancement effects. While there is some evidence about the potential mechanisms and moderators of the exercise-mood relation, much work remains to be done, particularly in the area of self-selected exertion level, which more closely approximates naturalistic conditions.

The present study sought to elucidate the nature of the relation between exertion level and mood improvement in the theoretical context of the dual-mode hypothesis and opponent-process theory by testing mood changes in highly active and sedentary college-age participants repeatedly evaluated before, during, and after exercising at their LT, before, during, and after exercising at 5% above and 5% below LT, and before, during, and after exercising at a self-selected speed. Participants' self-efficacy was also assessed to determine if this was correlated with in-task mood, as predicted by the dual-mode model. This study also examined whether activity level or exercise intensity preference/tolerance predicted mood response to exertion level, and whether these factors interacted in this prediction. This study contributes novel information to the field by assessing participants' mood with full-length instruments repeatedly *during* exercise, as well as before and after. The examination of the putative moderators of exercise intensity preference and tolerance are also novel contributions to the field. Additionally,

participants' activity level had not been examined as a potential moderator of mood change at different levels of exertion within the context of the dual-mode model and opponent-process theory.

The current study

The main aim of the current study was to test the dual-mode model of exercise and mood in the context of opponent-process theory to determine the relationship between exertion level (as a function of LT) and mood in both assigned and self-selected conditions. The main hypothesis was that exertion above LT would worsen *in-task* mood (as interoceptive cues take over from the physiological changes occurring), whereas exertion below LT would improve in-task mood (because cognitive factors will still be primary). For post-task mood, we expected improvement from baseline for all levels of exertion with a delay in mood improvement at exertion above LT due to physiological recovery processes occurring post-exercise. A second hypothesis was that individuals would select a speed that is close to their LT. A third hypothesis was that activity status would predict mood response, such that active participants would have a more positive response to exercise than inactive participants. A fourth hypothesis was that self-efficacy would be correlated with in-task mood improvement. Finally, a fifth hypothesis was that preference and tolerance for exercise intensity will predict RPE and mood response, such that individuals with preference and tolerance for higher intensity exercise would have lower RPE and better mood response to intense exercise than those with preferences for lower intensity exercise.

Methods

Participants

37 college students between the ages of 18 and 26 participated. Previous researchers have noted that college students are likely to be at least moderately active, and therefore it is important to obtain a sample of highly fit participants to achieve adequate separation between high active and low active groups (Petruzzello, Hall, & Ekkekakis, 2001). For this reason, active and inactive participants were recruited separately. Active participants were recruited through Rutgers University varsity and club sports teams. Inactive participants were Rutgers University undergraduate students enrolled in General Psychology classes or recruited from the campus at large, and were screened to determine that they engaged in moderate or strenuous physical activity less than once per week in the past six months. All participants received research credit and/or a chance to win a gift certificate for their participation in addition to feedback about their current state of physical fitness. All participants were screened to determine that they had a physical examination during the previous year that revealed no contraindications to vigorous physical activity, had no history of cardiovascular, respiratory, musculoskeletal, metabolic, or mental conditions, were not suffering from any injuries or other ailments, and were not taking any medication that would affect exercise tolerance or performance. In addition, all participants completed the Physical Activity Readiness Questionnaire (*Par-q and you*, 1994).

Measures

Physiological variables: Participants' lactate threshold (LT) was determined by a graded maximal treadmill test to exhaustion. Capillary blood samples (5 μ L) were taken

from the fingertip at rest and at the end of each 4-minute stage in order to analyze blood lactate accumulation. The Lactate Pro (Arkray, Japan) portable analyzer was used to determine whole blood lactate content. Lactate concentration was plotted against treadmill speed in order to determine the velocity at which lactate threshold (V_{LT}) occurred using the D_{MAX} method (Cheng et al., 1992). This method has been suggested to be the most sensitive and valid measure of velocity at lactate threshold (Nicholson & Sleivert, 2001).

Participants' body weight and height were measured on a scale and height chart, and percent body fat (%BF) was measured through a two-stage procedure. Body volume was measured using a two-chambered device called the BOD POD (Life Measurements Instruments, Concord, CA), which calculated body volume through computer analysis, and this measurement was used to calculate percent body fat using the Siri two-component equation: Percent Fat = $(495/\text{density}) - 450$, where density was calculated by dividing body mass by body volume.

Exercise self-efficacy: Participants' exercise self-efficacy was determined according to the method described by McAuley (McAuley, 1993). After one minute of exercise, participants were asked how confident they were that they could continue exercising at this pace for 20 minutes. Their response was scored on a 100-point percentage scale (100% = complete certainty, 0% = highly uncertain).

Mood Measures: *Activation-Deactivation Adjective Checklist*: (AD-ACL; Thayer, 1989). The short form of the AD-ACL is a brief self-report measure comprised of four subscales (Energy, Tiredness, Tension, and Calmness). Each subscale includes five adjectives, which are rated on a 4-point continuum from "definitely feel" to "definitely do

not feel.” It has been widely used in psychophysiological research. Test-retest reliabilities have been reported at .89 (energy), .89 (tiredness), .93 (tension), and .79 (calmness) (Thayer, 1989).

State-Trait Anxiety Inventory: State Anxiety Scale: (SAI; (Spielberger, Gorsuch, Luschene, Vagg, & Jacobs, 1983). The SAI is a brief self-report measure of 20 items, which are rated on a 4-point continuum from “not at all” to “very much so,” concerning the amount of anxiety currently experienced. It has been widely used in psychological research. Internal consistency alpha during recovery from exercise has been reported from .66 (Rejeski, Hardy, & Shaw, 1991) to .80 (Ekkekakis et al., 1999), and test-retest reliability has been adequate (Spielberger et al., 1983).

Rating of Perceived Exertion: (RPE; Borg, 1998). The RPE is a 15-point single-item scale ranging from 6 to 20, anchored at 6 for “very, very light” and 20 for maximal exercise or “very, very hard.” Correlations between RPE and heart rate across the stages of a graded exercise test have been found to range between 0.85 and 0.94 (Noble, 1996).

Preference for and Tolerance of the Intensity of Exercise Questionnaire: (PRETIE-Q; Ekkekakis et al., 2005b). The PRETIE-Q is a recently developed 16-item, 2-factor measure that exhibits acceptable psychometric properties and is meant to be used in research aimed at understanding individual differences in responses to exercise. Items concerning exercise preferences are rated on a 5-point scale, ranging from “I totally agree” to “I totally disagree.”

Procedures

All procedures took place in the Exercise and Human Performance Laboratory at Rutgers University, a state-of-the-art facility for exercise testing.

Lactate threshold assessment

After the informed consent procedure, participants completed a demographics questionnaire and the PRETIE-Q and were weighed and measured, and underwent the BOD POD procedure. They then underwent the exercise performance test consisting of a graded maximal treadmill test to exhaustion. Participants completed a series of 4-minute stages with 1-minute rest intervals between stages for the sampling of capillary blood in order to determine blood lactate values. Stage 1 speed was set at 5.0 mph for active males, 3.7 mph for active females, and 2.5 mph for the inactive individuals, while grade was set at 1% for all groups. Speed was increased by 1.2 mph with each incremental stage for active males, 1.0 mph for active females, and 0.9 mph for inactive individuals. Grade was maintained at 1% throughout the test in order to maintain biomechanical demands similar to flat-level running. This process continued until volitional exhaustion. Heart rate was continuously monitored using a Polar S810 HR monitor (Polar Electro Co., Woodbury, NY).

Participants came into the lab on four more occasions at the same time of day (within two hours) for experimental testing. They were instructed to eat a small meal two to three hours before testing but nothing after that, and to refrain from alcohol, tobacco, and drugs 24 hours prior to each session, and caffeine six hours prior to each session.

Experimental testing

Participants came to the lab for experimental testing on four separate occasions, and the order of testing was randomly assigned. While wearing a heart-rate monitor, they engaged in 20 minutes of treadmill walking or running at either 5% below, 5% above, or at their LT, or at a self-selected speed. After one minute, self-efficacy was assessed. After

completing the exercise task, participants sat and rested quietly for 60 minutes. They completed the AD-ACL and SAI at eight time points: immediately pre-exercise (t0), eight minutes into exercise (t8), 16 minutes into exercise (t16), immediately post-exercise (p0), 15 minutes post-exercise (p15), 30 minutes post-exercise (p30), 45 minutes post-exercise (p45), and 60 minutes post-exercise (p60). Participants also communicated RPE at times t8 and t16. At times t0, p0, p15, p30, p45, and p60, they completed the questionnaires with pen and paper. During in-task assessments (t8 and t16), participants viewed a poster-sized version of all questionnaires and responded verbally while a lab assistant recorded their answers.

Data Analytic Plan

Descriptive statistics of demographic variables (age, gender, and ethnicity) and physiological variables (LT and %BF) were examined to characterize the sample, and comparisons between active and inactive participants were made. As a manipulation check, an ANOVA to determine whether there was a difference in RPE in the various conditions was also performed, with post-hoc univariate comparisons with Bonferroni corrections.

In order to test the main hypothesis that exertion above LT would worsen in-task mood (H1a), whereas exertion below LT would improve in-task mood (H1b), and post-task mood would be improved from baseline for all levels of exertion without a difference between levels (H1c), two-way within-subjects ANOVA for all subscales of the ADAACL (energy, tiredness, tension, calmness) and the SAI for exertion levels above and below LT was performed, with planned two-tailed pair-wise comparisons of pre-task

to in-task, in-task to post-task, and pre-task to post-task mood. Because pair-wise comparisons were planned, no corrections for multiple testing were made.

In order to test the second hypothesis that individuals would select a speed that is close to their LT (H2), a dependent samples t-test to compare LT and self-selected speed was performed. Follow-up dependent samples t-test to compare 5% below LT and self-selected speed was also performed.

In order to test the third hypothesis that activity status would predict response to exercise, a 2x4x8 (status x condition x time) MANOVA to determine if activity status predicted response to condition at different time points was performed. Follow-up univariate analyses with Bonferroni corrections for multiple tests were performed as indicated.

In order to test the fourth hypothesis that self-efficacy would be correlated with mood improvement in-task (H3), a correlational analysis of self-efficacy and the subscales of the AD-ACL and SAI was performed.

In order to test the fifth hypothesis that preference and tolerance for exercise intensity would predict RPE (H4a) and affective response (H4b), a correlational analysis of the preference and tolerance subscales of the PRETIE-Q on RPE and on in-task mood for each mood measure was performed.

Results

37 participants, 14 in the active group and 23 in the inactive group, completed all study visits and have been included in analyses. Of the 37 participants, 18 (49%) were male and 19 (51%) were female. 21 (62%) were Caucasian, 8 (24%) were Asian/Pacific Islander, 2 (6%) were Black, 1 (3%) was Latino, 2 (6%) responded Other, and 3 did not provide information regarding race. The subjects ranged from 18-26 years in age ($M = 20.8$, $SD = 1.67$). %BF of the participants ranged from 3.6 (extremely lean) to 45.4 (obese) ($M = 24.8$, $SD = 11.2$). For males, %BF ranged from 3.6 (extremely lean) to 45.4 (obese) ($M = 22.2$, $SD = 13.2$) and for females, %BF ranged from 19.1 (lean) to 33.6 (obese) ($M = 27.6$, $SD = 7.6$). Among all participants, LT ranged from 3.1mph to 8.8mph ($M = 5.50$, $SD = 1.75$). There was a significant difference in LT and %BF for both males and females between active and inactive participants, such that active participants were significantly leaner and had higher LTs than inactive participants.

Table 1. Characteristics of active and inactive participants

	Active	Inactive	Total
% Male	57 (8/14)	43 (10/23)	49 (18/37)
Age in years (SD)	21.1 (2.07)	20.6 (1.37)	20.8 (1.67)
% Caucasian**	92 (11/12)	45 (10/22)	62 (21/34)
Males %BF (SD)*	10.8 (6.18)	31.2 (10.50)	22.2 (13.2)
Females %BF (SD)*	21.7 (5.56)	30.1 (7.05)	27.6 (7.6)
LT in mph (SD)*	7.66 (0.72)	4.26 (0.71)	5.5 (1.75)

* $p < 0.001$ between active and inactive participants

**Ethnicity data missing from 3 participants (2 active, 1 inactive)

As a manipulation check, two-way ANOVA was performed and determined that there was a significant effect of condition ($F = 5.102$ (3), $p = .002$) and group ($F = 5.480$ (1), $p = .021$), but not condition \times group ($F = .247$ (3), $p = .863$) on RPE. Post-hoc Bonferroni analyses indicated that there was a significant difference in RPE between the above LT and below LT conditions (Mean difference = 2.20, $SE = .554$, $p = .001$), and between the above LT and self-selected conditions (Mean difference = 1.53, $SE = .554$, $p = .042$) overall. There was also a significant difference in RPE between the above LT and below LT conditions (Mean difference = 1.893, $SE = .572$, $p = .01$) and between the above LT and self-selected conditions (Mean difference = 1.786, $SE = .572$, $p = .018$) for the active group, and a significant difference in RPE between the above LT and below LT conditions (Mean difference = 2.391, $SE = .817$, $p = .026$) for the inactive group.

Table 2. RPE for condition and group

	Active	Inactive	Total
Below LT (SD)	12.3 (1.36)*	10.8 (2.22)*	11.3 (2.05)*
At LT (SD)	13. (1.46)	12.2 (2.73)	12.5 (2.34)
Above LT (SD)	14.1 (1.41)^	13.2 (3.11)^	13.5 (2.62)^
Self-selected (SD)	12.4 (1.79)*	11.8 (2.94)	12.0 (2.56)*
Total (SD)	12.9 (1.96)''	12.0 (2.86)'	12.3 (2.70)

^ > * at $p < .05$; '' > ' at $p < .05$

To test the main hypothesis that exertion above LT would worsen in-task mood (H1a), whereas exertion below LT would improve in-task mood (H1b), and post-task mood would be improved from baseline for all levels of exertion without a difference between levels (H1c), two-way within-subjects ANOVA for all subscales of the ADACL

(energy, tiredness, tension, calmness) and the SAI for exertion levels above and below LT were performed, revealing significant within-subject differences (time effect) for energy (*Wilk's Lambda* = .288, $F = 23.327$ (7, 66), $p < 0.001$), tiredness (*Wilk's Lambda* = .548, $F = 7.783$ (7, 66), $p < .001$), tension (*Wilk's Lambda* = .429, $F = 12.535$ (7, 66), $p < 0.001$), calmness (*Wilk's Lambda* = .226, $F = 32.325$ (7, 66), $p < 0.001$), and the SAI (*Wilk's Lambda* = .185, $F = 41.661$ (7, 66), $p < 0.001$) and a significant time x condition interaction effect for tiredness (*Wilk's Lambda* = .718, $F = 3.696$ (7, 66), $p = .002$), tension (*Wilk's Lambda* = .699, $F = 4.06$ (7, 66), $p = 0.001$), calmness (*Wilk's Lambda* = .318, $F = 20.206$ (7, 66), $p < 0.001$) and the SAI (*Wilk's Lambda* = .326, $F = 19.495$ (7, 66), $p < 0.001$).

For each measure with a significant time x condition effect, planned follow-up two-tailed paired samples t-tests were performed to determine whether there was a difference in mood from pre-task (t0) to in-task (average of t8 and t16), in-task to immediately post-task (p0), in-task to post-task (average of p15, p30, p45, and p60), pre-task to immediately post-task, and pre-task to post-task within the above LT and below LT conditions.

For tiredness, follow-up pair-wise comparisons within the above LT condition revealed that pre-task was significantly higher than in-task ($t = 2.808$ (36), $p = .008$), in-task was significantly higher than immediately post-task ($t = 2.259$ (36), $p = .03$), post-task was significantly higher than in-task ($t = 3.195$ (36), $p = .003$), and pre-task was significantly higher than immediately post-task ($t = 3.646$ (36), $p = .001$). Pair-wise comparisons within the below LT condition for tiredness revealed that pre-task was significantly higher than in-task ($t = 4.555$ (36), $p < .001$), post-task was significantly

higher than in-task ($t = 2.044$ (36), $p = .048$), pre-task was significantly higher than immediately post-task ($t = 4.281$ (36), $p < .001$), and pre-task was significantly higher than post-task ($t = 2.842$ (36), $p = .007$). See *Figure 1*.

For tension, follow-up pair-wise comparisons within the above LT condition revealed that in-task was significantly higher than pre-task ($t = 3.996$ (36), $p < .001$), in-task was significantly higher than post-task ($t = 2.270$ (36), $p = .029$), immediately post-task was significantly higher than pre-task ($t = 5.840$ (36), $p < .001$), and post-task was significantly higher than pre-task ($t = 3.485$ (36), $p = .001$). Pair-wise comparisons within the below LT condition for tension revealed that in-task was significantly higher than pre-task ($t = 2.363$ (36), $p = .024$), in-task was significantly higher than post-task ($t = 2.111$ (36), $p = .042$), and immediately post-task was significantly higher than pre-task ($t = 3.562$ (36), $p = .001$). See *Figure 2*.

For calmness, follow-up pair-wise comparisons within the above LT condition revealed that pre-task was significantly higher than in-task ($t = 5.807$ (36), $p < .001$), post-task was significantly higher than in-task ($t = 6.144$ (36), $p < .001$), and pre-task was significantly higher than immediately post-task ($t = 7.453$ (36), $p < .001$). Pair-wise comparisons within the below LT condition for calmness revealed that pre-task was significantly higher than in-task ($t = 7.721$ (36), $p < .001$), immediately post-task was significantly higher than in-task ($t = 2.630$ (36), $p = .012$), post-task was significantly higher than in-task ($t = 8.960$ (36), $p < .001$), pre-task was significantly higher than immediately post-task ($t = 5.291$ (36), $p < .001$), and post-task was significantly higher than pre-task ($t = 2.471$ (36), $p = .018$). See *Figure 3*.

For the SAI, follow-up pair-wise comparisons within the above LT condition revealed that in-task was significantly higher than pre-task ($t = 3.755$ (36), $p = .001$), in-task was significantly higher than immediately post-task ($t = 2.777$ (36), $p = .009$), and in-task was significantly higher than post-task ($t = 4.487$ (36), $p < .001$). Pair-wise comparisons within the below LT condition for the SAI revealed that in-task was significantly higher than immediately post-task ($t = 2.478$ (36), $p = .018$), in-task was significantly higher than post-task ($t = 6.131$ (36), $p < .001$), and pre-task was significantly higher than post-task ($t = 6.830$ (36), $p < .001$). See *Figure 4*.

In order to test the second hypothesis that individuals will select a speed that is close to their LT (H2), a dependent samples t-test comparing LT and self-selected speeds was performed, revealing that LT was significantly higher than self-selected speed ($t = 3.134$ (36), $p = .003$). The same result was found when the data were split by group, such that LT was significantly higher than self-selected speed among both active participants ($t = 3.481$ (13), $p < .001$) and inactive participants ($t = 1.732$ (22), $p < .001$). A dependent samples t-test revealed that there was not a significant difference between 5% below LT speed and self-selected speed for either active participants ($t = -.076$ (13), $p = .94$) or inactive participants ($t = .151$ (22), $p = .88$). For active participants, 5% below LT speed $M = 7.01$, $SD = .659$, and self-selected speed $M = 7.02$, $SD = .974$. For inactive participants, 5% below LT speed $M = 4.00$, $SD = .653$, and self-selected speed $M = 3.97$, $SD = 1.08$.

A two-tailed paired samples t-test ($t = 1.485$ (36), $p = .146$) indicated that there was not a significant difference in RPE when participants were in the below LT condition ($M = 11.3$, $SD = 2.05$) and when they were in the self-selected condition ($M = 12.0$, $SD =$

2.55). Within the active group, a two-tailed paired samples t-test ($t = .264$ (13), $p = .796$) indicated that there was not a significant difference in RPE when participants were in the below LT condition ($M = 12.3$, $SD = 1.36$) and when they were in the self-selected condition ($M = 12.4$, $SD = 1.79$). Within the inactive group, a two-tailed paired samples t-test ($t = 1.489$ (22), $p = .151$) indicated that there was not a significant difference in RPE when participants were in the below LT condition ($M = 10.8$, $SD = 2.22$) and when they were in the self-selected condition ($M = 1.8$, $SD = 2.94$).

To test the third hypothesis that activity group would predict response to exercise, a 2x4x8 (group x condition x time) MANOVA was performed for energy, tiredness, tension, calmness and the SAI. Follow-up univariate analyses with Bonferroni corrections were performed as appropriate.

For energy, a significant effect of group (*Wilk's Lambda* = .877, $F = 2.331$ (8, 133), $p = 0.022$), but not condition (*Wilk's Lambda* = .919, $F = .473$ (24, 386.342), $p = .985$) or condition x group (*Wilk's Lambda* = .868, $F = .808$ (24, 386.342), $p = .727$) was observed. Follow-up analyses revealed that energy at t0 ($F = 16.352$ (1), $p < .001$) was significantly higher for active participants ($M = 10.393$, $SE = .452$) than inactive participants ($M = 8.076$, $SE = .352$). Energy at p45 ($F = 6.045$ (1), $p = .015$) was also significantly higher in active participants ($M = 9.946$, $SE = .466$) than inactive participants ($M = 8.495$, $SE = .363$). See *Figure 5*.

For tiredness, a significant effect of condition (*Wilk's Lambda* = .650, $F = 2.574$ (24, 386.342), $p < .001$), but not group (*Wilk's Lambda* = .961, $F = .682$ (8, 133), $p = .707$) or condition x group (*Wilk's Lambda* = .859, $F = .867$ (24, 386.342), $p = 0.649$) was found. Follow-up analyses revealed that significant differences were found at p15 (F

= 9.310 (3), $p < .001$), and p30 ($F = 3.994$ (3), $p = .000$). At p15, when in the above LT condition ($M = 12.747$, $SE = .635$), participants rated tiredness as significantly higher ($p < .01$), than when in the below LT ($M = 8.755$, $SE = .635$), at LT ($M = 8.675$, $SE = .635$), and self-selected ($M = 9.309$, $SE = .635$) conditions, which did not differ significantly from one another. At p30, when in the above LT condition ($M = 11.891$, $SE = .667$), participants rated tiredness significantly higher ($p < .05$) than when in below LT ($M = 9.247$, $SE = .667$) and LT ($M = 8.970$, $SE = .667$), but not significantly different from when in the self-selected condition ($M = 9.626$, $SE = .667$). See *Figure 6*.

For tension, a significant effect of group (*Wilk's Lambda* = .849, $F = 2.966$ (8, 133), $p = .004$) and condition (*Wilk's Lambda* = .653, $F = 2.547$ (24, 386.342), $p < .001$), but not group x condition (*Wilk's Lambda* = .889, $F = .667$ (24, 386.342), $p = .883$) were found. For group, follow-up analyses revealed significant differences between active and inactive participants at p30 ($F = 7.021$ (1), $p = .009$), p45 ($F = 4.136$ (1), $p = .044$), and p60 ($F = 10.543$, $p = .001$). At p30, active participants ($M = 6.982$, $SE = .253$) rated tension as significantly higher than inactive participants ($M = 6.130$, $SE = .198$). At p45, active participants ($M = 6.411$, $SE = .239$) rated tension significantly higher than inactive participants ($M = 5.793$, $SE = .187$). At p60, active participants ($M = 6.393$, $SE = .209$) rated tension significantly higher than inactive participants ($M = 5.533$, $SE = .163$). See *Figure 7*. For condition, follow-up analyses revealed significant differences between above LT and all other conditions at p15 ($F = 7.151$ (3), $p < .001$) and p30 ($F = 8.793$, $p < .001$). At p15, when in the above LT condition participants ($M = 8.224$, $SE = .370$) rated tension as significantly higher ($p < .05$) than in the below LT ($M = 6.106$, $SE = .379$), LT ($M = 6.185$, $SE = .370$), or self-selected ($M = 6.559$, $SE = .370$) conditions, in which

ratings did not differ significantly from one another. At p30, participants in the above LT condition ($M = 7.918$, $SE = .321$) rated tension as significantly higher ($p < .05$) than in below LT ($M = 5.884$, $SE = .321$), LT ($M = 5.910$, $SE = .321$), or self-selected ($M = 6.513$, $SE = .321$) conditions, in which ratings did not differ significantly from one another. See *Figure 8*.

For calmness, a significant effect of condition (*Wilk's Lambda* = .405, $F = 5.884$ (24, 386.342), $p < .001$), but not group (*Wilk's Lambda* = .940, $F = 1.068$ (8, 133), $p = .389$) or condition x group (*Wilk's Lambda* = .843, $F = .967$ (24, 386.342), $p = .496$) was observed. Follow-up analyses revealed significant differences at p15 ($F = 11.125$ (3), $p < .001$), p30 ($F = 15.637$ (3), $p < .001$), and p60 ($F = 6.091$ (3), $p = .001$). At p15, participants in the above LT condition ($M = 10.073$, $SE = .535$) rated calmness significantly lower ($p < .001$) than they did in the below LT ($M = 13.495$, $SE = .535$), LT ($M = 13.685$, $SE = .535$), and self-selected ($M = 13.725$, $SE = .535$) conditions, in which ratings did not differ significantly from one another. At p30, participants in the above LT condition ($M = 10.188$, $SE = .512$) rated calmness significantly lower ($p < .001$) than they did when in the below LT ($M = 13.992$, $SE = .512$), LT ($M = 14.686$, $SE = .512$), and self-selected ($M = 13.840$, $SE = .512$) conditions, in which ratings did not differ significantly from one another. At p60, participants in the LT ($M = 18.936$, $SE = 1.052$) and above LT ($M = 19.154$, $SE = 1.052$) conditions rated calmness significantly higher ($p < .05$) than they did when in the below LT ($M = 14.536$, $SE = 1.052$) and self-selected ($M = 14.568$, $SE = 1.052$). Ratings when in the LT and above LT conditions did not differ significantly from one another. Ratings when in the below LT and self-selected conditions were also not significantly different. See *Figure 9*.

For the SAI, a significant effect of condition (*Wilk's Lambda* = .358, $F = 6.846$ (24, 386.342), $p < .001$), but not group (*Wilk's Lambda* = .929, $F = 1.271$ (8, 133), $p = .264$) or condition x group (*Wilk's Lambda* = .872, $F = .872$ (24, 386.342), $p = .761$) was observed. Follow-up analyses revealed significant differences at p15 ($F = 10.001$ (3), $p < .001$), p30 ($F = 17.404$ (3), $p < .001$), and p60 ($F = 4.999$ (3), $p = .003$). At p15, participants in the above LT condition ($M = 40.967$, $SE = 1.423$) rated the SAI significantly higher ($p < .01$) than they did in the below LT ($M = 32.370$, $SE = 1.423$), LT ($M = 30.860$, $SE = 1.423$), and self-selected ($M = 33.388$, $SE = 1.423$) conditions, in which ratings did not differ significantly from one another. At p30, participants in the above LT condition ($M = 43.666$, $SE = 1.525$) rated the SAI significantly higher ($p < .001$) than they did when in the below LT ($M = 31.079$, $SE = 1.525$), LT ($M = 39.765$, $SE = 1.525$), and self-selected ($M = 32.650$, $SE = 1.525$) conditions, in which ratings did not differ significantly from one another. At p60, participants in the self-selected condition ($M = 32.025$, $SE = 1.609$) rated the SAI significantly higher ($p < .05$) than when there were in the LT ($M = 24.474$, $SE = 1.609$) and above LT ($M = 25.823$, $SE = 1.609$), in which ratings did not differ significantly from one another. Ratings of the SAI at p60 in the below LT condition ($M = 30.362$, $SE = 1.609$) did not differ significantly from SAI ratings at this time point in any other condition. See *Figure 10*.

Two-tailed Pearson correlation analysis of self-efficacy and in-task mood ratings across conditions revealed a significant but weak inverse correlation ($r = -.202$, $p = .014$) between self-efficacy and in-task tension, and a significant and moderate inverse correlation ($r = -.426$, $p < .001$) between self-efficacy and in-task SAI. When participants were in the below LT condition, their ratings of self-efficacy and in-task SAI were also

significantly and moderately inversely correlated ($r = -.529, p = .001$), but no other significant correlations between self-efficacy and in-task mood rating were found. When participants were in the LT condition, no significant correlations between self-efficacy and in-task mood rating were observed. When participants were in the above LT condition, a significant inverse correlation ($r = -.366, p = .026$) between self-efficacy and in-task SAI was observed, but no other significant correlations between self-efficacy and in-task mood ratings were found. When participants were in the self-selected condition, a significant and moderate inverse correlation ($r = -.676, p < .001$) between self-efficacy and in-task tension, a significant moderate correlation ($r = .420, p = .011$) between self-efficacy and in-task calmness, and a significant and moderate inverse correlation ($r = -.674, p < .001$) between self-efficacy and in-task SAI were observed, but no significant correlation between self-efficacy and in-task energy or tiredness was observed.

Two tailed independent samples t-tests revealed a significant difference between groups on the preference ($t = 4.57 (35), p < .001$) and tolerance ($t = 2.499 (35), p = 0.017$) subscales of the PRETIE-Q, such that the active group had a preference ($M = 27.4, SD = 3.84$) for higher levels of activity than the inactive group ($M = 23.7, SD = 4.59$), and tolerance ($M = 31.1, SD = 3.35$) for higher levels of activity than the inactive group ($M = 24.5, SD = 4.74$). Two-tailed Pearson correlation analysis of the preference subscale of the PRETIE-Q with RPE and in-task mood measures across conditions revealed a significant inverse correlation between preference and in-task SAI ($r = -.358, p = .029$). The preference subscale of the PRETIE-Q was not significantly correlated with any other mood measures or RPE. The tolerance subscale of the PRETIE-Q was not significantly correlated with any in-task mood measures or RPE. When participants were in the below

LT condition, their in-task ratings of the SAI were significantly inversely correlated with preference ($r = -.358, p = .029$). Neither RPE nor other mood measures were significantly correlated with the preference or tolerance subscales of the PRETIE-Q in the below LT condition. When participants were in the LT condition, their ratings of the SAI in-task were significantly inversely correlated with preference ($r = -.403, p = .013$). Neither RPE nor other mood measures were significantly correlated with the preference or tolerance subscales of the PRETIE-Q in the LT condition. There were no significant correlations between the preference and tolerance subscales of the PRETIE-Q and RPE or any mood measures when participants were in the above LT condition. When participants were in the self-selected condition, there was a significant correlation between preference and RPE ($r = .362, p = .028$). The preference subscale of the PRETIE-Q was not significantly correlated with any mood measures in the self-selected condition. The tolerance subscale of the PRETIE-Q was not significantly correlated with any in-task mood measures or RPE when participants were in the self-selected condition.

Discussion

The results of the study provide some support for the dual-mode model in the context of opponent-process theory. When in the above LT condition, participants' mood worsened in-task, as predicted, but when in the below LT condition, participants' mood did not improve in-task, which was predicted. Post-task mood was, as expected, improved from baseline for both above and below LT conditions with a delay in mood improvement at exertion above LT due to physiological recovery processes occurring post-exercise.

Across both above and below LT conditions, participants experienced in-task arousal, such that they were less tired, more tense, and less calm than they were pre-task. When in the above LT condition, but not the below LT condition, participants also experienced in-task increase in anxiety (as measured by the SAI). This provides some support for the dual-mode model, since participants experienced worsening of mood, in the form of increased anxiety and tension and reduced calmness, in-task in the above LT condition. They did not, however, experience improved mood in-task beyond reduced tiredness in the below LT condition, as the dual-mode model would predict if cognitions were positive. It is possible that cognitions were negative or neutral, which is plausible given the artificial nature of the laboratory environment, and therefore did not cause improvement in in-task mood in the below LT condition. Self-efficacy, operationalized as estimated likelihood of completing the task at one minute into the task, was the only measure of cognition, and it was generally high across conditions and participants. It may be that this measure was insufficiently sensitive to capture participants' self-efficacy throughout the task, or that cognitions other than self-efficacy were dominant. Although

there is evidence that self-efficacy contributes to changes in in-task mood (Blanchard et al., 2002; McAuley & Courneya, 1992; Mihalko et al., 1996; Treasure & Newberry, 1998), there is also evidence that cognitive factors such as exercise outcomes, focus of concentration, and perceived control can influence mood (Rose & Parfitt, 2007). None of these factors was examined here. If they had been, it is possible that there would have been evidence of negative or neutral cognitions accounting for the lack of improved mood in-task in the below LT condition.

Immediately post-task, across both the above and below LT conditions, participants experienced a reduction in anxiety compared to in-task. When in the above LT condition, participants experienced a reduction in tiredness immediately post-task compared to their in-task reports, and when in the below LT condition, they experienced an increase in calmness immediately post-task compared to in-task. In both conditions, participants experienced immediate improvement of mood upon cessation of the task. Across both above and below LT conditions immediately post-task, participants experienced a reduction in tiredness and calmness and an increase in tension compared to their pre-task reports. Although mood improved from in-task to immediately post-task, arousal remained higher than pre-task baseline, such that participants continued to experience higher levels of tension and lower levels of tiredness and calmness immediately post-task (as they did in-task) compared to pre-task. It is likely that arousal processes did not immediately cease when the task ended, accounting for the continued higher levels of arousal immediately post-task.

Across both conditions, participants felt more tired, more calm, less tense, and less anxious post-task than in-task, suggesting that once arousal processes ceased post-

task, participants experienced the opposite *b* process as opponent-process theory would predict. Across both conditions, participants were calmer post-task than pre-task, in line with the robust finding that exercise improves mood post-task regardless of type or duration (Yeung, 1996). When in the above LT condition, participants were also more tense post-task than pre-task. This can be explained by the fact that participants' tension remained high until 30 minutes post-task, after which point it drops to below pre-task levels, similar to post-task tension in the below LT condition (see *Figure 2*). Because the above LT condition is so physically demanding, it is likely that participants were still recovering physiologically during those 30 minutes post-task, and that is why tension remained high. When in the below LT condition, participants were also less tired and less anxious post-task than pre-task, again supporting the finding that exercise improves mood post-task, but in this case only for lower levels of exertion. When in the above LT condition, participants' level of tiredness and anxiety were high 15 minutes post-task, and remained high at 30 minutes post-task. At 45 and 60 minutes post-task, both tiredness and anxiety dropped lower than they had been pre-task, similar to tiredness in the below LT condition (see *Figure 1* and *Figure 4*). Again, this can be accounted for by the physiological recovery process occurring post-task in the above LT condition, such that participants were still more tired and anxious post-task until 30 minutes had elapsed, at which point they felt less tired and anxious than at baseline. Overall, these results support the main hypothesis as exertion above LT worsened in-task mood, though there was no evidence that exertion below LT improved in-task mood, and post-task mood was improved from baseline in both conditions.

In addition to the data comparing the above LT and below LT conditions, there is also evidence for differences in post-task mood between conditions from the group x condition x time MANOVA. At p15 and p30, participants in the above LT condition were more tired, tense, anxious, and less calm than participants in all other conditions. At p60, participants in the above LT and LT conditions were more calm and *less* anxious than participants in the below LT and self-selected conditions (see *Figures 6, 8, 9, and 10*). It seems that because the above LT condition was so demanding, participants took 30 minutes to recover, during which time their mood was worse than those in all other conditions. After their bodies had recovered physiologically from the more demanding conditions, participants experienced greater mood improvement from these conditions than they did in the less demanding conditions, as evidenced by feeling more calm and less anxious at p60 in the above LT and LT conditions than the below LT and self-selected conditions. It appears that exertion above LT worsened mood in-task and for 30 minutes post-task, after which a greater mood benefit was experienced than for exertion below LT, which appears to have caused in task-arousal, followed by post-task mood improvement. This is good evidence in support of opponent-process theory, as the *a* process of the sympathetic activation and parasympathetic withdrawal during exercise, and the *b* process of the parasympathetic rebound post-exercise accounts for the changes in mood, with a delay in onset of *b* processes in the above LT condition due to physiological recovery processes.

The results do not support the second hypothesis that individuals would choose a speed close to their LT. In fact, on average, participants chose a speed significantly slower than their LT, which was indistinguishable from the assigned speed of 5% below

LT. In addition to choosing a speed very close to 5% below LT, participants also rated their level of exertion similarly for the 5% below LT and self-selected conditions. This was true of both active and inactive participants. Zamparo and colleagues found that trained middle-aged runners selected a running speed that was not significantly different from their LT (2001). It is possible that the difference in this study is related to the younger age of participants. Parfitt and colleagues found that participants self-selected a level of exertion close to their LT, but did not give any data indicating how close (2006). Parfitt and colleagues calculated LT using a treadmill test that increased grade rather than speed and determined above LT and below LT conditions through blood lactate level directly, rather than % above or below LT (2006), so it is difficult to compare the results found in the current study to theirs. They gave participants the instruction to “select an intensity that you prefer that can be sustained for 20 minutes and that you would feel happy to do regularly,” which was different from the present study’s instruction to “choose whichever speed you prefer” (Parfitt et al., 2006). It could be that the specification “that you would feel happy to do regularly” led to participants choosing a higher speed than in the present study, when they may have felt that it was “just this once,” so a lower speed would be acceptable. Rose and Parfitt (2007) found that participants’ self-selected speed, which they allowed to vary throughout the task, was not significantly different from either LT or below LT. In this study, participants tended to increase their speed in the self-selected condition over the course of the 20-minute task (Rose & Parfitt, 2007). Perhaps if participants had been permitted to change speed during the task in the current study, they would have similarly increased to a speed closer to their LT.

No group x condition x time interaction was found, so the study does not contribute to previous evidence that active participants experience more mood benefit at higher levels of exertion than inactive participants (Blanchard et al., 2001; Boutcher et al., 1997; Parfitt et al., 1994; Tieman et al., 2002). The power to detect such a difference was .670, which may not have been sufficient. There was, however, evidence that there was a difference in fitness between the groups, as the active group was significantly leaner and had significantly higher LT than the inactive group. There was also limited support that there was a difference in overall response between the groups. Active participants reported feeling more energetic pre-task and 45 minutes post-task than inactive participants. It appears that active participants felt more energetic than inactive participants both before and after exercise, and inactive participants' level of energy approached active participants' during exercise (see *Figure 5*). We would expect fitter individuals to have more energy than less fit individuals, but it is interesting that energy level was not different during exercise, as the inactive participants' energy level rose more relative to baseline than active participants'. Active participants also reported feeling more tense than inactive individuals post-task. It appears that inactive participants had a greater increase in tension from pre-task to in-task than active participants, though this did not reach significance (see *Figure 7*). We would then expect, according to opponent-process theory, that inactive participants would experience a greater reduction in post-task tension than inactive participants, as observed.

The fourth hypothesis that self-efficacy would be correlated with mood improvement was supported, similar to previous research (Blanchard et al., 2002; McAuley & Courneya, 1992; Mihalko et al., 1996; Treasure & Newberry, 1998).

Overall, there was a moderate inverse correlation between self-efficacy and anxiety, indicating that higher self-efficacy was associated with lower anxiety, i.e., better mood. Similarly, there was an inverse, although weak, correlation between tension and self-efficacy across conditions and participants. When in the self-selected condition, an additional positive correlation between self-efficacy and calmness was also observed, which was not observed in any of the assigned conditions. It could be that self-efficacy plays a more important role in determining mood when participants are allowed to choose the speed, though further evidence of this is needed.

There was some evidence that the preference, but not the tolerance, subscale of the PRETIE-Q predicted mood response. There was an inverse correlation between preference and the SAI across conditions, indicating that participants who preferred higher levels of exertion felt less anxious in-task than those who preferred lower levels of exertion. When mood response was examined by condition, the same result was found in the below LT and LT conditions. In the above LT condition, where preference was expected to predict mood response, however, there was no relationship between preference and any mood measures or RPE. There is evidence that active participants experience more mood benefit at higher levels of exertion than inactive participants (Blanchard et al., 2001; Boutcher et al., 1997; Parfitt et al., 1994; Tieman et al., 2002), and active participants exhibited higher scores on the preference and tolerance subscales of the PRETIE-Q in this study, so we might expect a relationship between preference and mood in the above LT condition. It is possible that the higher levels of exertion examined in other studies showing this association did not reach above LT, and perhaps exertion was closer to LT. At LT, the relationship between preference and the SAI was

significant in this study. It could be that above LT, physiological processes have taken over, as the dual-mode model would predict, to the extent that any stated cognitive preferences are no longer related, but at and below LT this relationship is maintained. In the self-selected condition, there was a relationship between preference and RPE, indicating that those participants who preferred higher levels of exertion also reported higher levels of exertion when they were allowed to choose their own speed.

This study did provide some evidence for the dual-mode model in the context of opponent-process theory. As predicted, participants experienced worsening of mood in-task at exertion above LT. They also experienced post-task mood improvement compared to baseline; for lower levels of exertion, mood improvement occurred immediately post-task, and for above LT exertion, mood improvement was delayed due to physiological recovery processes. The dual-mode model accounts for such changes in mood in-task, as physiological cues above LT should worsen in-task mood. Opponent process theory accounts for the post-task effects, considering the delay in onset of *b* processes in the above LT condition due to physiological recovery processes.

This study also provides evidence that, on average, individuals are likely to select a speed near 5% below LT, regardless of fitness level, and that the mood course of self-selected speed mirrors that of when they are assigned such a speed. There is also some very preliminary evidence that self-efficacy may play a larger role in determining mood when individuals choose their speed than when they are assigned, but further evidence is necessary before such a claim can be made.

These results suggest that maximal mood benefit in- and for 30 minutes post-task is achieved through exercise below LT, either assigned or self-selected. Exercise above

LT, on the other hand, produces maximal mood improvement after 30 minutes post-task. Awareness of this information could be useful to individuals beginning an exercise routine; if they know what mood changes to expect at what intervals, they can choose a level of exercise that will help them achieve their preferred mood state, and possibly be more likely to adhere to an exercise program.

This study also serves as an example of how full measures of mood, as opposed to single item measures, may be utilized in-task to achieve a more complete understanding of mood changes during and after exercise. Participants were able to complete the ADAQL and SAI at two time points in-task at all levels of exertion without trouble (as well as five times post-task), thereby revealing patterns of mood change for energy, tension, tiredness, calmness, and anxiety over the time course of exercise and recovery. These data indicated that exercise increased arousal in-task, followed by post-task mood improvement (after a recovery period for levels of exertion above LT), thus lending more support to previous data indicating worsening of mood in-task at high levels of exertion, followed by post-task mood improvement.

Although the study has the strength of full mood measures used in-task, it is limited by its small sample size. Furthermore, the artificial setting of the laboratory allows for more precise control and manipulation of variables that may affect mood, but reduces external validity. People tend to exercise in social settings, such as gymnasiums, or outdoors, as opposed to the more sterile laboratory setting. After exercising, people generally do not sit quietly for 60 minutes, but rather continue on with their day. It is therefore important to recognize that the findings regarding exertion level and mood

improvement may not apply in more naturalistic exercise settings. Extension of this work in naturalistic settings is recommended.

This study contributes to the expanding body of research examining the mood effects of exercise, both in-task and post-task. Although it lends some support to the dual-mode model in the context of opponent process theory, there is still room for further investigation of this area. Additional research examining cognitions during exercise, particularly at low levels of exertion, could increase support for the dual-mode model. More work with different aged populations, larger sample sizes, and in more naturalistic settings is also warranted. As we learn more about the mood effects of different levels of exertion during and after exercise, this information can be used to help people begin and maintain exercise programs, which would have substantial public health implications, as exercise reduces the risk of developing or dying from heart disease, diabetes, and high blood pressure, which are leading causes of death and disability in the United States (“Healthy People 2010”, 2000; U.S. Department of Health and Human Services, 1996). Furthermore, we know exercise can effectively treat and prevent depression (Craft & Landers, 1998; Landers & Arent, 2001; North et al., 1990; Roth & Holmes, 1987), which is one of the most serious mental health problems in the country with substantial consequences of human suffering, loss of life, and lost productivity (Klerman, 1989; Klerman & Weissman, 1992). Exercise is a simple but powerful intervention for improving physical and mental health, but it is extremely challenging for people to maintain. Any research that may contribute to the inauguration or maintenance of exercise could be extremely useful.

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Figure 1. Tiredness in the Above and Below LT Conditions

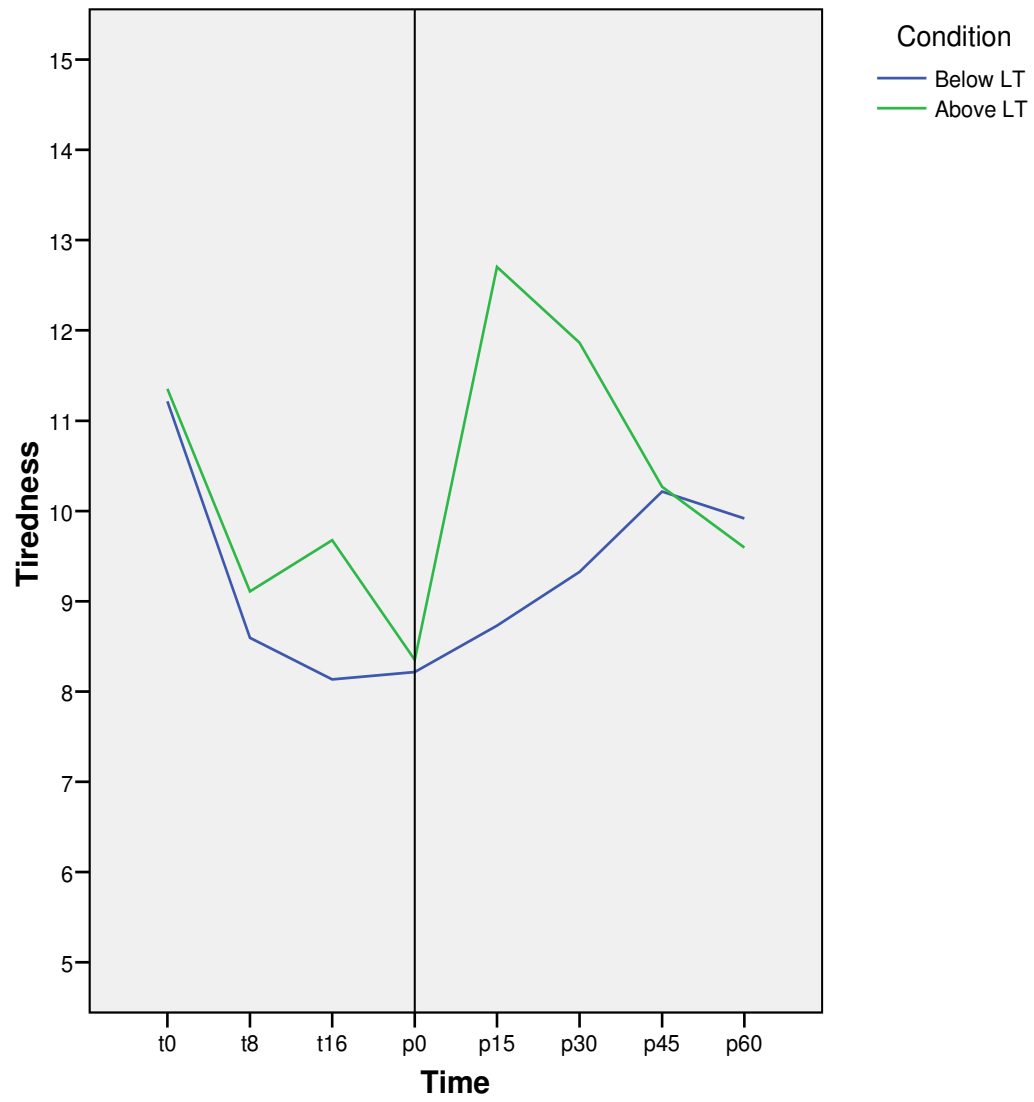


Figure 2. Tension in the Above and Below LT Conditions

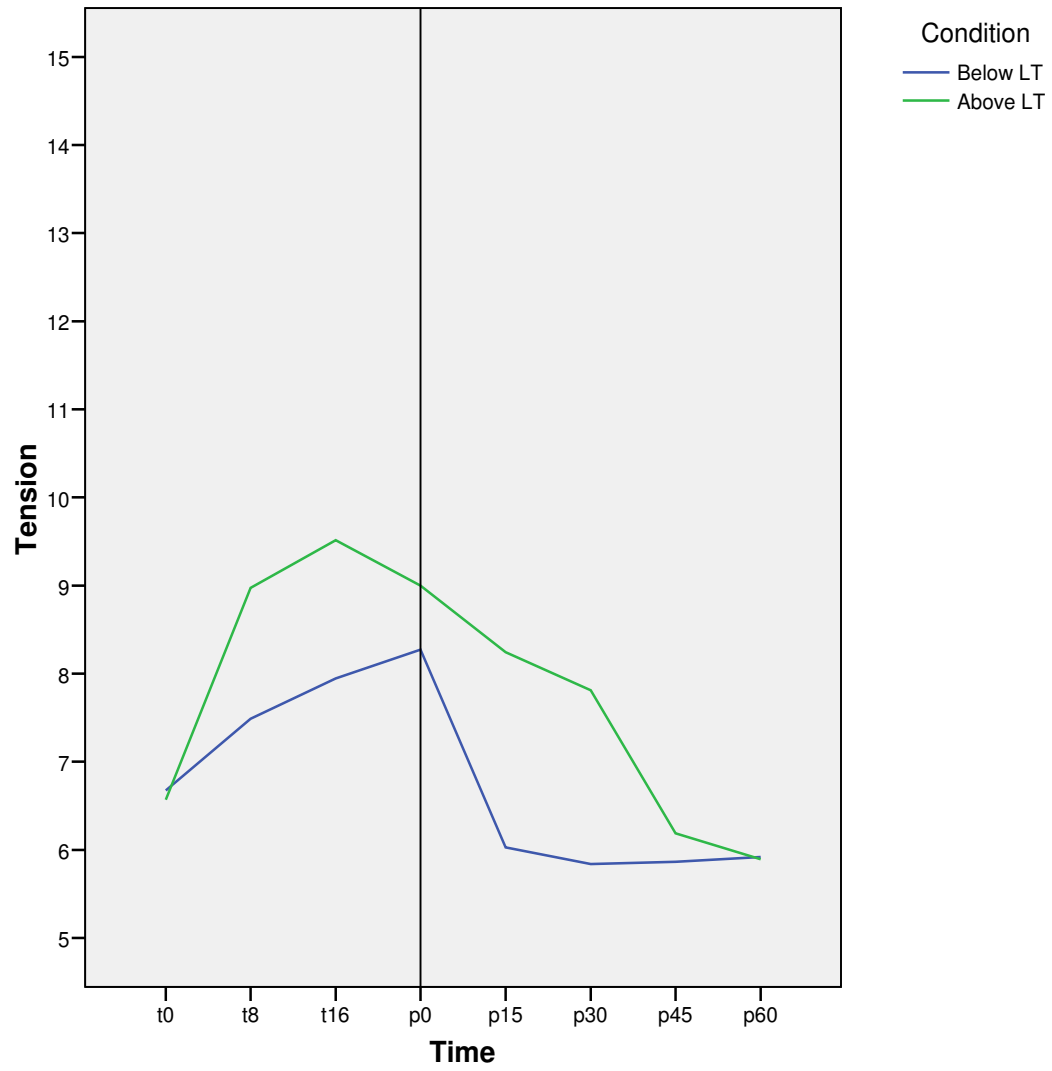


Figure 3. Calmness in the Above LT and Below LT Conditions

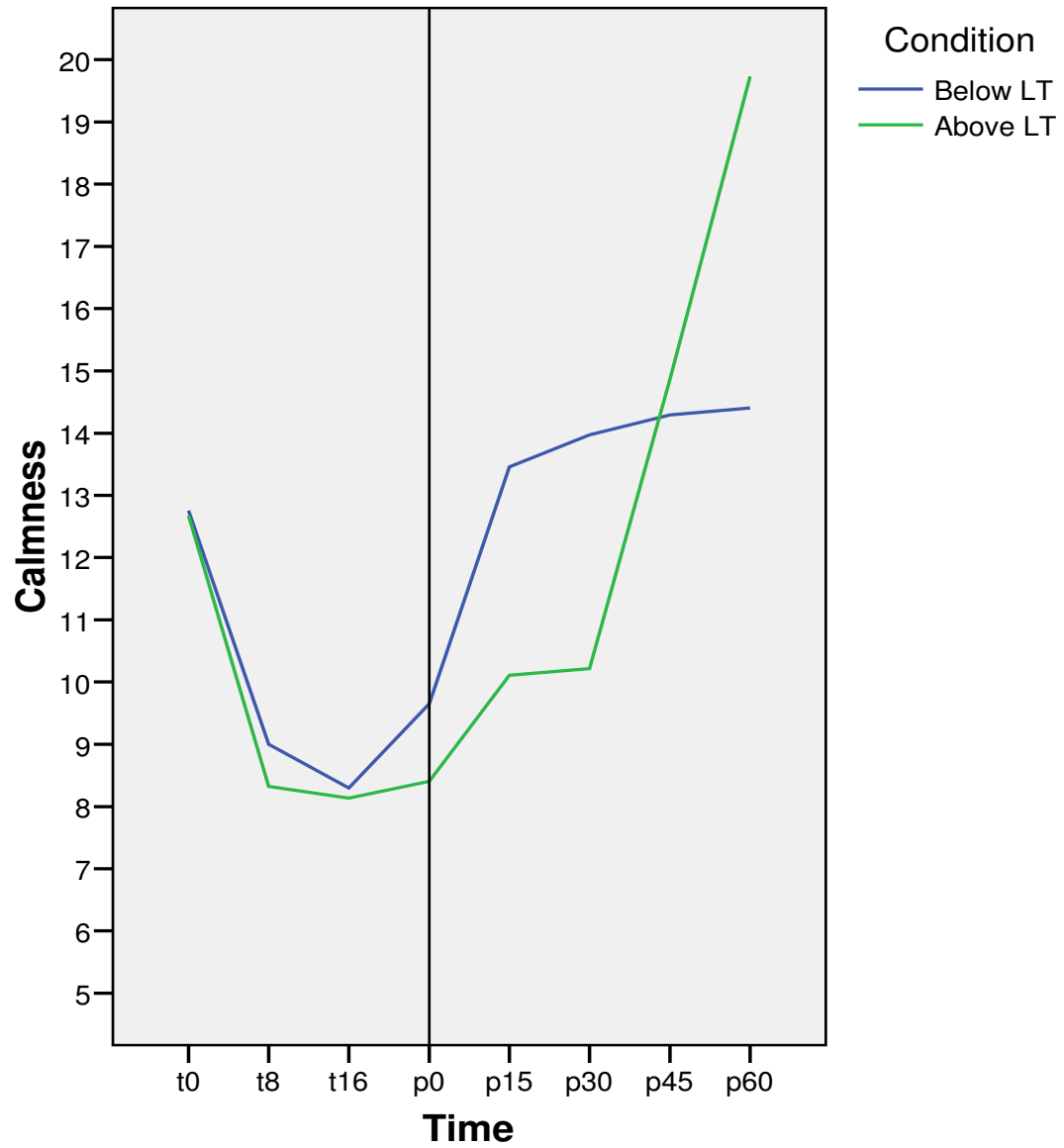


Figure 4. SAI in the Above and Below LT Conditions

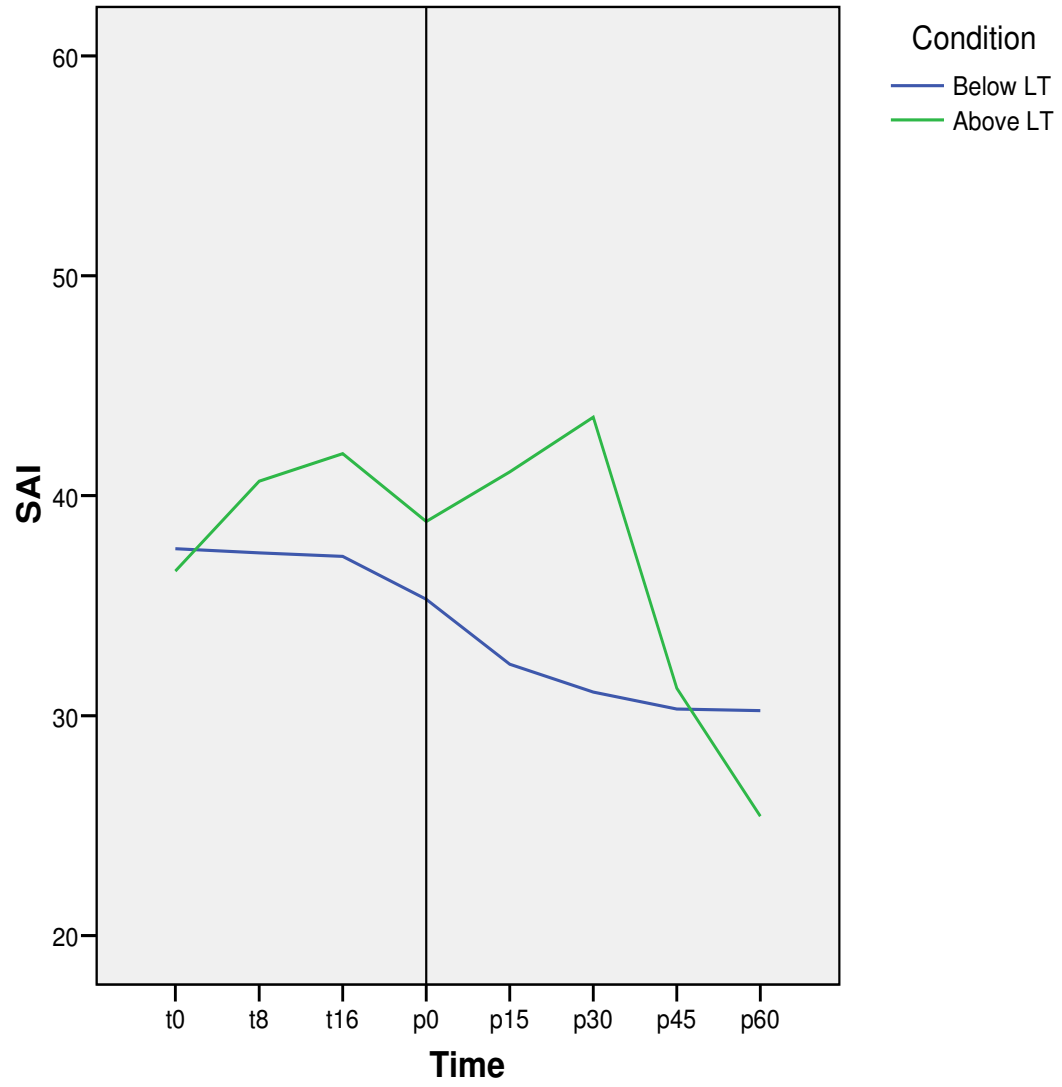


Figure 5. Energy in Active and Inactive Participants

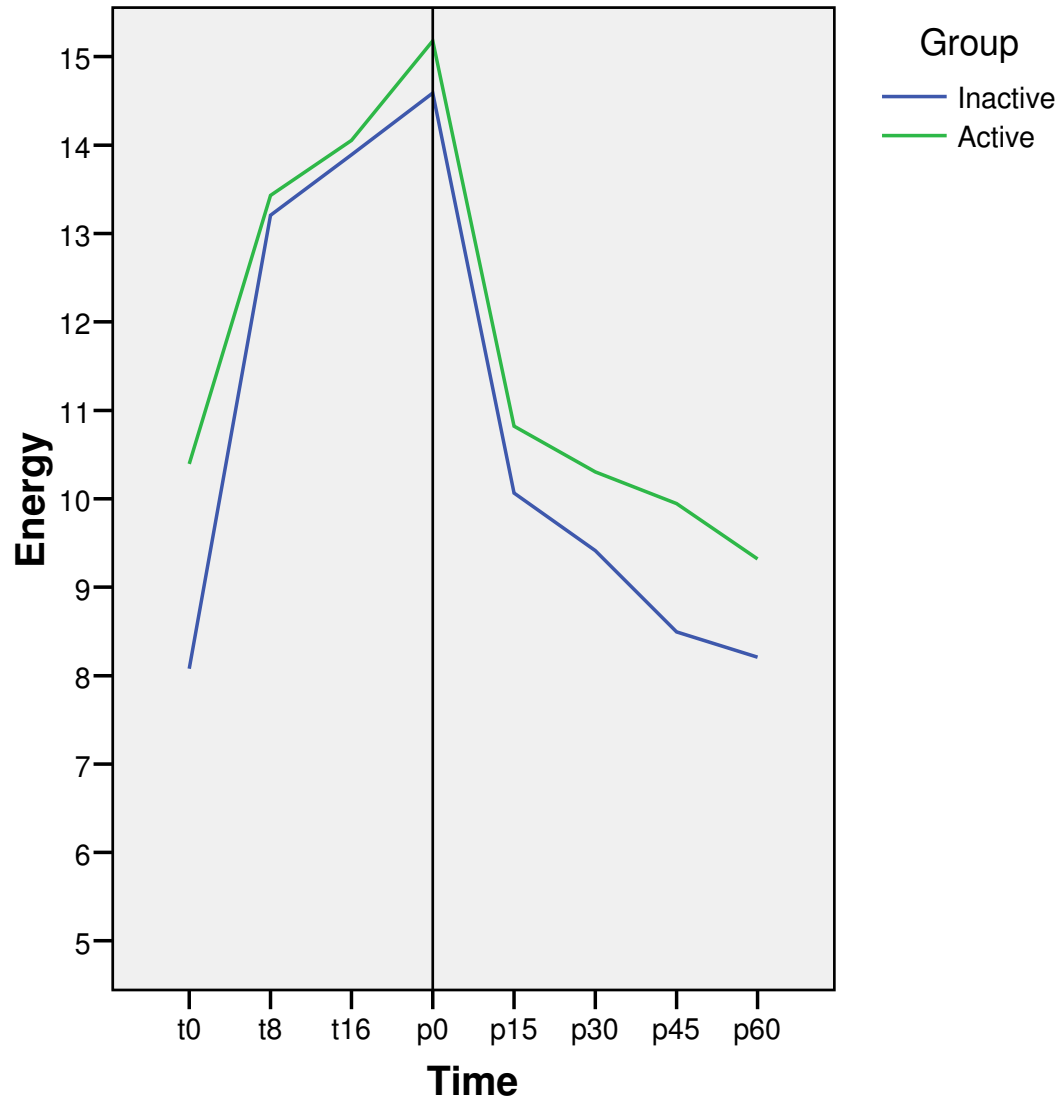


Figure 6. Tiredness in the Below LT, LT, Above LT, and Self-Selected Conditions

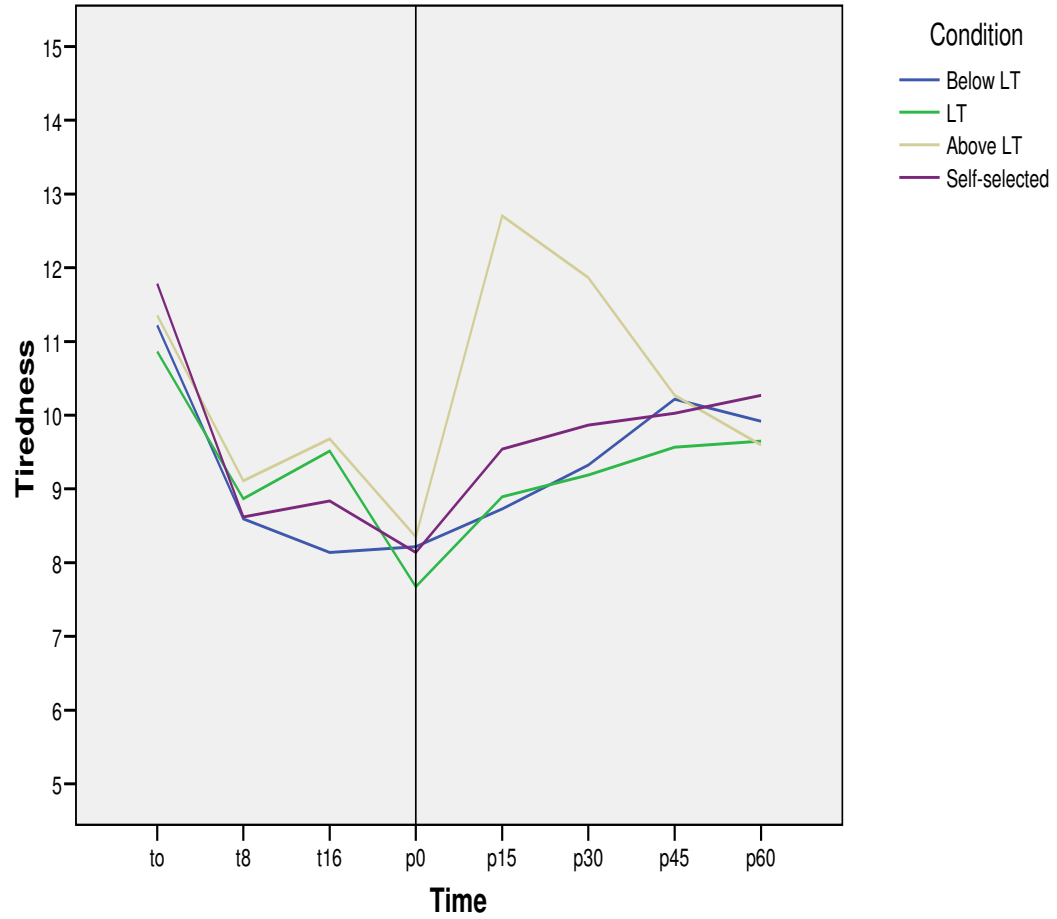


Figure 7. Tension in Active and Inactive Participants

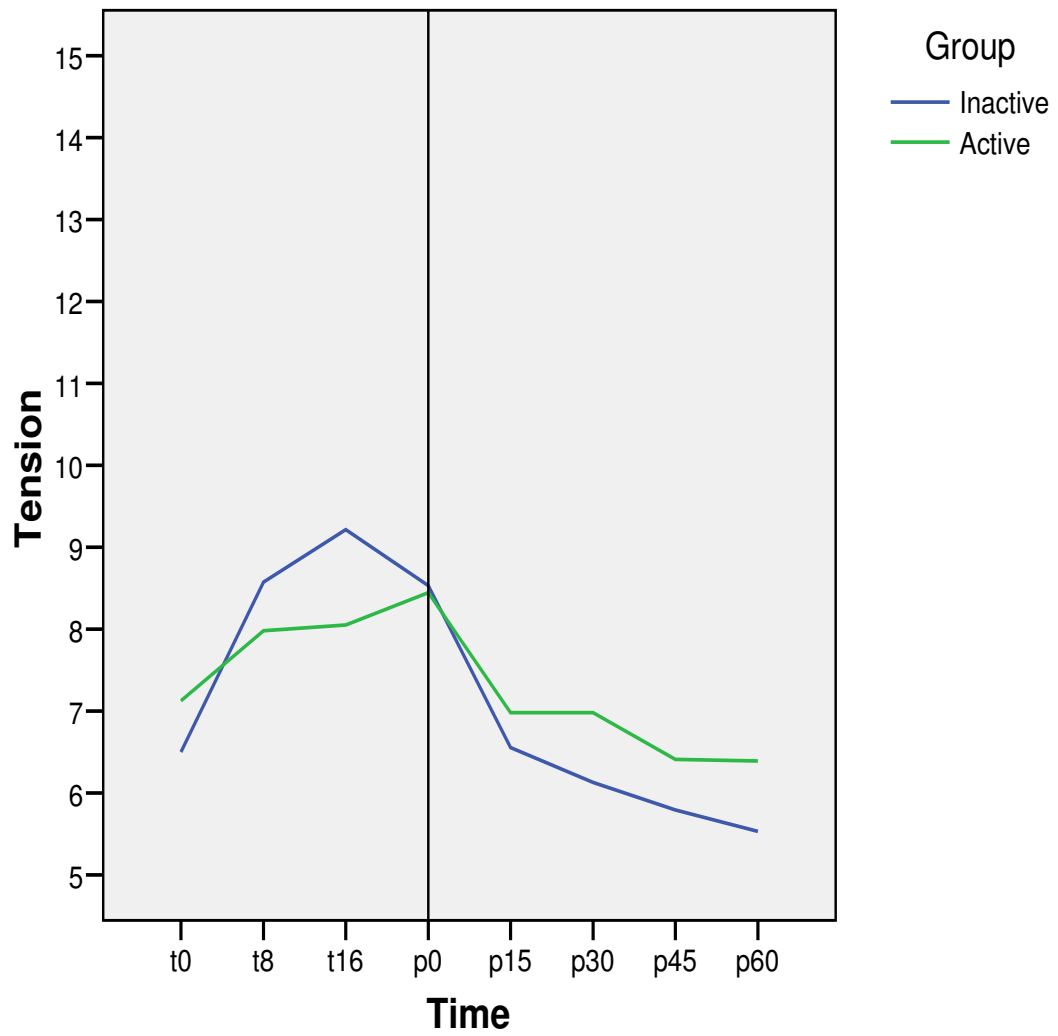


Figure 8. Tension in the Below LT, LT, Above LT, and Self-Selected Conditions

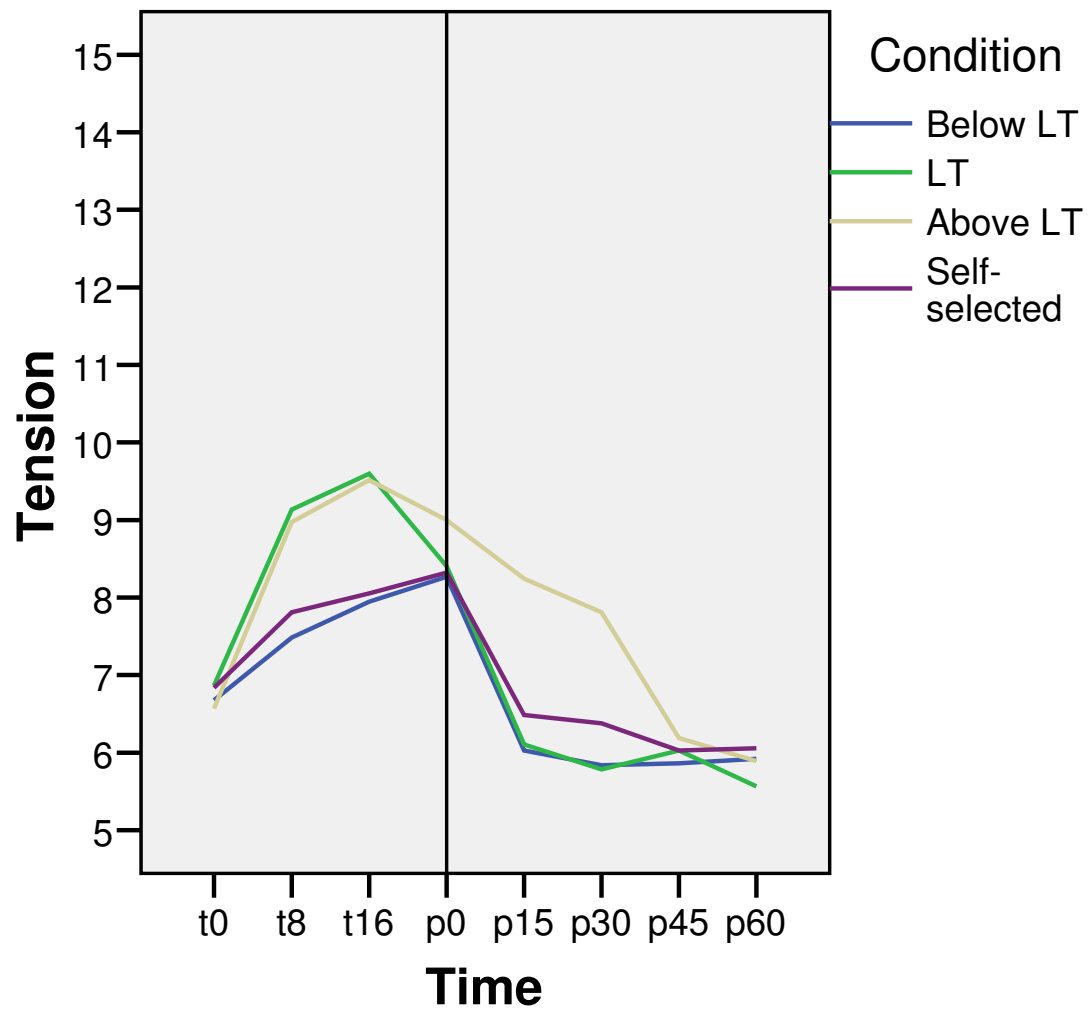


Figure 9. Calmness in the Below LT, LT, Above LT, and Self-Selected Conditions

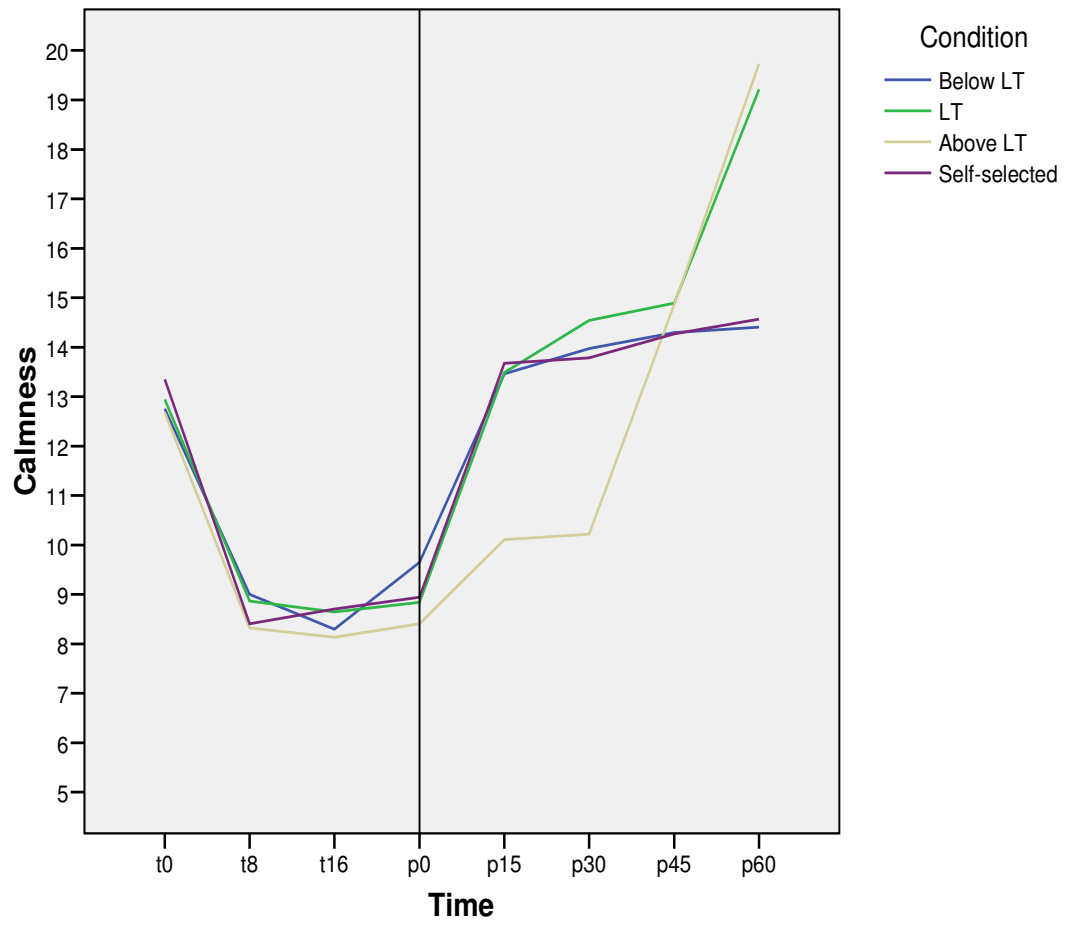
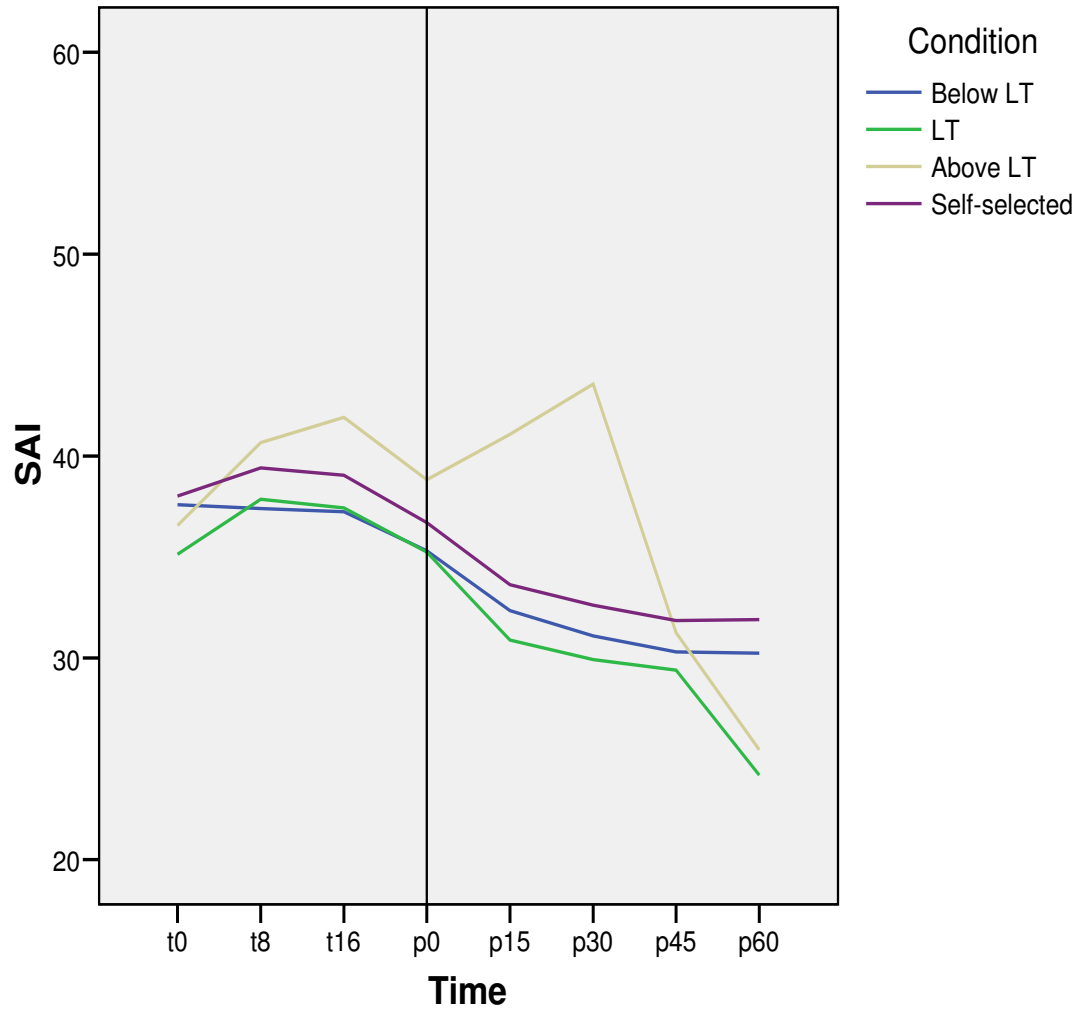


Figure 10. SAI in the Below LT, LT, Above LT, and Self-Selected Conditions



Curriculum Vitae
Sarah Melinda Markowitz

Education

- 1/2007-5/2009 Doctor of Philosophy in Psychology, Rutgers, the State University of New Jersey
- 9/2004-1/2007 Master of Science in Psychology, Rutgers, the State University of New Jersey
- 9/1998-5/2002 Bachelor of Arts in Psychology, Brown University

Work

- 7/2002-7/2004 Research Assistant, Pediatric Psychopharmacology Unit of Massachusetts General Hospital

Publications

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