REST DAY STRESS IN RUNNERS

by

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ABSTRACT

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Exercise has long been known to promote psychological well-being and resilience against stress. More recently, research has shown that habitual exercisers who are deprived of exercise experience negative psychological changes as a result. It is not completely known how planned non-exercise ("rest") days affect exercisers affectively, physiologically, or behaviorally, nor how factors like exercise dependence or cognitive appraisal may moderate these effects. This study used an in situ methodology to monitor stress in 18 runners on a run day and a rest day, in comparison to 21 non-exercising controls who ran on neither day. Stress was assessed via affective self-reports, ambulatory physiological measurements, and performance on a timed arithmetic task. Exercise dependence and appraisal of rest days was also assessed in the sample. It was hypothesized that runners would exhibit greater stress responses on the rest day than the run day, and that runners with higher levels of exercise dependence and more negative appraisals of rest days would exhibit greater changes in stress between the two days. Results showed that runners reported less positive affect and more negative affect on the rest day than the run day, and that levels of high frequency heart rate variability decreased over time on the rest day. Degree of exercise dependence was found to moderate the affective changes. The study indicates that runners experience negative affective and physiological changes on their rest days, and that exercise dependence can exacerbate these effects.

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LIST OF ABBREVIATIONS

ECG	Electrocardiogram
EDS	Exercise Dependence Scale
HF-HRV	High frequency heart rate variability
HRV	Heart rate variability
LF-HRV	Low frequency heart rate variability
NN50	Number of adjacent NN intervals that differ by more than 50 ms
nu	Normalized units
pNN50	Proportion of adjacent NN intervals that differ by more than 50 ms
RDN	Rest day negativity
RMSSD	Root mean square of successive differences
SDNN	Standard deviation of NN intervals

Rest Day Stress in Runners

Benefits of Exercise

Regular aerobic exercise, such as running, confers numerous physical and psychological health benefits. People who exercise enjoy reduced risk of disease factors including obesity and hypertension, reduced risk of diseases including coronary heart disease, diabetes, and cancer; and lower all-cause mortality (U.S. Department of Health and Human Services, 2018). Compared to non-exercisers, people who exercise also exhibit lower resting hearts (Reimers, Knapp, & Reimers, 2018), lower ambulatory blood pressures (Fagard, 2001), and greater heart rate variability (HRV; Aubert, Seps, & Beckers, 2003), cardiovascular adaptations which are themselves associated with favorable health outcomes (Dyer et al., 1980; SPRINT Research Group, 2015; Thayer & Lane, 2007; Thayer, Yamamoto, & Brosschot, 2010). Psychologically, exercise has been shown to enhance mood (Berger & Motl, 2000), reduce state and trait anxiety (Petruzzello, Landers, Hatfield, Kubitz, & Salazar, 1991), reduce symptoms of depression (Mikkelsen, Stojanovska, Polenakovic, Bosevski, & Apostolopoulos, 2017), and improve self-esteem (Yìğìter, 2014), among other positive effects.

These psychological and physiological adaptations are particularly advantageous in regard to stress. Exercisers report less perceived life stress (Tucker, Cole, & Friedman, 1986) and greater perceived ability to cope with stress (Steptoe, Edwards, Moses, & Mathews, 1989) than non-exercisers, and when confronted with acute stressors, they show less psychological and physiological reactivity. In response to physical stressors, such as exercise stress tests or cold pressor tests, people who exercise exhibit lesser heart rate (Throne, Bartholomew, Craig, & Farrar, 2000), blood pressure (Throne et al., 2000), and cortisol (Luger et al., 1987) responses than non-exercising controls. They also report less state anxiety (Throne et al., 2000), less negative affect (Throne et al., 2000) and more positive affect (Petruzzello et al., 1991) in the face of such stressors. Psychosocial stressors, such as Trier and Stroop tasks, similarly evoke lesser heart rate (Rimmele et al., 2007), blood pressure (Hamer, Taylor, & Steptoe, 2006), cortisol (Rimmele et al., 2007), and HRV (Klaperski, von Dawans, Heinrichs, & Fuchs, 2014) responses, as well as more calmness (Rimmele et al., 2007), better mood (Rimmele et al., 2007), and more positive affect (Childs & de Wit, 2014) in exercisers than non-exercisers. Altogether, aerobic exercise has a robust, positive effect on various trait measures of psychological and physiological stress, as well as a protective effect against acute stressors.

Detriments of Exercise Deprivation

Once one is accustomed to the benefits of an exercise routine, ceasing it can have detrimental effects that are equally profound. The effects of "running loss," for example, have been demonstrated in a study of runners who became unable to run due to injury (Chan & Grossman, 1988). In that study, runners who had injuries that temporarily prevented running but did not impede other day-to-day activities were compared to non-injured controls who continued to run during the observation period. Both groups were asked about their present mood, self-esteem, and body image. The injury-prevented runners were worse off than the continuing runners on every measure, indicating that an abrupt loss of running due to injury is associated with significant psychological distress.

Injuries and similar misfortunes can certainly force one to stop exercising, but they may also beget their own stress responses that can obscure those which are unique to exercise cessation. Many studies on exercise deprivation have attempted to control for such confounds by beginning with samples of healthy, unimpeded exercisers and asking half of them to abstain from exercise for a period of time. Studies using this kind of experimental design have shown that one- to two-week deprivations from various kinds of exercise lead to significant disturbances in mood (Evans, 2016; Morris, Steinberg, Sykes, & Salmon, 1990; Szabo & Parkin, 2001), which abate when exercise is resumed (Morris et al., 1990). This experimental approach shows that, coincident injuries notwithstanding, exercise cessation by itself can cause psychological distress.

Although psychological disturbance is one of the most common findings in studies of exercise deprivation, physical and physiological effects have been found as well. One of the earliest studies on the subject, for instance, found disturbances in sleep during a one-month experimental deprivation from exercise (Baekeland, 1970). Another study found an increase in perceived physical symptoms such as headache, stomach pain, and chest pain during a one-week deprivation (Gauvin & Szabo, 1992), and a third found an increase in symptoms similar to those of chronic multi-symptom illness after a week without exercise (Zeller, Abu-Shakra, Weitzman, & Buskila, 2011). Physiological reactivity to stressors has been shown to be affected by deprivation as well: one study (Berlin, 2004) tested this by measuring participants' heart rates during a mentally stressful task over the course of a two-week deprivation from exercise. During successive presentations of the task, the heart rates of those in the control group (who had continued exercising) attenuated, while those of the deprived group did not, indicating a reduced physiological coping response as a result of the deprivation.

Heart rate variability (variation in the time interval between heartbeats), despite its burgeoning popularity as a measure of stress response (Kim, Cheon, Bai, Lee, & Koo, 2018), has been assessed in relatively few deprivation studies. One study that examined HRV recorded electrocardiograms (ECG) of aerobic exercisers before and after a two-week deprivation from exercise (Weinstein, Deuster, & Kop, 2007). Although the exercise cessation did not have an effect on HRV outright, it was found that baseline levels of HRV predicted the mood and fatigue changes that were caused by the cessation. Specifically, the pre-deprivation ratio of low frequency (LF) to high frequency (HF) HRV was positively correlated with post-deprivation fatigue and depression scores. It was further found that these correlations were primarily driven by the high frequency component of HRV, such that lower baseline HF-HRV predicted greater increases in fatigue and depression as a result of deprivation.

A similar study, however, found no changes in HRV after a two-week deprivation, and no correlations between HRV and cessation-induced mood changes (Poole, Hamer, Wawrzyniak, & Steptoe, 2011). These conflicting findings indicate that further study is warranted on how physiological variables, particularly HRV, relate to exercise cessation.

Effects of Short-Term Abstinences

The studies discussed so far have concerned “long-term” (one week or longer) deprivations, and in fact, two weeks has been suggested as an “optimal” length of time for negative effects to develop (Berlin, 2004; Weinstein et al., 2007). However, the effects of deprivation can also be seen, to some degree, in much shorter periods of non-exercise. For example, one study (Niven, Rendell, & Chisholm, 2008) assessed affect and body satisfaction in women before and after a 72-hour abstinence from exercise, and found affective disturbances and decreased body satisfaction in response to the brief abstinence. Another study (Mondin et al., 1996) monitored exercisers over a five-day period during which they exercised as normal on the first day, abstained from exercising for the next three days, and returned to normal exercise on the fifth day. Daily measures of anxiety, depression, and mood showed that feeling states became increasingly disturbed during the three-day period of non-exercise. On the fifth day, when participants resumed exercising, the measures returned to baseline levels. This evidence shows that affective disturbances can emerge within days of exercise cessation, and, with resumption of exercise, can remit just as quickly.

Even abstinences as brief as 24 hours have been shown to yield negative effects. One study (Thaxton, 1982) directed runners to either run as normal or to abstain from running for one day while the researchers assessed their mood states and galvanic skin response during a mental stressor. Those who had abstained from running for the day reported greater levels of depression and showed more electrodermal reactivity than those who had run. Another study (Aidman & Woollard, 2003) assessed mood states and self-recorded heart rates from cross-country runners two days prior and 24 hours after a one-day abstinence from running. The researchers found that, from the pre- to post-abstinence measurements, moods had worsened and resting heart rates had increased. These studies show that even very brief deprivations—essentially, one missed workout—can cause negative affective and physiological changes.

Effects of Natural Lapses

To most habitual exercisers, these findings would not likely come as a surprise. Short-term lapses from exercise can happen often, whether because of a planned day off, or due to impediments like illness, lack of time, or inclement weather. Anecdotal reports show that, to the average fitness hobbyist, the transient mood effects of a missed workout are painfully familiar (peachykeen102, 2020). In order to assess the impact of these kinds of naturally occurring non-exercise days, several studies have forgone the experimental deprivation paradigm in favor of an in situ approach.

One such study (Conboy, 1994) followed runners for 15 consecutive days while they went about their normal running routines and answered daily mood questionnaires. The researcher compared the runners' moods on days they had run to days they had not, and found that, overall, moods were more dysphoric on the non-running days. A similar study (Szabo, Frenkl, Janek, Kálmán, & Lászay, 1998) monitored runners for 21 consecutive days of normal running. Nightly mood and anxiety measures showed that, on average, the runners had better moods and less anxiety on running days than non-running days.

In situ studies such as these two provide an important contribution to the exercise deprivation literature because they rely on natural withdrawals from exercise rather than forced ones. In effect, they explore a different, but more commonplace, phenomenon. However, as noted previously, these organically-arising abstinences can still occur for a variety of different reasons, and neglecting to account for those differences is a significant limitation of these kinds of studies. Put another way, a catch-all measure of non-running days is likely to include both planned rest days and unplanned layoffs, when these two kinds of non-exercise may be qualitatively different. In fact, the latter type (those imposed by external forces) could conceivably feel similar to the study-imposed abstinences of experimental deprivation research.

It is important, then, to differentiate between planned and unplanned non-exercise in studies of short-term withdrawal. One study (Hausenblas, Gauvin, Symons Downs, & Duley, 2008) has attempted to do this by experimentally manipulating the source of the deprivation. In this study, the researchers asked exercisers to disclose their plans for exercising that week, so that it was known beforehand on which days they planned to exercise and on which they planned to rest. Each morning, the researchers then instructed the participants to either exercise as planned or to abstain from exercising. Because the participants' planned non-exercise days were known in advance, an instruction to abstain from exercise produced either a "true deprivation" (the participant planned to exercise, but was told not to) or a "false deprivation" (the participant planned not to exercise, and was told not to). After the instruction, ecological momentary assessment was used to gauge the participants' feeling states throughout the day. The findings of this lone study on planned versus unplanned non-exercise, however, generate relatively more questions than answers. Unexpectedly, positive feeling states were found to be higher after true deprivation than false deprivation, meaning that the participants felt better when they were forced not to exercise than when they themselves chose not to. These findings are seemingly in contradiction to the wealth of research demonstrating that deprivation, specifically, induces negative mood changes. The researchers suggested a possible explanation for this discrepancy:

because the feeling inventory used in the study primarily assessed positive feeling states, rather than negative ones, they speculated that deprivation may manifest differently in positive and negative feeling states. Whereas negative states are definitely affected, positive ones may not be. Nevertheless, this study remains one of the only so far to specifically explore the effects of exercisers' planned, internally-motivated rest days, and its peculiar findings indicate that more research on this topic is certainly needed.

Moderating Effects of Exercise Dependence

Several studies that have investigated the affective and physiological effects of exercise deprivation have additionally examined whether certain types of exercisers are more prone to, or more adversely affected by, these effects. Such studies have primarily focused on measures of exercise addiction or dependence. In fact, the concept of exercise dependence was first introduced by Baekeland (1970) in an early study on exercise deprivation, when, in recruiting participants for the study, he had considerable difficulty finding any habitual exercisers who would be willing to forgo it.

Since then, the phenomenon of exercise dependence has been well-substantiated, though some disagreements remain about its nature. Some have characterized it as a "positive addiction" (Glasser, 1976), because, ultimately, it promotes a health behavior. Others have understood it in terms of addiction as defined by the Diagnostic and Statistical Manual of Mental Disorders, and so have regarded it as decidedly negative (Hausenblas & Symons Downs, 2002). On the whole, there is no universally embraced definition for the term, but compulsive engagement in exercise and experience of withdrawal symptoms are both widely accepted characteristics (Landolfi, 2013).

Deprivation studies that have assessed exercise dependence in their samples have found differential responses to deprivation based on level of dependence. In Aidman and Woollard's

(2003) one-day experimental deprivation study, participants were assessed at the outset with the Running Addiction Scale (Chapman & de Castro, 1990). When the sample was split at the median addiction score, the researchers found that those in the upper (more addicted) half had more significant deprivation-induced changes in mood and resting heart rate than those in the lower half. Additionally, in most of the mood states assessed, the magnitude of the changes correlated with the addiction score: runners who were more addicted were more affected.

Another study (Antunes et al., 2016) assessed runners using the Negative Addiction Scale (Hailey & Bailey, 1982) and then monitored their mood states before, during, and after a two-week deprivation period. The researchers found that only the runners who had symptoms of exercise dependence showed negative changes in mood during the deprivation—the non-exercise-dependent runners were not affected.

Hausenblas & Symons Downs' (2008) true-versus-false deprivation study used the Exercise Dependence Scale (EDS [Hausenblas & Symons Downs, 2002]) to assess the sample, though due to concerns about adherence to the deprivation protocol, anyone meeting the criteria for "at risk for exercise dependence" (the most severe classification on the scale) was excluded. Of the remaining participants, those with lower levels of exercise dependence experienced greater positive feeling states on true deprivation days than false deprivation days, while those with higher levels of exercise dependence felt about the same on both days. Although, as previously noted, the findings in this study regarding positive feeling states during deprivation differ somewhat from those of other research, what is consistent is the finding that the more dependent participants fared worse.

Moderating Effects of Cognitive Appraisal

Conboy's (1994) in situ study also assessed dependence factors in its sample, and in doing so, posed questions about the additional role of cognitive appraisal in the withdrawal response. Conboy evaluated his sample using a two-factor model of running addiction (Sachs & Pargman, 1984), which considers both degree of dependence (a psychophysiological phenomenon) and degree of commitment (a cognitive phenomenon). Elsewhere, these concepts have been characterized as "negative addiction" and "positive addiction," respectively (Szabo, Frenkl, & Caputo, 1997). By classifying the participants as either "high" or "low" on each factor, Conboy split his sample into four distinct groups. Surprisingly, and in contrast to the model's predictions, runners in the high-dependence, high-commitment group (i.e., those with both positive and negative addiction) showed the least change in mood between running and non-running days. Those with high dependence, but low commitment, on the other hand, experienced the most significant changes. Conboy speculated that the high-commitment runners may not have experienced dissonance on their rest days because they view those days as an important part of their overall training plan. In other words, a day off may be less distressing to a runner who appraises it as positive, and ultimately congruous with their running habit overall.

The notion that appraisal of a potential stressor can moderate the stress response was introduced by Lazarus and Folkman (1984) in their transactional model of stress and coping, and appraisal factors have since been proven to influence a number of stress responses in wide-ranging situations. In the context of exercise, differences in cognitive appraisal and reappraisal of exercise have been shown to alter affective responses (Rose & Parfitt, 2010), perceived exertion (Giles et al., 2018), and enjoyment of the exercise (Harte & Eifert,1995), among other factors, indicating that the way one thinks about exercise can alter their experience of it. By the same token, appraisal factors could conceivably influence the experience of missed exercise as well. The questions posed by Conboy's study and the analogous evidence regarding exercise and appraisal highlight a need for considering appraisal of rest days as a potential moderator of the rest day stress response.

Summary of Literature and Gaps in Knowledge

The literature demonstrates robust evidence of a negative affective response to non-exercise, with some evidence for a physiological response as well. These effects include profound disturbances in long-term deprivations and more subtle, transient disturbances in short-term ones. In habitual exercisers, as little as one day without exercise has been shown to provoke a response, and even natural lapses can produce the effect. Studies that have incorporated dependence as a variable have largely found qualitatively or quantitatively worse responses in dependent participants.

However, an important gap in the research concerns the nature of short-term lapses: although anecdotal reports suggest as much, there lacks a scientific confirmation as to whether these effects are present, and to what extent, on exercisers' planned rest days. Additionally, other dimensions of the stress response, including the physiological and behavioral effects of non-exercise, remain remarkably understudied. As such, it is still not fully known how changes in physiology and behavior complement affective disturbances during a planned rest day, nor how exercise dependence or cognitive appraisal factors may moderate these effects.

Present Study

This study used an in situ, naturalistic observation method with a mixed-model design in order to assess the affective, physiological, and behavioral stress responses runners experience on rest days. Running was the exercise modality chosen for the study because it is a common form of aerobic exercise and can be easily quantified. An in situ methodology was essential because this study aimed to monitor the effects of planned, voluntary—not forced—non-running days. As such, the study did not impose particular running and rest days, but these coincided with participants' planned running schedules. Naturalistic observation was similarly important in capturing an authentic picture of the short-term stress response. For this reason, participants were monitored remotely and asked to go about their normal routines during the observation period. A mixed-model design allowed for comparison of the runners to non-exercising controls over the same time period, which was necessary for identifying changes that were unique to the runners.

Stress Measurement

To the vexation of many psychophysiologists, there is no standardized way of measuring "stress." This shortcoming is due in part to the view that, rather than as a singular variable, stress is best understood as a general concept which encompasses numerous phenomena (Cooper & Dewe, 2008; Lazarus & Folkman, 1984). More specifically, the stress response is commonly conceptualized as including psychological (including subjective, cognitive, and affective), physiological, and behavioral dimensions (Lazarus & Folkman, 1984; Tomaka, Blascovich, Kelsey, & Leitten, 1993). In order to capture a comprehensive picture of the stress response, this study used several measures of stress across these three dimensions.

Psychological stress was measured via self-reported affect and perceived stress; physiological stress was measured via ambulatory heart rate and heart rate variability, collected remotely via a wearable electrocardiogram device; and behavioral stress was measured via performance on a timed arithmetic task, which served as an acute stressor. Collecting measurements over the course of the day as well as in proximity to the acute stressor yielded both tonic and phasic measures of stress response.

About Heart Rate Variability

A particular focus of the physiological stress measurement in this study was heart rate variability, a measure of cardiovascular autonomic function that has been increasingly scrutinized over the last fifty years (Billman, 2011). HRV exists because heart beats are not metronomic; the sinoatrial node receives a variety of constantly-fluctuating inputs that act to change the heart rate moment-to-moment, and the resulting variation is HRV. An animal's ability to vary its heart rate signifies greater regulatory ability of the autonomic nervous system, and is thought to confer a survival advantage. For this reason, many reports suggest that greater HRV is desirable in terms of coping with stress (Kim et al., 2018). In addition, HRV reactivity has been found to be a reliable measure of psychological stress (Kim et al., 2018). Although HRV is largely tied to heart rate itself (de Geus, Gianaros, Brindle, Jennings, & Berntson, 2019), changes in HRV that indicate distress have been found to precede changes in heart rate (Hon & Lee, 1965), indicating that it may be a more sensitive measure of psychophysiological stress than heart rate alone.

HRV is typically measured via electrocardiogram, from which it is calculated based on variations in the RR intervals. Analysis of HRV is commonly done using either time-domain or frequency-domain methods, and each type of method yields several indices that can be used to represent HRV. The time-domain measures use calculations based on the interbeat interval—these include the standard deviation of NN intervals (SDNN), the root mean square of successive differences (RMSSD), the number of adjacent intervals that differ by more than 50 ms (NN50), and the proportion of adjacent intervals that differ by as much (pNN50). The frequency-domain measures are based on spectral analysis, typically done through a fast Fourier transform. The spectral components of HRV include high frequency (.15–.4 Hz), low-frequency (.04–.15 Hz), and very low frequency (.0033–.04 Hz) bands. The frequency-domain measures are of particular interest because they convey information about the physiological correlates of HRV: HF is attributable to parasympathetic nervous system activity, while LF is thought to be influenced by activity in both the sympathetic and parasympathetic systems (Task Force of the European Society of Cardiology, 1996). The HF and LF components of HRV can be measured in absolute values (ms^2), but the interest in direct comparison of the two makes normalized units (nu) a more appropriate representation.

Hypotheses

In light of these variables, it was hypothesized that the runners would exhibit worse affect (more negative affect and less positive affect), more perceived stress, more physiological stress (higher heart rate and lower HRV), greater physiological reactivity to the stress task, and worse performance on the task on the rest day than the run day. It was further hypothesized that runners who are more exercise dependent and runners with more negative appraisals of rest days would experience more significant changes between the two days.

Method

Overall Methodological Approach

The study used a quasi-experimental, one-between-subjects, one-within-subjects design (Runners vs. Controls, Run Day vs. Rest Day) to test the hypotheses. The dependent variables included measures of physiological arousal (heart rate and heart rate variability), affect (self-report scales), and behavior (performance on the stress task). The purpose of the design was to assess the changes that took place in runners between run and rest days, as compared to controls who ran on neither day.

Participants

Three hundred and forty-four adult undergraduate psychology students at the University of Wisconsin–Milwaukee took a preliminary survey to determine eligibility for the study. Because of the significance of the physiological variables in this study, participants were excluded from consideration if they reported having cardiovascular health abnormalities (such as high blood pressure or history of heart attack) or taking medications that affect the cardiovascular or central nervous system (such as steroids or beta-blockers). Respondents with incomplete or missing data were also excluded.

Participants were considered for inclusion in the running group if they reported (a) typically running at least three times per week (b) for a total of at least five miles per week, and (c) having done so for at least one month. In order to sample recreational runners as opposed to elite or professional runners, any respondents indicating that they participated in official training related to running (e.g., being on the track team) or considered themselves "elite" runners were excluded. Participants were considered for the control group if they reported that they did not regularly engage in aerobic exercise.

One hundred and thirty-one survey respondents met criteria for participation in the experimental portion of the study and were invited to participate via email. Of these, 64 did not respond and 28 declined to participate. Thirty-nine participants, including 18 runners and 21 controls, took part in the experimental portion of the study. These participants ranged in age from 18 to 40 (M = 22.46, SD = 5.14) and were predominantly women (76.9%). Participants were compensated for their participation with extra credit in their psychology courses.

Difficulty finding qualified runners, coupled with low response rates and eventual cessation of recruitment due to the COVID-19 pandemic, resulted in a smaller than desired sample size. However, a 0% attrition rate in the experimental portion of the study partially compensated for this limitation.

Materials

Pre-Experimental Survey

The preliminary survey was delivered online through the Sona Experimental Management System. For the purpose of determining eligibility in the second portion of the study, this survey collected participants' basic demographic and contact information, running and exercise habits, and cardiovascular health history (see Appendices A and B for a complete list of survey questions). It also collected scores on math aptitude tests (the UW System Math

Placement Test and the math components of the SAT and ACT) and baseline measures on six questionnaires: the Brief Symptom Inventory, Beck Anxiety Inventory, Beck Depression Inventory, Perceived Stress Scale, Exercise Dependence Scale, and, for participants who said they were runners, a rest day negativity questionnaire.

Brief Symptom Inventory. The Brief Symptom Inventory (Derogatis & Melisaratos, 1983) is a 53-item questionnaire designed to measure psychological distress. Respondents are asked to report the degree to which they have experienced symptoms such as "faintness or dizziness," "trouble falling asleep," and "feelings of worthlessness" over the past seven days on a five-point Likert scale from 0 (not at all) to 4 (extremely) (see Appendix C). This study used the Global Severity Index sub-scale of the inventory, where higher scores indicate higher psychological distress. The Global Severity Index has shown particularly strong reliability (r = .90) and the Brief Symptom Inventory has shown strong convergent validity with analogous components of the Minnesota Multiphasic Personality Inventory (Derogatis & Spencer, 1982). Cronbach's α for the present study was .97.

Beck Anxiety Inventory. The Beck Anxiety Inventory (Beck, Epstein, Brown, & Steer, 1988) is a 21-item questionnaire for measuring anxiety. Respondents indicate the extent to which they have been bothered by symptoms such as "numbness or tingling," "difficulty breathing," and "fear of the worst happening" over the past seven days on a four-point Likert scale from 0 (not at all) to 3 (severely) (see Appendix D). Higher scores indicate greater anxiety. The measure has been found to be internally consistent (Cronbach's α = .92) and reliable (r = .75 over one week) (Beck et al., 1988), and to have convergent validity with the State-Trait Anxiety Inventory (Fydrich, Dowdall, & Chambless, 1992). Cronbach's α for the present study was .92.

Beck Depression Inventory. The Beck Depression Inventory (Beck, Ward, Mendelson, Mock, & Erbaugh, 1961) is a 21-item, multiple-choice questionnaire designed to measure depression. For each question, respondents choose one of four statements that best describes their experience over the past seven days. Statements in each group range from reflecting minimal or no depressive feelings to reflecting severe depressive feelings. For example, respondents endorse “I do not feel sad,” “I feel sad,” “I am sad all the time and I can’t snap out of it,” or “I am so sad or unhappy that I can’t stand it” (see Appendix E). Higher scores indicate greater depression. In nonpsychiatric participants, the measure is internally consistent (Cronbach’s α = .81) and has convergent validity with the Hamilton Psychiatric Rating Scale (*r* = .74) (Beck, Steer, & Carbin, 1988). Cronbach’s α for the present study was .90.

Perceived Stress Scale. The Perceived Stress Scale-10 (Cohen & Williamson, 1988) is a 10-item questionnaire that measures the degree to which a person perceives situations in their life as stressful. Respondents answer questions such as, “In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?” on a five-point Likert scale from 0 (never) to 4 (very often) (see Appendix F). Higher scores indicate greater perceived stress. Among college students, the measure has been found to be internally consistent (Cronbach’s α = .89) and convergently valid (e.g., State Trait Anxiety Inventory, *r* = .73) (Roberti, Harrington, & Storch, 2006). Cronbach’s α for the present study was .89.

Exercise Dependence Scale. The Exercise Dependence Scale-21 (Hausenblas & Symons Downs, 2002) is a 21-item questionnaire designed to assess psychological dependence on exercise. Respondents are asked to report how often they have experienced beliefs and behaviors such as “exercis[ing] to avoid feeling irritable,” “exercis[ing] when injured,” and “continually increas[ing] exercise intensity to achieve the desired effects/benefits” over the last three months on a six-point Likert scale from 1 (never) to 6 (always) (see Appendix G). Based on the recommended scoring procedure, participants were classified as “at risk for exercise dependence,” “nondependent-symptomatic,” or “nondependent-asymptomatic.” The scale has shown good test-retest reliability (7 days; $r = .95$) and internal consistency (Cronbach's α = .78–.93 for the seven sub-scales) (Symons Downs, Hausenblas, & Nigg, 2004). Cronbach's α for the present study was .97.

Rest Day Negativity Questionnaire. Survey respondents who indicated that they were runners were also given a rest day negativity (RDN) questionnaire. This 13-item questionnaire was created for the present study to assess the degree of negativity with which runners regard their rest days. A "rest day" was defined in the instructions as "a day off from running." Respondents endorsed statements such as "I look forward to my rest days," "I feel anxious on rest days," and "Sometimes I run on a planned rest day," on a five-point Likert scale from 1 (disagree completely) to 5 (agree completely) (see Appendix H for a complete list of questions). Higher scores indicate greater negativity toward rest days. Cronbach's α for the present study was .81.

BioHarness

Zephyr BioHarness 3.0 devices (Zephyr Technology, 2012) were used to take the physiological measurements. The BioHarness is a wireless, wearable electrocardiograph monitor designed for remote collection of physiological data, including heart rate and heart rate variability. The device consists of a nylon chest strap and a detachable plastic module. ECG sensors on the strap contact the wearer's skin and conduct signals from the heart at a 250 Hz sample rate. This data is saved to the module and can later be exported to a computer. The BioHarness has demonstrated excellent reliability and validity in heart rate measurement across activity states and populations (Nazari et al., 2018).

Users secure the strap around the upper chest and press a button to turn the device on, which begins data collection. Because of the importance of naturalistic observation in this study, it should be noted that the device is comfortable and can be worn inconspicuously under clothes, allowing users to carry out most everyday activities. Ten size small and ten size large BioHarnesses were used in the study. Each participant was issued a device after having had the opportunity to try on and choose between sizes. Straps were laundered and modules, disinfected between uses.

Folder Materials

Participants were each given a folder with materials for the at-home portion of the study.

Hourly Affect Questionnaires. Participants were given eight identical questionnaires to be completed at each hour of the study on both days. These one-page questionnaires contained the Physical Activity Affect Scale (Lox, Jackson, Tuholski, Wasley, & Treasure, 2000), a 12-item scale for measuring exercise-induced affect. Participants indicate the extent to which they are experiencing feeling states like "energetic," "relaxed," and "worn-out" on a five-point Likert scale from 0 (do not feel) to 4 (feel very strongly) (see Appendix I). The Physical Activity Affect Scale yields four sub-scales: positive affect, negative affect, tranquility, and fatigue. Higher scores on each sub-scale indicate greater affective experience. The scale has demonstrated adequate reliability and validity (Lox et al., 2000) and measurement invariance across exercising and non-exercising participants (Carpenter, Tompkins, Schmiege, Nilsson, & Bryan, 2010). Cronbach's alphas for the present study were .84 (positive affect), .70 (negative affect), .88 (tranquility), and .88 (fatigue).

The hourly questionnaires additionally asked participants to rate their stress level over the past ten minutes on a five-point Likert scale from 0 (no stress at all) to 4 (highly stressed), and to briefly describe their activity for the past ten minutes.

Math Tasks. A math task was used as an acute stressor. The math task was given on paper and consisted of 168 three-addend, single-digit addition problems, such as 9 + 3 + 8. Participants were instructed to complete as many of the problems as they could in a five-minute period. Participants completed three different versions of the task: one as a baseline measure during the introductory meeting, and one on each day of the study. A research assistant timed the task for the participant during the introductory meeting, and participants timed themselves on the study days. Scoring was based on the number of items completed and the percentage of items completed correctly.

Daily Activity Logs. Participants were also given daily logs for each day of the at-home portion of the study. They were asked to use them to briefly report their activity hour-by-hour throughout the day.

Timing Devices. To assist with timing the questionnaire intervals and the math task, participants were given the option to use a lab-issued timing device (Invisible Clock II; Time Now, Inc., 2003) or to use the timing feature on their personal smartphones or devices. All participants elected to use their own devices. They were instructed to set an hourly alarm on their device for the questionnaires, and to set a five-minute countdown timer for the math task.

Procedure

Participants took the preliminary survey online after giving informed consent. Those who met eligibility requirements and agreed to participate in the second part of the study came into the laboratory and met with a trained research assistant. After obtaining informed consent, the research assistant issued the participant their study equipment, including a BioHarness and folder of materials. The research assistant explained the study procedure in detail and made sure the participant understood their role. The research assistant also taught the participant how to wear and use the BioHarness. At this initial meeting, the participant completed their first math task in the presence of the research assistant.

Participants took the study equipment home and completed the remainder of the study on their own. The at-home portion of the study took place over two consecutive days. Participants wore the BioHarness for the same four-hour period on both days (e.g, from 12:00–4:00 p.m. on Tuesday and Wednesday). While wearing the device, participants completed the affect questionnaires at hourly intervals, for a total of four times each day. At Hour 3 on each day, they additionally completed the five-minute math task. At the end of each day, they filled out the daily activity log.

Those in the running group were additionally instructed to run on either the first or second study day, the order of which was counterbalanced. These run and rest days were assigned in advance to fit participants' planned running schedules. To capture a typical and authentic run, participants were asked to run at their usual time of day, distance, and intensity. For consistency, runners were instructed that the four-hour monitoring period should take place sometime after, not before or concurrent with, the run. Controls (who were not regular aerobic exercisers) did not run on either day. When the take-home portion of the study was complete, participants returned to the lab to turn in their study equipment and receive compensation.

Data Analysis

Raw ECG data files were exported from the BioHarness modules via OmniSense 5.0 Analysis software (Medtronic, 2017). Five samples were extracted from each day of recording: one ten-minute sample at each of the four hourly intervals, and one five-minute sample during the math task. Samples were analyzed in Kubios HRV 3.3 (Tarvainen, Niskanen, Lipponen, Ranta-aho, & Karjalainen, 2009), a heart rate variability analysis software. Pre-processing of RR intervals was done using the smoothness priors detrending method and a Lambda value of 500. Trained research assistants manually assessed the ECG traces and beat detections; artefacts were corrected using deletion or interpolation. Resulting calculations were extracted for the time-domain parameters of SDNN, RMSSD, NN50, and pNN50; and, using the fast-Fourier transform algorithm, the frequency-domain parameters of low and high frequency power in normalized units (quantified at 0.04–0.15 Hz and 0.15–0.40 Hz, respectively).

Controls were randomly assigned nominal "run" and "rest" days, so that comparisons could be made between runners and controls on the basis of Run Day vs. Rest Day in addition to Day 1 vs. Day 2. Differences between the runners and controls were assessed for each of the demographic characteristics, baseline psychological measures, and math aptitude scores. For each affective and physiological variable, measures reported throughout the observation period were aggregated to produce an average daily level for each participant on each day. Two-way, mixed ANOVAs were then used to assess changes across the two study days by group. Mixed ANOVAs were also used to compare the individual hourly measures across days, and to assess changes in the variables throughout each day. Differences in performance on the math task were similarly assessed across run and rest day, as well as across trials chronologically. Lastly, within the running group, differences in each of the variables were assessed on the basis of degree of exercise dependence and degree of rest day negativity.

Results

Pre-Experimental Survey

Demographics

Between the running and control groups, there was no significant difference in age, $t(37) = 0.54$, $p = .594$, or gender distribution, χ^2 (1, $N = 39$) = 0.42, $p = .519$.

Psychological Measures

Runners and controls did not significantly differ in scores on the Brief Symptom Inventory, $t(36) = 1.15$, $p = .257$, Beck Anxiety Inventory, $t(36) = 0.93$, $p = .368$, Beck Depression Inventory, $t(36) = 0.85$, $p = .403$, or Perceived Stress Scale, $t(36) = 0.03$, $p = .976$. Scores on the Exercise Dependence Scale, however, did differ significantly between the two groups, $t(35) = 4.38$, $p < .001$. Runners reported greater exercise dependence ($M = 56.67$, $SD = 19.07$) than controls ($M = 31.05$, $SD = 16.49$). By the scale's classification system, no participants met criteria for exercise dependence, but 66% of runners were symptomatic, compared to only 20% of controls, χ^2 (1, $N = 38$) = 8.46, $p = .004$. Runners' scores on the rest day negativity scale ranged between 20 and 52 out of the maximum 65 possible points ($M = 36.83$, $SD = 7.69$).

Math Aptitude

Runners reported significantly higher scores on the math component of the ACT than controls, $t(24) = 2.23$, $p = .036$. On the seven-point range of scores, runners reported a mean score of 5.42 (equivalent to scores of 21–25 on the ACT) ($SD = 1.08$), whereas controls reported a mean of 4.57 (or scores of 15–20) ($SD = 0.85$) Scores on the math component of the SAT and the University of Wisconsin Math Placement Test were also collected, but too few participants responded to these questions to make effective comparisons between groups.

Running Habits

Most runners (77.8%) reported a typical running frequency of three to four days per week, and the majority (61.1%) reported a typical weekly running mileage of 5–14 miles. See Table 1 for a complete breakdown of the sample's typical running habits. Runners who ran on Day 1 of the study and those who ran on Day 2 did not differ on any demographic, psychological, math aptitude, or running behavior variables.

Affective Measures

Affect by Day

Using the daily aggregates of each affect measure, two-way, mixed ANOVAs were conducted to examine the effects of group (runners vs. controls) and day (run day vs. rest day) on self-reported affect.

Positive Affect. In the ANOVA for positive affect, there was no main effect of group, $F(1, 37) = 0.65$, $p = .425$, $\eta^2_p = .02$, indicating that runners and controls did not have significantly different overall levels of positive affect. There was a statistically significant interaction between the effects of group and day, $F(1, 37) = 25.29$, $p < .001$, $\eta^2_p = .41$. Follow-up analysis indicated that there was no difference based on day in the controls, $F(1, 20) = .3.37$, $p = .081$, $\eta^2_p = .14$, but that the runners reported significantly greater positive affect on run day ($M = 6.06$, $SD = .64$) than rest day ($M = 3.19$, $SD = .57$), $F(1, 17) = 21.54$, $p < .001$, $\eta^2_p = .56$ (see Figure 1).

Negative Affect. One participant reported extremely high levels of negative affect throughout the measurement period; analysis of the data set showed that this participant's overall level of negative affect had a z-score of 3.95 and fell more than three times the interquartile range above the third quartile of data, and so was considered an extreme outlier and excluded from the analysis[1]. There was no main effect of group on levels of negative affect, $F(1, 36) = 0.40$, $p = .533$, $\eta^2_p = .01$, but there was a significant interaction between the effects of group and day, $F(1, 36) = 4.43$, $p = .043$, $\eta^2_p = .11$. Follow-up analysis revealed that in controls, the effect of day made no difference on level of negative affect, $F(1, 20) = 0.77$, $p = .391$, $\eta^2_p = .04$. Runners, on the other hand, reported greater negative affect on rest day ($M = 0.94$, $SD = 0.28$) than run day ($M = 0.40$, $SD = 0.20$), though this difference was not statistically significant, $F(1, 16) = 3.76$, $p = .070$, $\eta^2_p = .19$ (see Figure 2).

Tranquility, Fatigue, and Perceived Stress. On the measure of tranquility, there was no main effect of group, $F(1, 37) = 0.58$, $p = .453$, $\eta^2_p = .02$, nor was there an interaction between the effects of group and day, $F(1, 37) = 1.21$, $p = .278$, $\eta^2_p = .03$. Likewise, there was no main

[1] With the outlier included in the analysis, the results of the between-subjects effect were $F(1, 37) = 1.42$, $p = .242$, $\eta^2_p = .04$ and those of the interaction effect were $F(1, 37) = 3.26$, $p = .079$, $\eta^2_p = .08$.

effect of group on the measure of fatigue, $F(1, 37) = 0.01$, $p = .928$, $\eta^2_p < .001$, nor an interaction effect, $F(1, 37) = 2.09$, $p = .157$, $\eta^2_p = .05$. The measure of perceived stress also showed no main effect of group, $F(1, 37) = 1.53$, $p = .223$, $\eta^2_p = .04$, and no significant interaction, $F(1, 37) = 0.25$, $p = .623$, $\eta^2_p = .01$.

Affect by Hour

Two-way, mixed ANOVAs were performed on the hourly self-reports of affect to examine changes over time based on group. Most of the variables showed no significant effects of time or interactions between time and group. In the reports of positive affect on rest day, however, there was a significant interaction between time and group, $F(1.90, 62.72) = 3.94$, $p = .026$, $\eta^2_p = .11$. Follow-up analysis showed that runners' levels of positive affect did not change throughout the day, $F(1.47, 23.46) = 1.50$, $p = .242$, $\eta^2_p = .09$, but that controls' positive affect decreased from Hour 1 ($M = 4.89$, $SD = 0.86$) to Hour 4 ($M = 3.22$, $SD = 0.65$), though this change was not significant, $F(3, 48) = 2.63$, $p = .060$, $\eta^2_p = .13$.

Physiological Measures

Heart Rate and HRV by Day

Using the daily aggregates of each physiological measure, two-way, mixed ANOVAs were conducted to examine the effects of group (runners vs. controls) and day (run day vs. rest day) on the physiological variables.

Heart Rate. Throughout the measurement period, runners' mean heart rates ($M = 79.96$, $SD = 2.51$) were significantly lower than controls' ($M = 88.56$, $SD = 2.31$), $F(1, 33) = 6.81$, $p = .014$, $\eta^2_p = .17$. Additionally, there was a significant interaction between the effects of group and day on participants' mean heart rates, $F(1, 33) = 10.85$, $p = .002$, $\eta^2_p = .25$. Tests of simple effects showed that heart rate did not differ based on day for the controls, $F(1, 33) = 2.64$, $p =$

.122, η^2_p = .13, but that the runners had significantly higher heart rates on run day (*M* = 85.21, *SD* = 10.53) than rest day (*M* = 74.72, *SD* = 10.34), $F(1, 33) = 14.60$, $p = .002$, η^2_p = .49.

HRV. None of the heart rate variability variables differed significantly between runners and controls, but like heart rate, they showed interaction effects. Controls experienced no changes in SDNN, RMSSD, NN50, pNN50, LFnu, or HFnu between the two days, but runners did. From run day to rest day, runners showed increases in SDNN, RMSSD, NN50, pNN50, and HFnu, and decreases in LFnu (see Tables 2 and 3).

Heart Rate and HRV by Hour

Two-way, mixed ANOVAs were performed on the hourly samples of each physiological variable to examine changes over time based on group. There were no significant effects of time or interactions between time and group on any of the physiological variables on the run day. On the rest day, however, there were a number of effects. There was a main effect of time on mean heart rate on the rest day, $F(2.64, 60.81) = 3.23$, $p = .034$, η^2_p = .12, such that heart rates decreased from Hour 1 (*M* = 90.74, *SD* = 2.89), to Hour 4 (*M* = 85.03, *SD* = 2.45), $F(1, 23) = 5.20$, $p = .032$, η^2_p = .18. Time also affected SDNN on rest day, $F(4, 92) = 2.81$, $p = .030$, η^2_p = .11. SDNN increased significantly from Hour 1 (*M* = 43.38, *SD* = 4.29) to Hour 2 (*M* = 52.24, *SD* = 4.09), $F(1, 23) = 9.68$, $p = .005$, η^2_p = .30. There was a main effect of group on rest day measures of pNN50: runners exhibited higher pNN50 (*M* = 22.70, *SD* = 3.90) than controls (*M* = 9.90, *SD* = 3.24), $F(1, 25) = 6.38$, $p = .018$, η^2_p = .20.

The frequency-domain variables of HRV also showed changes over time on the rest day. There was an interaction between the effects of time and group on measures of low frequency normalized units on rest day, $F(3, 75) = 2.95$, $p = .038$, η^2_p = .17. Tests of simple effects showed that controls' levels of LFnu did not change over time, $F(3, 45) = 1.12$, $p = .356$, η^2_p = .07, but that runners' did, $F(3, 30) = 6.18$, $p = .002$, η^2_p = .38. Contrast tests showed that runners' LFnu increased significantly from Hour 2 (M = 56.86, SD = 4.34) to Hour 4 (M = 70.63, SD = 6.09), $F(1, 10) = 8.72$, $p = .014$, $\eta^2_p = .47$. Similarly, there was an interaction effect on measures of high frequency normalized units on the rest day, $F(3, 75) = 2.94$, $p = .038$, $\eta^2_p = .11$. Controls again did not vary in HFnu over time, $F(3, 45) = 1.11$, $p = .353$, $\eta^2_p = .07$, while runners did, $F(3, 30) = 6.17$, $p = .002$, $\eta^2_p = .38$. Runners' HFnu decreased significantly from Hour 2 (M = 43.05, SD = 4.33) to Hour 4 (M = 29.25, SD = 6.08), $F(1, 10) = 8.77$, $p = .014$, $\eta^2_p = .47$. Together, these changes in the frequency-domain variables indicate a change in power distribution of runners' HRV over the course of the rest day measurement period: power in the low frequency band increased and that in the high frequency band decreased (see Figure 3).

Math Task

Runners vs. Controls

Runners performed significantly better than controls on all trials and on both scoring metrics of the math task. On average, runners completed more problems (M = 98.80, SD = 23.54) than controls (M = 79.54, SD = 23.88), $t(37) = 2.53$, $p = .016$, and runners answered a higher percentage of problems correctly (M = .983, SD = 0.012) than controls (M = .962, SD = 0.027), $t(28.47) = 3.20$, $p = .003$.

Run Day vs. Rest Day

Two-way, mixed ANOVAs were conducted to compare participants' performance on the math task between their run and rest days. There were no significant interactions between the effects of day and group on the number of items completed, $F(1, 36) = 0.39$, $p = .539$, $\eta^2_p = .01$, or the percentage of items answered correctly, $F(1, 36) = 0.46$, $p = .501$, $\eta^2_p = .01$.

Trials by Group and Run Day

Because the order of the run and rest days was counterbalanced, it was necessary to account for the effects of practice at the task by comparing participants' performance over the three trials chronologically. Two-way, mixed ANOVAs were conducted to compare the effects of trials (first trial [baseline] vs. second trial [study day 1] vs. third trial [study day 2]), group (runners vs. controls), and run day (run day vs. rest day) on task performance. Mauchly's Test was not violated, so sphericity was assumed. There was a main effect of trials for the number of items completed, $F(2, 68) = 6.30$, $p = .003$, $\eta^2_p = .16$. Participants completed significantly more items on their third trial ($M = 93.60$, $SD = 3.85$) than their first ($M = 86.29$, $SD = 4.20$), $F(1, 34) = 12.34$, $p = .001$, $\eta^2_p = .27$. Although the interaction between the effects of trials and group was not statistically significant, $F(2, 68) = 2.57$, $p = .084$, $\eta^2_p = .07$, the two groups appeared to show a differential pattern of progression through the three trials (see Figure 4). Specifically, both groups improved between the first and second trials, and the controls continued to improve between the second and third. The runners, however, showed no additional improvement between their second and third trials. This pattern appears to be explained by the interaction between trials, group, and run day. Though again not statistically significant, $F(2, 68) = 1.32$, $p = .273$, $\eta^2_p = .04$, runners progressed differentially through the three trials based on which day they ran. Both groups of runners improved at the task between the first and second trial. On the third trial, however, those who ran that day continued to improve at the task, while those who didn't run performed worse (see Figure 5).

For the percentage of items answered correctly, Mauchly's Test was significant, so a Greenhouse-Geisser correction was applied. There was no effect of trials on performance, $F(1.45, 49.43) = 2.84$, $p = .084$, $\eta^2_p = .08$, nor was there a significant interaction between trials and group, $F(1.45, 49.43) = 0.68$, $p = .469$, $\eta^2_p = .02$, nor between trials, group, and run day, $F(1.45, 49.43) = 0.43$, $p = .587$, $\eta^2_p = .01$.

Exercise Dependence

Within the running group, two-way, mixed ANOVAs were conducted to determine whether scores on the Exercise Dependence Scale had effects on the affective, physiological, and math performance variables between the run and rest days. Scores on the EDS affected a number of variables. Runners who were symptomatic for exercise dependence reported lesser overall fatigue ($M = 2.55$, $SD = 0.61$) than those who were asymptomatic ($M = 6.42$, $SD = 0.87$), $F(1,16) = 13.34$, $p = .002$, $\eta^2_p = .39$. The effect of EDS scores interacted with the effect of day on positive affect, $F(1,16) = 4.60$, $p = .048$, $\eta^2_p = .22$. Asymptomatic runners did not differ significantly in positive affect between the two days, $F(1, 5) = 2.85$, $p = .152$, $\eta^2_p = .36$, but symptomatic runners reported significantly less positive affect on rest day ($M = 3.07$, $SD = 2.22$) than run day ($M = 6.79$, $SD = 2.46$), $F(1, 11) = 23.88$, $p < .001$, $\eta^2_p = .69$ (see Figure 6). Fatigue was similarly affected by EDS scores, such that symptomatic runners' fatigue was significantly greater on rest day ($M = 3.38$, $SD = 1.67$) than run day ($M = 1.71$, $SD = 1.30$), $F\ (1, 11) = 14.56$, $p = .003$, $\eta^2_p = .57$, while asymptomatic runners' fatigue did not differ between days, $F(1, 5) = 1.39$, $p = .291$, $\eta^2_p = .22$. In other words, participants with symptoms of exercise dependence felt less positive affect and more fatigue on rest day than run day, while those without symptoms felt about the same on both days.

Though not significant, there was an apparent interaction between the effects of EDS score and day on mean heart rates, $F(1, 14) = 4.33$, $p = .056$, $\eta^2_p = .24$, such that asymptomatic runners' mean heart rates decreased more from run day to rest day than symptomatic runners' heart rates did (see Figure 7).

Rest Day Negativity

Two-way, mixed ANOVAs were conducted to determine whether rest day negativity scores had effects on any of the variables between run and rest day. The sample was split into thirds based on RDN scores, creating groups of "low," "medium," and "high" negativity. Though not significant, $F(2, 14) = 3.34$, $p = .065$, $\eta^2_p = .32$), Rest day negativity scores appeared to affect levels of negative affect. There was a significant difference in negative affect levels on rest day based on RDN, $F(2, 14) = 4.29$, $p = .035$, $\eta^2_p = .38$. A Tukey post hoc test showed that those in the high RDN group had more negative affect on rest day ($M = 2.00$, $SD = 0.43$) than the medium group ($M = 0.46$, $SD = 0.39$), $p = .048$, but not the low group ($M = 0.54$, $SD = 0.39$), $p = .062$ (see Figure 8).

Discussion

This study used an in situ methodology to assess the affective, physiological, and behavioral stress responses that runners experience on rest days, as well as how exercise dependence and cognitive appraisal moderate these experiences. The major findings of this study were a pattern of negative affective, physiological, and behavioral changes on the rest day, and a pattern of more adverse changes in runners with symptoms of exercise dependence.

Affective Findings

Runners reported less positive affect and more negative affect on their rest day than their running day, consistent with the hypotheses. These findings demonstrate a pattern of negative affective changes on the rest day. Affective disturbance is one of the most frequently reported findings in research on exercise cessation—such changes have been reported as a result of long-term deprivations (Antunes et al., 2016; Berlin, 2004; Chan & Grossman, 1988; Evans, 2016; Morris et al., 1990; Poole et al., 2011; Szabo & Parkin, 2001), short-term deprivations (Aidman & Woollard, 2003; Mondin et al., 1996; Thaxton, 1982), and short-term voluntary abstinences (Conboy, 1994; Hausenblas et al., 2008; Szabo et al., 1998). This study affirms that negative changes in mood are also characteristic of some runners' planned rest days.

A more unique aspect of these findings is that both positive and negative indices of affect were impacted. The vast majority of deprivation studies have focused on measures of negative affect, particularly via the Profile of Mood States (McNair, Lorr, & Droppleman, 1971). In one of the few studies that used a measure of primarily positive mood states (the Exercise-Induced Feeling Inventory [Gauvin & Rejeski, 1993]), Hausenblas et al. (2008) found no negative effects of deprivation on positive feeling states. Because of the abundance of research demonstrating that negative feeling states are affected by deprivation, the researchers speculated that deprivation may manifest differently in positive and negative feeling states. In point of fact, there is some debate about the conceptual structure of positive and negative affect—whether the concepts are bipolar, independent, or somewhere in between (Barrett & Russell, 1999). Therefore, measuring only one valence of affect may neglect important differences (or lack thereof) on the other side. This study assessed both positive and negative indices of affect and found a change in both measures on rest days, indicating that exercise cessation can manifest in positive feeling states as well as negative ones.

An alternative explanation for the self-reported affect changes is that they are the result of a demand characteristic. The running participants, of course, knew that the observation period included one run day and one rest day, and it is a common belief among runners that running can have a positive effect on one's mood. However, if participants were catering to perceived demand, it would be expected that all subscales of the Physical Activity Affect Scale would change similarly, which was not the case—positive and negative affect changed more drastically than tranquility and fatigue. The measure of perceived stress would also be expected to change with demand, but it showed no changes. Therefore it is likely that the self-reported changes in affect were not the result of a demand characteristic, but were authentically generated by the running manipulation.

Physiological Findings

In contrast to the hypothesis, and to previous findings (Aidman & Woollard, 2003), ambulatory heart rates were higher on run day than rest day. However, these findings may not necessarily reflect greater psychophysiological stress on the run day. Though heart rate can be a measure of stress, it is a complex variable that has a multitude of other influences. Physical activity itself can have a lasting effect on heart rate due to the increased energy expenditure needed to return the body to a resting state. In fact, this elevation in heart rate can last for over an hour after moderate-intensity exercise (Forjaz, Matsudaira, Rodrigues, Nunes, & Negrão, 1998; Terziotti, Schena, Gulli, & Cevese, 2000). Because all measurements on the running day were taken subsequent to the run, it is possible that chronotropic states may still have been elevated in response to the exercise.

HRV likewise did not change in the expected direction: all time-domain measures of HRV were found to be lower on the run day than the rest day. Like heart rate, HRV can be a measure of stress, but it is also naturally inversely correlated with heart rate itself—as heart rate increases, there is less room for variability between beats, and so HRV naturally decreases (de Geus et al., 2019). The unexpected elevation in heart rates on the run day therefore probably drove at least part of this decrease in HRV as well.

In that case, the hourly, as opposed to daily, measures of HRV may offer a more compelling account of the changes the runners experienced. There were no changes in heart rate or HRV throughout the running day—measures remained more or less stable over the four hours. On the rest day, however, power distribution in the low and high frequency bands of HRV changed significantly over time: LF-HRV increased and HF-HRV decreased. This trend toward lower HF-HRV reflects decreased parasympathetic activity, and has been shown to be associated with increased psychological stress (Shaffer & Ginsberg, 2017). In fact, a review of studies measuring HRV reactivity to stress found that decreased HF-HRV coupled with increased LF-

HRV was the most frequently reported change in HRV variables in response to stress (Kim et al., 2018). In the present study, this shift was only evident in runners, and only on the rest day. This finding could indicate that, with increasing time after that of their normal run, runners began to show the psychophysiological effects of the missed run more strongly.

Behavioral Findings

The runners showed no difference in performance on the math task between their run and rest days. However, because the order of run and rest days was counterbalanced, a direct comparison of the two is likely to be confounded by the effects of practice at the task. Comparing participants' three attempts at the task chronologically therefore yields a more meaningful result. There was an overall pattern of improved performance (more items completed) on successive trials, which is consistent with the effects of practice at a challenging task. Additionally, the percentage of items answered correctly did not change throughout the three attempts, indicating that the participants' improvements in speed did not come at the expense of accuracy. However, the pattern of progression through the three tasks appeared to differ between the runners and the controls. Both groups improved at the task between the first and second attempts, but while the controls continued to improve between the second and the third, the runners did not. This stagnation in the runners appears to be explained by the effects of the run and rest days. Runners who rested and then ran improved steadily at the task through the three trials, but those who ran and then rested did not improve between the second and third trials. In other words, Day 1 runners appeared to be hindered at the task by their rest day. If the rest day was, in fact, to blame for their lack of improvement on the task, it would be expected that the Day 2 runners would be similarly affected on Day 1. However, the rest day had no noticeable impact for these runners. The absence of an apparent handicap in this group may be due to the fact that performance at a task increases logarithmically over multiple practice trials.

Runners who rested on Day 1 may have, in fact, experienced impairment on the task that was masked by the considerable boost in performance afforded by the first practice session. The pattern of progression between the second and third trials, then, may be the more important one, because the additional boost in performance from the second practice session is much smaller, and so the rest day impairment is more visible.

Previous studies have used acute stressors like Trier or Stroop tasks to assess phasic stress responses in participants deprived of exercise, and changes in physiological reactivity to such stressors have been found as a result of deprivation (Thaxton, 1982; Berlin, 2004). However, this study is one of the first to assess performance on such a task, and thus to show evidence suggesting a behavioral stress response on rest days.

Comparison between the runners and controls is hindered to some degree because the runners performed significantly better than the controls on all measures of the task. The runners were also found to have had higher scores on a pre-study math aptitude test, indicating a higher baseline math ability in the runners. These findings may be partly explained by the running habit itself. There is evidence that regular physical activity is linked to improved cognitive performance, including in areas of attention, memory, and reaction time (Loprinzi, Herod, Cardinal, & Noakes, 2013). Additionally, people who are able to maintain a regular exercise routine—especially in the midst of a busy college lifestyle—may be more precocious in general. For instance, college students who exercise regularly have been found to have higher grade point averages than those who do not (Judge, et al., 2014; Whitehead, Leath, Davis, & Drake, 2011). Nonetheless, the relevant facet of the task in this study was the participants' within-subjects changes, which should not have been affected by differences in baseline ability.

Moderating Effects of Exercise Dependence and Cognitive Appraisal

Another major finding of this study was that runners who were more exercise dependent were more adversely affected by the rest day stress response. Runners who had symptoms of exercise dependence experienced less positive affect and more fatigue on rest day than running day, whereas asymptomatic runners felt about the same on both days. These differential experiences based on level of dependence are consistent with prior research. Antunes et al. (2016) found that, in a two-week deprivation, negative affective changes occurred only in exercise dependent runners. Aidman & Woollard (2003) and Conboy (1994) each found greater mood changes in the dependent groups of their samples after one day of missed exercise. This study affirms that runners with symptoms of exercise dependence experience worse affective changes on rest days than those without symptoms.

The symptomatic runners also reported less overall fatigue than the asymptomatic runners. This could indicate that they were affected differently not only by the rest day, but by the running day as well. Symptomatic runners may have derived more benefit from the run than asymptomatic runners did—in particular, the run may have caused them to feel more energized, rather than tired, leading to lower scores on the fatigue measure.

Changes in the physiological variables with respect to dependence did not reach significance, but the decrease in heart rates from run day to rest day was considerably smaller in symptomatic runners than in asymptomatic runners. In other words, symptomatic runners' heart rates on rest day were more equivalent to the elevated heart rates seen on run day. Although the decrease in heart rate itself was unexpected, this differential change between symptomatic and asymptomatic runners may still be indicative of the expected finding, that rest day psychophysiological stress was worse in symptomatic runners. Symptomatic runners had significantly higher heart rates than asymptomatic runners on the rest day, which may indicate reduced recovery in the symptomatic group. This finding is different from, but perhaps complementary to, that of Aidman and Woollard (2003), who also measured heart rates during a one-day lay-off from running. Whereas that study found increased heart rates during the lay-off, with greater shifts in the dependent participants, this study found decreased heart rates, with lesser shifts in the dependent group. It should be noted that there are important differences between the two studies: Aidman and Woollard's study collected self-assessed resting heart rates, and the deprivation was imposed by the study, while this study collected ambulatory heart rate readings via electrocardiogram, and the lay-off was the result of a planned rest day. Despite these differences, these findings may be driven by the same basic effect, that dependent runners exhibit worse physiological stress responses after a missed run than nondependent runners.

Differences in stress response were also observed as a function of how participants appraised their rest days. Runners who negatively appraised their rest days showed more overall negative affect than runners who appraised their rest days more positively. This difference may indicate that appraisal of the rest day is an important factor in determining the affective stress response. However, none of the other affective variables, and none of the physiological or behavioral variables, showed differences based on appraisal. It is possible that the measure of rest day negativity actually tapped levels of negativity more generally, and this negativity was borne out in the measure of negative affect. In view of this uncertainty, the role of cognitive appraisal with respect to the rest day stress response should be further explored.

Limitations and Future Research

Some of the observed findings appeared to support the study's hypotheses, but did not reach the level of statistical significance. In particular, the measures of tranquility and fatigue changed only modestly in response to the rest day, and effects on performance on the math task fell short of a conclusive result. The nonsignificance of these findings may be due to the small effect sizes found to be characteristic of in situ studies like this (Szabo et al., 1998). Running (or not running) is just one event in the increasingly busy daily lives of college students like the ones in this sample, and so in situ momentary assessments capture a lot more than merely the effects of a missed run. Future studies may benefit from using bigger sample sizes, or from collecting data on more than two days, so that the effects of running and resting can be more clearly defined.

Another possible reason that some findings were nonsignificant is that the runners in the sample may not have run frequently enough to induce a significant rest day stress response. Most of the runners in this sample (77.8%) typically ran just three or four days per week. As such, they normally experienced running and non-running days about equally. Runners who run more frequently would experience significantly more run days than rest days, making their run days more customary, and their rest days more aberrant. In those runners, the stress effects of a rest day may be more pronounced. Future studies may wish to recruit only participants who run above a certain frequency, or may attempt to compare the effects of rest days among runners of different frequencies.

Another limitation of this study was a lack of participants who were classified as "at risk for exercise dependence," the highest classification on the Exercise Dependence Scale. All participants fell into one of the two nondependent categories, being either symptomatic or asymptomatic. Although exclusion of fully-dependent participants has been a conscious choice in some previous studies due to concerns that they may not adhere to study protocol (Hausenblas et al., 2008), this study did not involve forced deprivation, but rather voluntary rest days, and so compliance would not likely have been an issue. This study did find differences in response between the two "subclinical" levels of dependence, but it would be interesting to see how participants with more severe levels of dependence respond in comparison.

Conclusion

Through in situ observation, this study has shown that runners experience a pattern of negative affective, physiological and behavioral changes on their rest days. This is one of the first studies to show that rest day stress responses can manifest in both positive and negative feeling states, and to show evidence of a behavioral stress response, in the form of impaired task performance, on rest days. Additionally, this study has shown that these rest day-induced changes more adversely affect runners who are more exercise dependent.

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Figure 1

Mean Positive Affect Levels as a Function of Day and Group

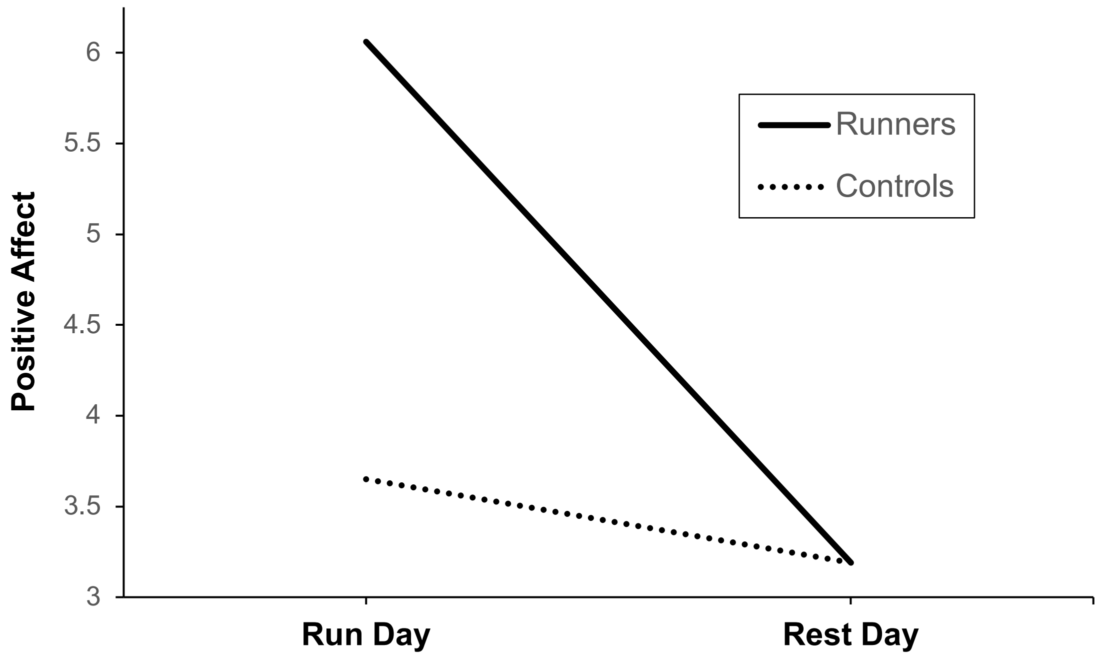


Figure 2

Mean Negative Affect Levels as a Function of Day and Group

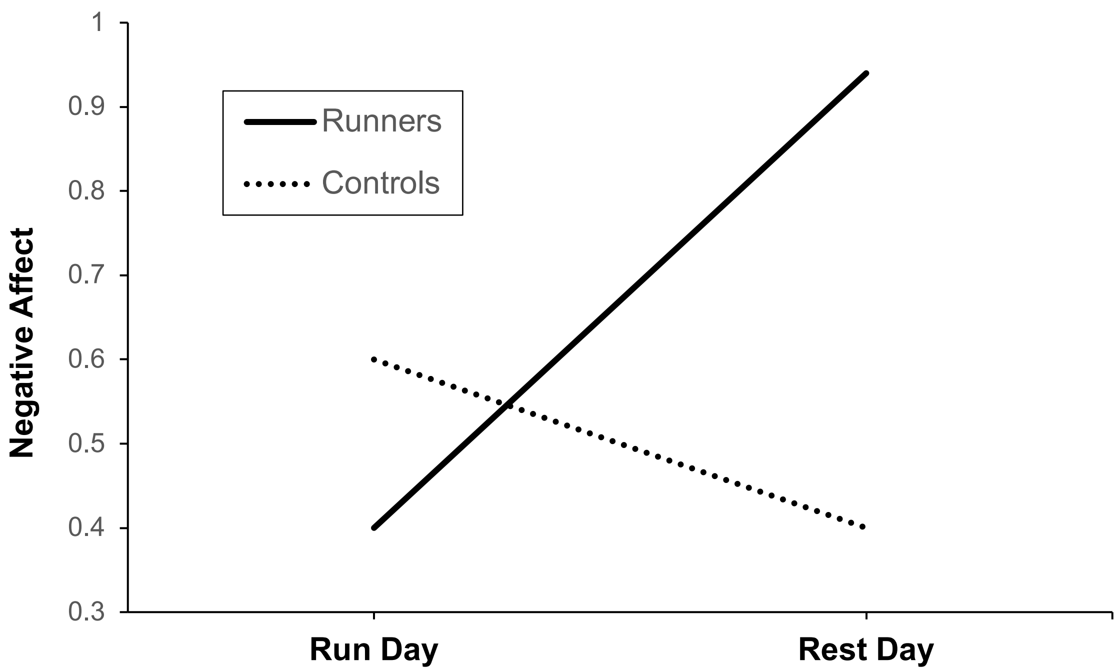


Figure 3

Changes in High Frequency Heart Rate Variability on Rest Day by Group

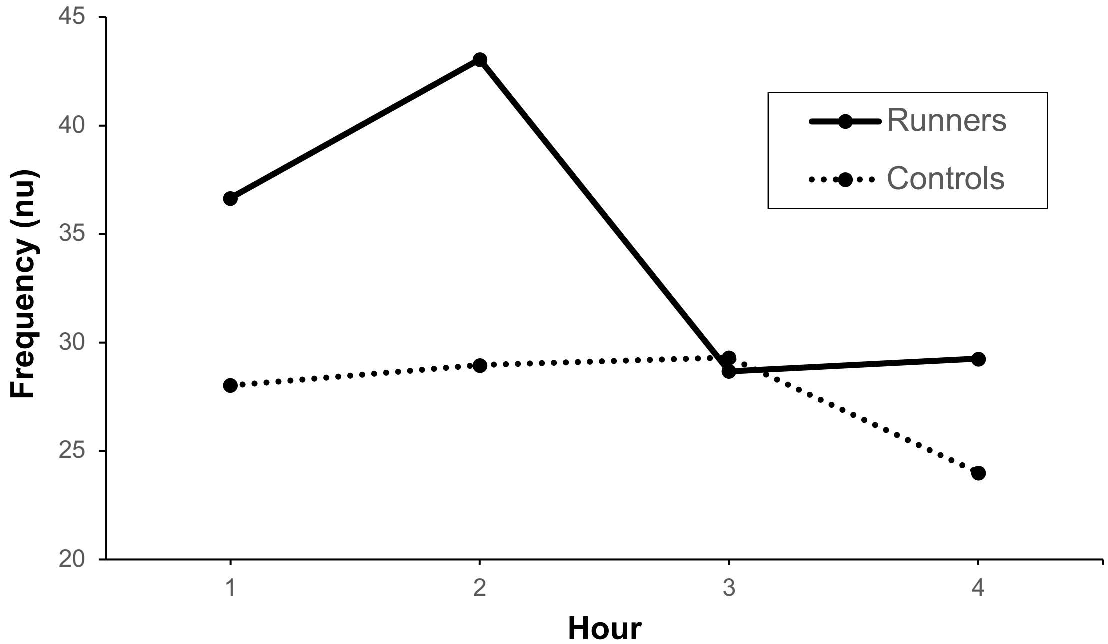


Figure 4

Math Task Performance over Time by Group

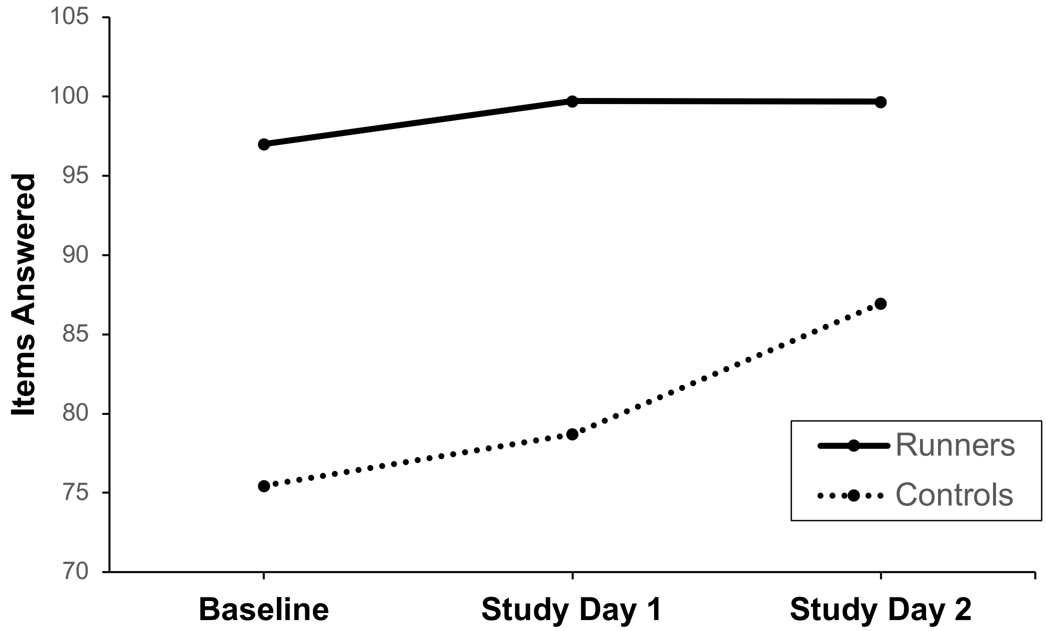
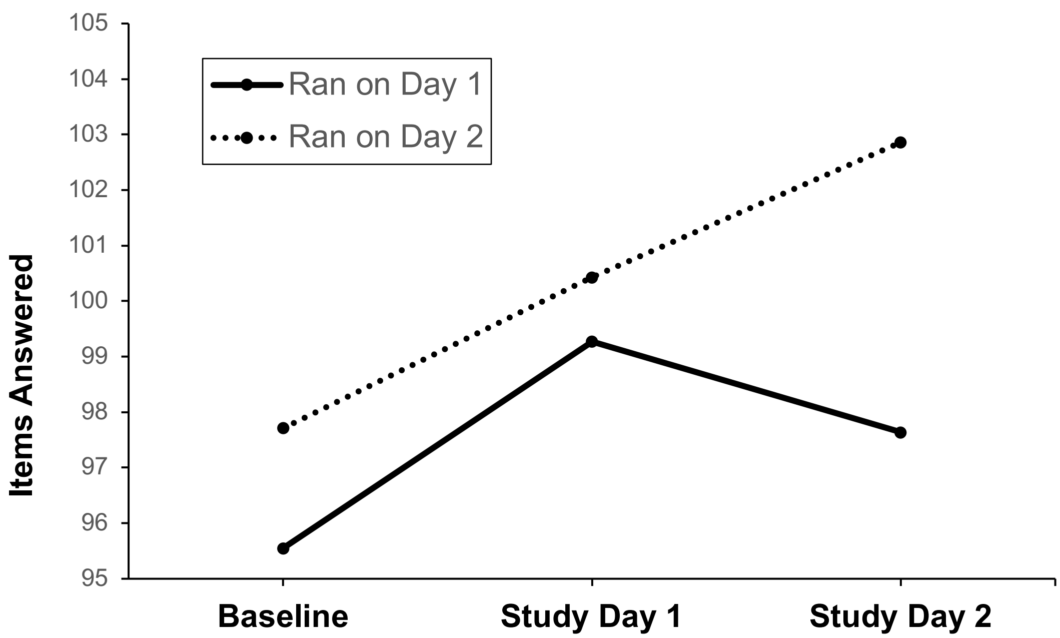


Figure 5

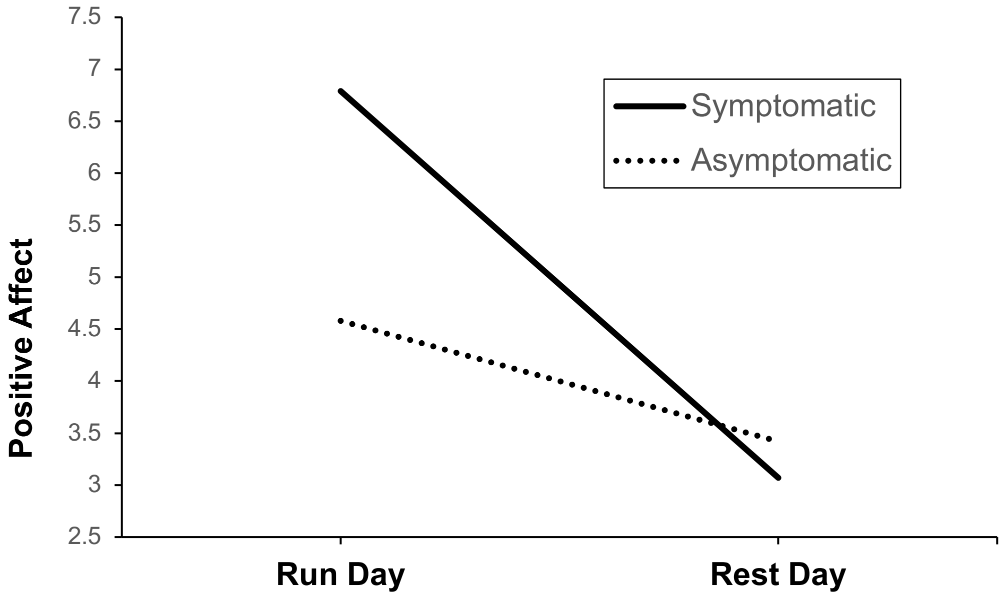
Math Task Performance over Time by Run Day



Note. Data includes runners only.

Figure 6

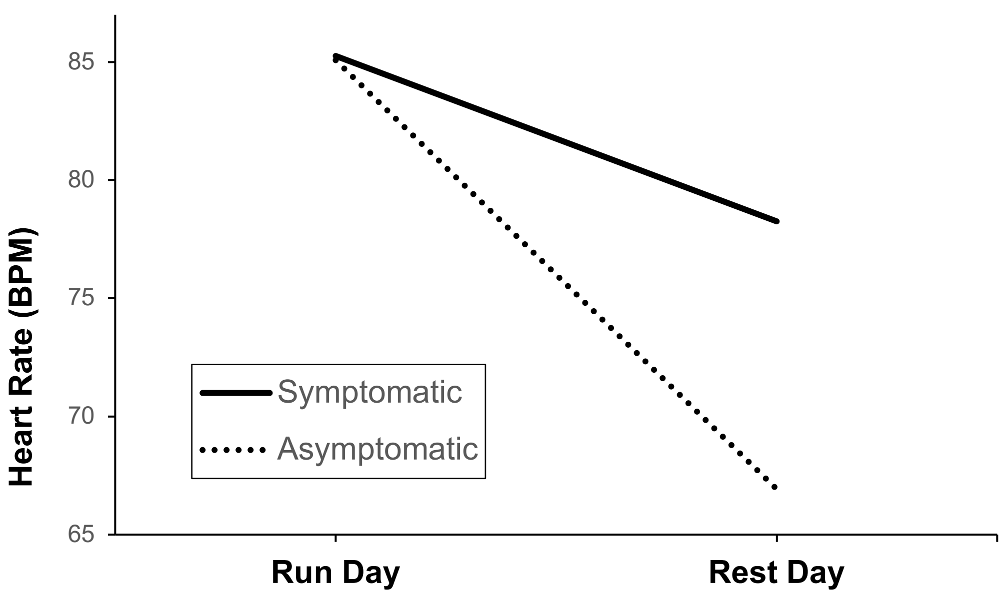
Mean Positive Affect Levels as a Function of Day and Exercise Dependence



Note. Data includes runners only.

Figure 7

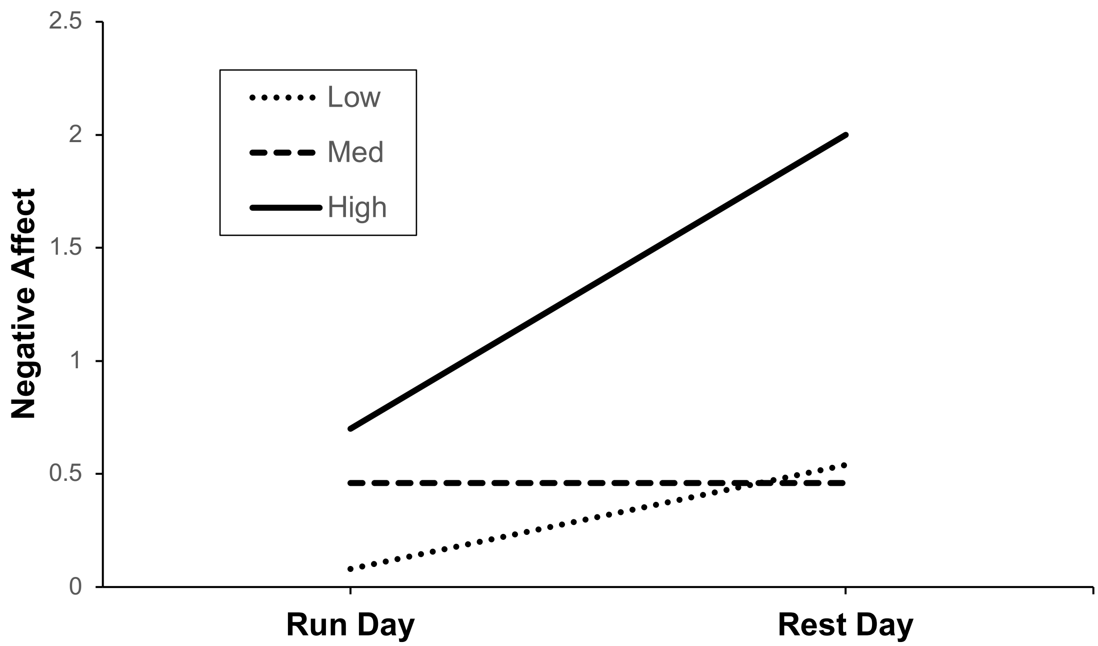
Mean Heart Rates as a Function of Day and Exercise Dependence



Note. Data includes runners only.

Figure 8

Mean Negative Affect Levels as a Function of Day and Rest Day Negativity



Note. Data includes runners only.

Table 1

Typical Running Habits of Runners in the Sample

Running Metric	n	%
Runs per week		
3–4	14	77.8%
5	2	11.1%
7	2	11.1%
Weekly mileage		
5–14 miles	11	61.1%
15–24 miles	4	22.2%
25–34 miles	2	11.1%
35–44 miles	1	5.6%

Table 2

Two-Way Mixed Analyses of Variance for Physiological Measures

Measure	$F(1, 33)$	p	η^2_p
Heart rate (BPM)			
Group	6.81	.014*	.17
Day	0.46	5.04	.01
Group*Day	10.85	.002**	.25
SDNN			
Group	1.64	.209	.05
Day	0.41	.527	.01
Group*Day	9.39	.004**	.22
RMSSD			
Group	0.94	.340	.03
Day	0.33	.571	.01
Group*Day	9.98	.003**	.23
NN50			
Group	1.20	.281	.04
Day	0.17	.682	.01
Group*Day	8.65	.006**	.21

Measure	$F(1, 33)$	p	η^2_p
pNN50			
Group	2.45	.127	.07
Day	0.81	.375	.02
Group*Day	12.31	.001**	.27
LF (nu)			
Group	0.002	.965	<.001
Day	0.05	.821	.002
Group*Day	8.55	.006**	.21
HF (nu)			
Group	0.003	.958	<.001
Day	0.04	.837	.001
Group*Day	8.52	.006**	.21

Note. SDNN = standard deviation of NN intervals; RMSSD = root mean square of successive differences; NN50 = number of adjacent NN intervals that differ by more than 50 ms; pNN50 = proportion of adjacent NN intervals that differ by more than 50 ms; LF (nu) = relative power of the low frequency band in normalized units; HF (nu) = relative power of the high frequency band in normalized units

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

Table 3

Means and Standard Deviations for Physiological Measures by Day

Measure	Run Day		Rest Day	
	M	*SD*	*M*	*SD*
		Runners		
Heart rate (BPM)*	85.21	10.53	74.72	10.34
SDNN*	45.27	12.76	58.12	20.85
RMSSD*	38.15	19.53	59.66	34.92
NN50*	105.82	90.82	169.41	74.25
pNN50*	14.02	13.22	25.41	19.13
LF (nu)*	72.58	13.58	64.54	16.94
HF (nu)*	27.30	13.49	35.36	16.87
		Controls		
Heart rate (BPM)	85.40	15.14	92.32	10.53
SDNN	48.48	27.40	40.06	14.38
RMSSD	47.57	43.69	32.66	21.12
NN50	126.85	139.58	78.93	74.25
pNN50	16.19	17.39	9.45	8.77
LF (nu)	64.06	19.80	73.46	11.73
HF (nu)	35.73	19.75	26.45	11.68

Note. SDNN = standard deviation of NN intervals; RMSSD = root mean square of successive differences; NN50 = number of adjacent NN intervals that differ by more than 50 ms; pNN50 = proportion of adjacent NN intervals that differ by more than 50 ms; LF (nu) = relative power of the low frequency band in normalized units; HF (nu) = relative power of the high frequency band in normalized units

* Indicates a significant difference ($p < .05$) across days

APPENDIX A:

Demographic and Background Screening Questions

1. What is your age? __________
2. What is your gender? ______________________________
3. What was your score on the UW math placement test? __________
4. What was your math subject score on the ACT and/or SAT? ____________________
5. Are you a runner?
   a. Yes
   b. No
6. **If Yes**:
   a. Typically, how often do you run? _____________________________________
   b. Typically, on which days of the week do you run? ________________________

      ____
   c. Typically, how far do you run? _______________________________________
   d. Typically, how many miles do you run per week? _________________________
   e. Typically, what time(s) of day do you run? ______________________________
   f. Typically, do you run outdoors, on an indoor track, on a treadmill, or elsewhere?

      ____
   g. How long have you been running consistently at this mileage and frequency? If you ceased running at this mileage/frequency for more than three weeks, please do not count time before that period. ___________________________________
   h. Do you do any official training (e.g. you are on the track team)? _____________
   i. Do you consider yourself an 'elite' runner? __________
   j. Do you use running to cope with or relieve stress? __________

7. Please list any other forms of aerobic (cardio) exercise you do, along with how often you do them. ____

   ____
8. Please list any other forms of anaerobic (non-cardio) exercise you do, along with how often you do them. ____

   ____

APPENDIX B:

Cardiovascular Health History Questionnaire

Instructions. Please answer the following questions about your cardiovascular health, medications you are currently taking, the history of cardiovascular health in your family, and your diet. You may circle all that apply. Remember, your responses will be kept confidential.

1. Do **you** have any of the following cardiovascular problems?
    a. Hypertension (high blood pressure)
    b. Coronary Artery Disease
    c. Atherosclerosis
    d. Stroke
    e. Myocardial Infarction (heart attack)
    f. Aortic stenosis
    g. Mitral regurgitate
    h. Any other cardiovascular disease not listed above (please indicate the name of this disease) ____
    i. **I do not** have any cardiovascular problems.

2. Does **your mother** have any of the following cardiovascular problems?
    a. Hypertension (high blood pressure)
    b. Coronary Artery Disease
    c. Atherosclerosis
    d. Stroke
    e. Myocardial Infarction (heart attack)
    f. Aortic stenosis
    g. Mitral regurgitate
    h. Any other cardiovascular disease not listed above (please indicated the name of this disease) ____
    i. **My mother does not** have any cardiovascular problems.

3. Does **your father** have any of the following cardiovascular problems?
    a. Hypertension (high blood pressure)
    b. Coronary Artery Disease
    c. Atherosclerosis
    d. Stroke
    e. Myocardial Infarction (heart attack)
    f. Aortic stenosis
    g. Mitral regurgitate
    h. Any other cardiovascular disease not listed above (please indicated the name of this disease) ____
    i. **My father does not** have any cardiovascular problems.

4. Does **anyone in your family** have any of the following cardiovascular problems?
    a. Hypertension (*Family member:* ____________________)
    b. Coronary Artery Disease (*Family member:* ________________)
    c. Atherosclerosis (*Family member:* __________________)
    d. Stroke (*Family member:* ___________________)
    e. Myocardial Infarction (heart attack) (*Family member:* ___________________)
    f. Aortic stenosis (*Family member:* ___________________)
    g. Mitral regurgitate (*Family member:* _________________)
    h. Any other cardiovascular disease not listed above (please indicated the name of this disease) ____
    (*Family member:* ___________________)
    i. **None of my relatives** have any cardiovascular problems.

5. Do you currently take any of the following medications in any form:
    a. Dexamethasone
    b. Steroids (e.g., prednisone, or inhaled steroids for asthma)
    c. Diet pills (please, indicate the name of the pill:________________________)
    d. Beta-blockers
    e. Histamines

f. Decongestants

g. Any other medications not listed above (please, write a name of this medication)____

h. **I do not** currently take any medications.

6. Do you smoke?

    a. Yes

    b. No

7. If you smoke, how many cigarettes do you smoke per day? __________

8. How many cups of (caffeinated) coffee do you usually consume per day? __________

9. How many ounces of (caffeinated) soda do you usually consume per day? __________

10. Please list any other caffeinated foods or beverages you usually consume, along with how much of each you consume per day. ____

    ____

    ____

APPENDIX C:

Brief Symptom Inventory

Instructions. The following is a list of problems people sometimes have. Using the scale provided, please indicate how much that problem has distressed or bothered you **during the past 7 days, including today**.

0	1	2	3	4
Not at all	**A little bit**	**Moderately**	**Quite a bit**	**Extremely**

1. Nervousness or shakiness inside _____
2. Faintness or dizziness _____
3. The idea that someone else can control your thoughts _____
4. Feeling others are to blame for most of your troubles _____
5. Trouble remembering things _____
6. Feeling easily annoyed or irritated _____
7. Pains in the heart or chest _____
8. Feeling afraid in open spaces _____
9. Thoughts of ending your life _____
10. Feeling that most people cannot be trusted _____
11. Poor appetite _____
12. Suddenly scared for no reason _____
13. Temper outbursts that you could not control _____
14. Feeling lonely even when you are with people _____
15. Feeling blocked in getting things done _____
16. Feeling lonely _____
17. Feeling blue _____
18. Feeling no interest in things _____
19. Feeling fearful _____
20. Your feelings being easily hurt _____
21. Feeling that people are unfreindly or dislike you _____
22. Feeling inferior to others _____
23. Nausea or upset stomach _____
24. Feeling that you are watched or talked about by others _____
25. Trouble falling asleep _____
26. Having to check and double check what you do _____
27. Difficulty making decisions _____
28. Feeling afraid to travel on buses, subways or trains _____
29. Trouble getting your breath _____
30. Hot or cold spells _____

0	1	2	3	4
Not at all	**A little bit**	**Moderately**	**Quite a bit**	**Extremely**

31. Having to avoid certain things, places, or activities because they frighten you _____
32. Your mind going blank _____
33. Numbness or tingling in parts of your body _____
34. The idea that you should be punished for you sins _____
35. Feeling hopeless about the future _____
36. Trouble concentrating _____
37. Feeling weak in parts of your body _____
38. Feeling tense or keyed up _____
39. Thoughts of death or dying _____
40. Having urges to beat, injure, or harm someone _____
41. Having urges to break or smash things _____
42. Feeling very self-conscious with others _____
43. Feeling uneasy in crowds _____
44. Never feeling close to another person _____
45. Spells of terror or panic _____
46. Getting into frequent arguments _____
47. Feeling nervous when you are left alone _____
48. Others not giving you proper credit for your achievements _____
49. Feeling so restless you couldn't sit still _____
50. Feelings of worthlessness _____
51. Feeling that people will take advantage of you if you let them _____
52. Feeling of guilt _____
53. The idea that something is wrong with your mind _____

APPENDIX D:

Beck Anxiety Inventory

Instructions. Below is a list of common symptoms of anxiety. Please carefully read each item in the list. Indicate how much you have been bothered by each symptom **during the past week, including today**, by placing a check mark in the corresponding space in the column next to each symptom.

	Not at all	**Mildly** *It did not bother me much*	**Moderately** *It was very unpleasant but I could stand it*	**Severely** *I could barely stand it.*
1. Numbness or tingling	☐	☐	☐	☐
2. Feeling hot	☐	☐	☐	☐
3. Wobbliness in legs	☐	☐	☐	☐
4. Unable to relax	☐	☐	☐	☐
5. Fear of the worst happening	☐	☐	☐	☐
6. Dizzy or lightheaded	☐	☐	☐	☐
7. Heart pounding or racing	☐	☐	☐	☐
8. Unsteady	☐	☐	☐	☐
9. Terrified	☐	☐	☐	☐
10. Nervous	☐	☐	☐	☐
11. Feelings of choking	☐	☐	☐	☐
12. Hands trembling	☐	☐	☐	☐
13. Shaky	☐	☐	☐	☐
14. Fear of losing control	☐	☐	☐	☐
15. Difficulty breathing	☐	☐	☐	☐
16. Fear of dying	☐	☐	☐	☐
17. Scared	☐	☐	☐	☐
18. Indigestion or discomfort in abdomen	☐	☐	☐	☐
19. Faint	☐	☐	☐	☐
20. Face flushed	☐	☐	☐	☐
21. Sweating (not due to heat)	☐	☐	☐	☐

APPENDIX E:

Beck Depression Inventory

Instructions. On this questionnaire are groups of statements. Please read each group of statements carefully. Then pick out the one statement in each group which best describes the way you have been feeling **during the past week, including today**. Be sure to read all the statements in each group before making your choice.

1. ☐ I do not feel sad.
   ☐ I feel sad.
   ☐ I am sad all the time and I can't snap out of it.
   ☐ I am so sad or unhappy that I can't stand it.

2. ☐ I am not particularly discouraged about the future.
   ☐ I feel discouraged about the future.
   ☐ I feel I have nothing to look forward to.
   ☐ I feel that the future is hopeless and that things cannot improve.

3. ☐ I do not feel like a failure.
   ☐ I feel I have failed more than the average person.
   ☐ As I look back on my life, all I can see is a lot of failures.
   ☐ I feel I am a complete failure as a person.

4. ☐ I get as much satisfaction out of things as I used to.
   ☐ I don't enjoy things the way I used to.
   ☐ I don't get real satisfaction out of anything anymore.
   ☐ I am dissatisfied or bored with everything.

5. ☐ I don't feel particularly guilty.
   ☐ I feel guilty a good part of the time.
   ☐ I feel quite guilty most of the time.
   ☐ I feel guilty all of the time.

6. ☐ I don't feel I am being punished.
   ☐ I feel I may be punished.
   ☐ I expect to be punished.
   ☐ I feel I am being punished.

7. ☐ I don't feel disappointed in myself.
   ☐ I am disappointed in myself.
   ☐ I am disgusted with myself.
   ☐ I hate myself.

8. ☐ I don't feel I am any worse than anybody else.
☐ I am critical of myself for my weaknesses or mistakes.
☐ I blame myself all the time for my faults.
☐ I blame myself for everything bad that happens.

9. ☐ I don’t have any thoughts of killing myself.
☐ I have thoughts of killing myself, but I would not carry them out.
☐ I would like to kill myself.
☐ I would kill myself if I had the chance.

10. ☐ I don't cry any more than usual.
☐ I cry more now than I used to.
☐ I cry all the time now.
☐ I used to be able to cry but now I can't cry even though I want to.

11. ☐ I am no more irritated by things than I ever was.
☐ I get annoyed or irritated more easily than I used to.
☐ I feel irritated all the time now.
☐ I don't get irritated at all at the things that used to irritate me.

12. ☐ I have not lost interest in other people.
☐ I am less interested in other people now than I used to be.
☐ I have lost most of my interest in other people.
☐ I have lost all my interest in other people.

13. ☐ I make decisions about as well as I ever could.
☐ I put off making decisions more than I used to.
☐ I have greater difficulty in making decisions than before.
☐ I can’t make decisions at all anymore.

14. ☐ I don't feel I look any worse than I used to.
☐ I am worried that I am looking old or unattractive.
☐ I feel that there are permanent changes in my appearance that make me look unattractive.
☐ I believe that I look ugly.

15. ☐ I can work about as well as before.
☐ It takes an extra effort to get started at doing something.
☐ I have to push myself very hard to do anything.
☐ I can't do any work at all.

16. ☐ I can sleep as well as usual.
☐ I don’t sleep as well as I used to.
☐ I wake up 1-2 hours earlier than usual and find it hard to get back to sleep.
☐ I wake up several hours earlier than I used to and cannot get back to sleep.

17. ☐ I don't get more tired than usual.
☐ I get tired more easily than I used to.
☐ I get tired from doing almost anything.
☐ I am too tired to do anything.

18. ☐ My appetite is no worse than usual.
☐ My appetite is not as good as it used to be.
☐ My appetite is much worse now.
☐ I have no appetite at all anymore.

19. ☐ I haven't lost much weight, if any, lately.
☐ I have lost more than five pounds.
☐ I have lost more than 10 pounds.
☐ I have lost more than 15 pounds.

I am purposely trying to lose weight by eating less ☐ Yes ☐ No

20. ☐ I am no more worried about my health than usual.
☐ I am worried about physical problems such as aches and pains, or upset stomachs, or constipation.
☐ I am very worried about physical problems and it's hard to think of much else.
☐ I am so worried about my physical problems that I cannot think about anything else.

21. ☐ I have not noticed any recent change in my interest in sex.
☐ I am less interested in sex than I used to be.
☐ I am much less interested in sex now.
☐ I have lost interest in sex completely.

APPENDIX F:

Perceived Stress Scale

Instructions. The questions in this scale ask you about your feelings and thoughts **during the last month**. In each case, you will be asked to indicate how often you felt or thought a certain way.

1. In the last month, how often have you been upset because of something that happened unexpectedly?

0	1	2	3	4
Never	almost never	sometimes	fairly often	very often

2. In the last month, how often have you felt that you were unable to control the important things in your life?

0	1	2	3	4
Never	almost never	sometimes	fairly often	very often

3. In the last month, how often have you felt nervous and stressed?

0	1	2	3	4
Never	almost never	sometimes	fairly often	very often

4. In the last month, how often have you felt confident about your ability to handle your personal problems?

0	1	2	3	4
Never	almost never	sometimes	fairly often	very often

5. In the last month, how often have you felt that things were going your way?

0	1	2	3	4
Never	almost never	sometimes	fairly often	very often

6. In the last month, how often have you found that you could not cope with all the things that you had to do?

0	1	2	3	4
Never	almost never	sometimes	fairly often	very often

7. In the last month, how often have you been able to control irritations in your life?

0	1	2	3	4
Never	almost never	sometimes	fairly often	very often

8. In the last month, how often have you felt that you were on top of things?

0	1	2	3	4
Never	almost never	sometimes	fairly often	very often

9. In the last month, how often have you been angered because of things that happened that were outside of your control?

0	1	2	3	4
Never	almost never	sometimes	fairly often	very often

10. In the last month, how often have you felt difficulties were piling up so high that you could not overcome them?

0	1	2	3	4
Never	almost never	sometimes	fairly often	very often

APPENDIX G:

Exercise Dependence Scale-21

Instructions. Using the scale provided below, please complete the following questions as honestly as possible. The questions refer to current exercise beliefs and behaviors that have occurred in the past 3 months. Please place your answer in the blank space provided after each statement.

1	2	3	4	5	6
Never					Always

1. I exercise to avoid feeling irritable. _____
2. I exercise despite recurring physical problems. _____
3. I continually increase my exercise intensity to achieve the desired effects/benefits. _____
4. I am unable to reduce how long I exercise. _____
5. I would rather exercise than spend time with family/friends. _____
6. I spend a lot of time exercising. _____
7. I exercise longer than I intend. _____
8. I exercise to avoid feeling anxious. _____
9. I exercise when injured. _____
10. I continually increase my exercise frequency to achieve the desired effects/benefits. _____
11. I am unable to reduce how often I exercise. _____
12. I think about exercise when I should be concentrating on school/work. _____
13. I spend most of my free time exercising. _____
14. I exercise longer than I expect. _____
15. I exercise to avoid feeling tense. _____
16. I exercise despite persistent physical problems. _____
17. I continually increase my exercise duration to achieve the desired effects/benefits. _____
18. I am unable to reduce how intense I exercise. _____
19. I choose to exercise so that I can get out of spending time with family/friends. _____
20. A great deal of my time is spent exercising. _____
21. I exercise longer than I plan. _____

APPENDIX H:

Rest Day Questionnaire

Instructions. In this context, a "rest day" is defined as a day off from running. Using the scale provided below, please indicate the extent to which you agree with the following statements regarding your rest days. Please place your answer in the blank space provided after each statement.

5	4	3	2	1
Agree Completely	**Agree Somewhat**	**Neither Agree Nor Disagree**	**Disagree Somewhat**	**Disagree Completely**

1. "I look forward to my rest days." _____

2. "I wish I didn't have to take rest days." _____

3. "Rest days are a productive part of a running schedule." _____

4. "Sometimes I skip rest days." _____

5. "It is essential to take rest days." _____

6. "On my rest days, I feel that I should be doing more." _____

7. "It is not necessary to take a rest day every week." _____

8. "Taking rest days on a regular basis makes me a better runner." _____

9. "Sometimes I run on a planned rest day." _____

10. "Running on a planned rest day is counterproductive." _____

11. "I feel guilty on rest days." _____

12. "I feel anxious on rest days." _____

13. "I feel less productive on rest days." _____

APPENDIX I:

Sample Hourly Affect Questionnaire

Day 1
Prompt A

Date: _____/_____/_____

Time: _____:_____ am / pm

Using the scale provided below, please respond to the following statements indicating how you are feeling *at this moment*.

	Do Not Feel 0	Feel Slightly 1	Feel Moderately 2	Feel Strongly 3	Feel Very Strongly 4
Energetic	☐	☐	☐	☐	☐
Peaceful	☐	☐	☐	☐	☐
Tired	☐	☐	☐	☐	☐
Miserable	☐	☐	☐	☐	☐
Calm	☐	☐	☐	☐	☐
Enthusiastic	☐	☐	☐	☐	☐
Fatigued	☐	☐	☐	☐	☐
Relaxed	☐	☐	☐	☐	☐
Worn-out	☐	☐	☐	☐	☐
Discouraged	☐	☐	☐	☐	☐
Upbeat	☐	☐	☐	☐	☐
Crummy	☐	☐	☐	☐	☐

Please briefly describe your activity for the past 10 minutes:

Please indicate your stress level over the past 10 minutes on the below scale.

0 1 2 3 4

No stress at all **Highly stressed**

APPENDIX J:

Sample Page of Math Task

9	4	7	4	9	7
3	8	6	4	2	1
+ 8	+ 2	+ 9	+ 6	+ 1	+ 8
3	8	4	4	6	1
4	7	2	8	6	7
+ 8	+ 7	+ 1	+ 1	+ 9	+ 6
2	1	8	1	7	3
1	3	1	4	2	2
+ 6	+ 7	+ 1	+ 3	+ 5	+ 7
7	7	7	6	6	9
7	1	3	4	9	6
+ 7	+ 1	+ 3	+ 3	+ 7	+ 9
7	9	4	8	3	3
7	1	6	5	6	4
+ 6	+ 6	+ 1	+ 8	+ 3	+ 2
6	7	8	9	9	6
2	6	4	1	4	1
+ 2	+ 8	+ 6	+ 4	+ 4	+ 9
2	5	2	1	6	5
7	2	3	3	8	5
+ 6	+ 2	+ 6	+ 7	+ 6	+ 3

APPENDIX K:

Daily Activity Log

Date: _____/_____/_____

Instructions: Please record your general activities throughout the day, as well as your stress level during each on a scale of 1–5. *Ex: sleep, attend class, study, watch TV, run.*

Time	Activity	Stress Level (1–5)
12:00 am		
1:00 am		
2:00 am		
3:00 am		
4:00 am		
5:00 am		
6:00 am		
7:00 am		
8:00 am		
9:00 am		
10:00 am		
11:00 am		
12:00 pm		
1:00 pm		
2:00 pm		
3:00 pm		
4:00 pm		
5:00 pm		
6:00 pm		
7:00 pm		
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