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Short-term Changes in Responses to Stress in Runners

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SHORT-TERM CHANGES IN RESPONSES TO STRESS IN RUNNERS

by

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ABSTRACT

SHORT-TERM CHANGES IN STRESS RESPONSES IN RUNNERS

by

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The use of physical activity to cope with stress is becoming increasingly popular. Research indicates that individuals who routinely engage in cardiovascular exercise report better overall physical and psychological health and reduced reactions to stress than those who do not. In addition, there may be short-term improvements for these individuals on days when they exercise. The current study was designed to examine short- and long-term differences between runners and non-runners. Cardiovascular, affective, and behavioral data were collected from runners over a two-day period that included a running day and a rest day, and over a similar period in a non-running control group. Runners had lower heart rates and less negative affect during the two days than the controls, indications of long-term benefits of physical exercise. They also performed better on a simple math task on their running day than on their rest day, signifying that they may also realize short-term benefits from running.

DEDICATION AND ACKNOWLDEGMENTS

I would like to dedicate my dissertation work to my family, and especially to my parents. Thank you for your unwavering and unconditional support and encouragement throughout my education and my life.

I would also like to express my gratitude to my advisor, Dr. Raymond Fleming. Without your guidance and the extensive hours of instruction I could not have completed this project, and your dedication and support are extremely appreciated.

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Introduction

While all coping strategies may assist in reducing stress, some are generally believed to be more adaptive than others (Taylor, 2006). The use of physical exercise to cope with stress is considered adaptive (Salmon, 2001). It is well-known that regular engagement in physical exercise has a positive impact on physical health in a variety of ways (i.e., Blair, 1994, Centers for Disease Control and Prevention [CDC], 2010). Besides these benefits, regular exercise can also have a significant impact on the psychological health of exercisers as well (Salmon, 2001). Regular exercise has been repeatedly associated with positive psychological outcomes. Studies show that exercising regularly is associated with lower levels of both anxiety and depression (Salmon, 2001; Stephens, 1988; Weyerer, 1992). The use of physical exercise can be so effective on these symptoms that treatment plans for those suffering from depression and anxiety often include engagement in regular exercise (Martinsen & Morgan, 1997; Raglin, 1997; Salmon, 2001).

Physiological Benefits of Exercise

A recent longitudinal study (Rueggeberg, Wrosch, & Miller, 2012) examined the longer-term effects of regular exercise. Participants completed a baseline survey, and follow-up surveys two and four years after the initial assessment. The study found that participants with a high baseline level of perceived stress had significantly less perceived stress at the two-year assessment if they exercised on a regular basis. Further, it also found that regular exercisers reported significantly fewer physical health symptoms at the four-year follow-up. The regular exercisers in the study not only felt less stressed, but were also generally healthier.

Physical activity can have a beneficial effect on the physiological changes that occur in response to stress, associated with both short-term and long-term improvements. The link between regular aerobic exercise and low rates of cardiac disease has been well documented (e.g., Jolliffee et. al., 2001; Thompson et. al., 2003). Regular exercise can also be used to help decrease risk of hypertension (Hagberg, Park, & Brown, 2000). Frequent engagement in aerobic activity helps train the heart to function more efficiently. An early study by Bruning and Frew (1987) showed that exercisers, as well as comparison groups trained in either meditation or management skills, had lowered pulse rates compared to a non-trained control group. A similar study followed individuals who did not initially exercise regularly through an 8-month training program with assessments completed at the start of the program, the 4-month mark, and the 8-month mark (Gues, van Doornen, & Orlebeke, 1993). Measurement at the 4-month training mark showed significant decreases in resting heart rate and blood pressure. Additional decreases in both were found at the 8-month training mark. These long-term effects can help buffer the physiological effects of stress for habitual exercisers.

Short-term benefits are often observed from exercise sessions as well. Some studies have associated exercise with shorter physiological recovery times in response to stressors (Anshel, 1996; Hollander & Seraganian, 1984). In other cases, exercisers have shown lower levels of physiological reactivity (i.e., heart rate, blood pressure, etc.) to a stressful condition when they exercised before the stressor occurred (Anshel, 1996; Plante & Karpowitz, 1987). This mitigation of cardiovascular reactivity may be influenced by the exercise intensity. Roy and Steptoe (1991) found that individuals who engaged in intense exercise before the stressor had significantly reduced heart rate and blood pressure reactions than those who exercised at a moderate intensity, and both exercise groups showed lower reactivity than the non-exercise group. The results of studies with similar designs are less clear when the stressor occurs before an exercise session. Although less commonly studied, in some cases post-stressor exercise sessions also lead to reduced reactivity (Chafin, Christenfield, & Gerin, 2008). In other studies, however, exercising post-stressor produced no significant reductions in stress reactivity (Gues et. al., 1993). It should be noted, however, that Gues et. al. studied individuals who had completed 8 months of aerobic training while Chafin et. al. did not have a fitness requirement for their participants. The differences in these populations may explain the inconsistent outcomes, as the participants who were regular exercisers may have already had reduced reactivity *before* the exercise session, and therefore experienced no significant change after exercising. These acute responses to stress provide further evidence for the physiological benefits of physical activity.

Psychological Benefits of Exercise

Besides providing physical health benefits, regular engagement in exercise has also been associated with better psychological health. The link between physical activity and reduced symptoms of anxiety and depression has been widely accepted (Salmon, 2001). Long-term engagement in regular exercise has also been associated with lower levels of perceived stress. A study that followed exercisers and non-exercisers for a 12-month period found that the exercise group had significant reductions in both anxiety and perceived stress in comparison to the non-exercise group (King, Taylor, & Haskell, 1993). An assessment of blue-collar workers showed that those who engaged in physical activity in their leisure time reported a greater decrease in perceived stress after a two-month period than those who engaged in minimal leisure-time physical activity.

One common way to study the psychological effects of exercise is to assess how it affects mood (as mood disturbances may be an indication of stress). Regular exercisers have reported lower levels of emotional distress (Steptoe & Butler, 1996) and early research on the effects of running on mood indicated positive changes in affect after running (i.e., lower depression, anxiety, tension), although in some cases this effect only lasted a few hours (Seeman, 1978; Lichtman & Poser, 1983; Wilson, Morley, & Bird, 1980). To further explore this finding, Dyer and Crouch (1987) compared variations in affect for non-runners, novice runners, and experienced runners. They measured the affect of subjects three hours before, ten minutes before, ten minutes after, and three hours after either a running session (for the runners) or a class session (for the non-runners). The runners (both novice and experienced) report significant improvement in affect not only in both post-run assessments, but they reported smaller improvements for the ten-minute period prior to running as well. This could mean that the activity of running itself may not be the only contributor to change in affect. Anticipation of a positive event, such as an upcoming run, may also play a role in the improvement.

There are other factors that may also impact the relationship between affect and exercise. The intensity of a particular exercise session can play a role, with the ideal level of intensity thought to be low to moderate (Ekkekakis, Parfitt, & Petruzzello, 2011). The enjoyment that people experience while running has a strong positive correlation with improvement in affect after exercise is complete (Raedeke, 2007). In addition, the duration of a workout can also impact change in affect. Positive changes have been found after as little as ten minutes of exercise (Hansen, Stevens, & Coast, 2001). While in some studies additional change in affect for longer work-outs has been found to be minimal, in other cases increases work-out length leads to significantly greater improvements in affect (Rocheleau, Webster, Bryan, & Frazier, 2004).

The psychological effects of exercise can also be illuminated when studying what happens when regular exercisers are unable to engage in their normal exercise behavior. For every regular exerciser, there are many reasons why he or she may not be able to exercise on any particular day. Many exercise programs have rest or recovery days built in. Unexpected changes in schedule, or bad weather, can prevent exercise sessions. Injuries can keep exercisers from working-out for longer periods of time. Abstaining from exercise has been linked to a variety of changes in regular exercisers. Szabo, Frenkl, Janek, Kálman, and Lászay (1998) examined changes in runners on both running and scheduled non-running days for three weeks. Participants reported on both their mood and their anxiety levels just before bed on each of the 21 days, and average scores for each condition (running and non) were calculated. The results indicated that participants experienced significantly higher positive affect and lower anxiety on days when they ran than on days when they did not. Subsequent research has replicated these findings and has shown increases in negative affect on non-exercise days (Hausenblas & Symons Downs, 2002a).

Other research has looked at the effects of unexpected or involuntary exercise deprivation. Increases in negative affect and physical symptoms can occur after even short periods of deprivation, often imitating symptoms of withdrawal (Mondin et.

al.,1996; Morris, Steinberg, Sykes, & Salmon 1990), with negative symptoms increasing the longer exercise deprivation continues. These effects can be further enhanced when the reason for deprivation is injury (Szabo, 1998). The presence of withdrawal symptoms after deprivation may be indicative of an addiction to exercise (exercise dependence). This dependence may be the result of a growing number of exercisers who rely on the activity to regulate their mood and stress levels (Symons Downs, Hausenblas, & Nigg, 2004). It may result from addiction to the exercise itself, or could be a reliance on the positive changes that follow exercise sessions. The negative symptoms experienced when exercisers are deprived may then be a result not of the lack of exercise itself, but of the positive changes that occur in tandem with the activity. Exercise dependence has previously been shown to contribute to a differential effect in response to exercise deprivation when compared to exercisers who are not dependent (Hausenblas, Gauvin, Symons Downs, & Duley, 2008). While these findings seem to indicate exercise addiction, it is possible that these individuals are instead experiencing these negative responses to a loss of control. The reactance and negativity they experience in response to this loss may be interpreted as stress.

Stress and Exercise Measurement

When studying the relationship between stress and exercise, there are many different ways to measure stress responses. Researchers are often interested in physiological assessment of stress. Among the most commonly-used measures of physiological stress are heart rate and blood pressure, with decreases and faster recovery times indications of efficient responses to stress, and increases and slow recover indications of more severe stress (Forcier et. al., 2006). Changes in heart activity are also considered in studies that use heart rate variability (HRV) as an indication of stress (e.g., Collins, 2001; Karasek, Collins, Clays, Bortkiewicz, & Ferrario, 2010). In this case, increases in high frequency HRV (HF-HRV) and decreases in low frequency HRV (LF-HRV) are indicative of lower stress levels.

Psychological assessment of stress is often accomplished through self-report measures, although the nature of the measures can vary greatly. Measures regarding symptoms of anxiety and depression are often used in exercise studies because of the strong link between reductions of these symptoms and exercise (Salmon, 2001). Individual level of perceived stress is also commonly used (King, Taylor, & Haskell, 1993; Rueggeberg, Wrosch, & Miller, 2012), which can help clarify personal appraisals of events that may or may not be considered stressful. Many studies also rely on changes in affect as an indication of the psychological experience of stress (i.e., Dyer and Crouch, 1987; Hausenblas & Symons Downs, 2002b; Steptoe & Butler, 1996; Szabo, 1998). Because of the links between physiological activity and emotionality, stress may be considered a form of negative affect, and measuring changes in affect in response to stressors may give a strong indication of the experience of a stress reaction.

Laboratory settings for studies of the effects of exercise, while allowing tight control over experimental conditions, are associated with a number of disadvantages. For example, in many cases the lab setting provides a single type of activity that may not be the preferred exercise of subjects (i.e., runners on a stationary bike, swimmers on a treadmill, etc.). This inconsistency may cause reactions from subjects not typical of their normal responses to physical activity (Kerr & Kuk, 2001). Even when subjects are participating in their preferred activity, doing so in a laboratory has been shown to increase arousal and anxiety (Gale & Baker, 1981; Kerr & Kuk, 2001). A direct comparison of the same runners in both a lab setting and in a natural setting (an outdoor footpath) reported higher levels of pride, as well as greater levels of effort in the natural setting (Kerr et. al., 2006).

Because of the artificial nature of studies conducted in laboratory settings, and the confounds that may be associated with it, an alternative method of ecological momentary assessment (EMA) may be used. EMA uses repeated assessments collected in real time to track momentary changes in participants' natural settings (Stone & Shiffman, 1994; Smyth et. al., 2009; Smyth & Stone, 2003). This can help to eliminate some of the common confounds that occur in laboratory research, such as the increased anxiety that has been reported. EMA has been used previously to examine the relationship between physical activity and affect. Kanning and Schlicht (2010) followed subjects for a period of 10 weeks, periodically assessing their mood and noting fluctuations that occurred around sessions of physical activity. Mood assessments taken after engagement in physical activity were more positive than those taken after periods of inactivity. In another instance, subjects were assessed over a period of six days (Hausenblas, Symons Downs, & Duley, 2008). These subjects spent three of these days following their normal workout routine, and the other three abstaining from exercise. On each day, they were paged multiple times to prompt the completion of a mood assessment. Participants reported lower positive and higher negative affect on days when they did not exercise as part of their normal routine than on exercise days and days when they were forced to abstain. Overall, these studies show that EMA can be used to identify short-term changes in affect that occur in relation to physical activity.

While these studies provide a good starting point to understanding the short-term effects of physical activity, they only measure these effects on a single dimension – self-reported affect. While changes in affect can be used as a psychological indication of stress, stress can also be assessed through other methods. Rather than rely on self-report measures, observable behavior can also be assessed. Some studies have used performance on cognitive tasks such as proofreading, embedded figures puzzles, or mental arithmetic as indications of stress experience (Fleming, Baum, Gisriel, & Gatchel, 1982; Forcier et. al., 2006; Kirschbaum, Pirke, & Hellhammer, 1993). Such tasks may simultaneously act as an acute stressor while performance indicates stress experience.

Current Study

With the prevalence of high obesity rates – the Centers for Disease Control and Prevention estimates that 35.7% of U.S. adults are obese – many people are beginning to exercise as a way to manage not only their weight, but their overall physical health (CDC, 2010). While there are many different forms of physical activity that individuals can partake in for physical fitness, in many cases the opportunities to do so may be limited. For example, swimming can only be done with access to a pool, cycling requires expensive equipment, and many gyms can have restrictive hours. However, running requires minimal equipment, and sidewalks and trails are available for use at nearly any time. Running is becoming an increasingly popular form of physical activity. An estimated 13,974,000 people finished road races in the year 2011 in the United States, compared to 5,368,000 in the year 2000, an increase of about 260% (Running USA, 2013). As the popularity of running continues to rise, more people are exposed to the benefits associated with exercising on a regular basis.

The current study examined short-term changes in indications of affective and physiological stress for runners both on days when they ran and on days when they didn't by nature of their running schedule (not involuntary abstinence). EMA was used to assess a combination of physiological activity, changes in affect, and concentration ability, providing a three-dimensional assessment of stress, where previous EMA studies (Hausenblas, Gaufin, Symons Downs, & Duley, 2008; Kanning & Schlicht, 2010) have only looked at self-reported indications.

Hypotheses

Differences were assessed not only between the running and non-running groups, but within participants between running days and non-running days. It was predicted that the running group would report lower levels of perceived stress, anxiety, and depression than those in the non-running group on measures completed for the initial screening survey. It was also predicted that the running group would report better affect, better math performance and less physiological reactivity during the math task and throughout the two-day at-home assessment. Finally, it was predicted that the running group would report better affect and show better math performance and less physiological reactivity after the acute math stressor task on running day than on non-running day of the at-home assessment.

Methods

Participants

The survey portion of this study was completed by 498 undergraduate students enrolled in introductory level psychology courses at the University of Wisconsin-Milwaukee. These participants answered questions about their levels of stress (Beck Anxiety Inventory, Beck Depression Inventory, Perceived Stress Scale). From this pool, participants were screened and selected for the at-home portion of the study. Those who ran at least three times per week for the previous three months but were not highly competitive (e.g., elite runners), and who reported using running to cope with stress were contacted for recruitment into the running group. Those who did not engage in aerobic exercise and had no cardiovascular issues were contacted for recruitment into the non-exercise group. The screening included questions about participants' exercise background and methods, addiction to exercise (Exercise Dependence Scale), and cardiovascular health. Runners who had no cardiovascular issues that could impede data collection and who alternated running days were invited to complete the at-home procedure.

Instruments

Demographic Questions

Demographics included a variety of questions about the participants' background information (gender, ethnicity, age, education, height, weight).

Beck Anxiety Inventory

Anxiety was assessed using the Beck Anxiety Inventory (BAI; Beck, Epstein, Brown, & Steer, 1988). The questionnaire contains 21 items that assess severity of anxiety according to their response to statements such as "unable to relax" on a four-point Likert scale that ranges from "Not at all" to "Severely", with higher scores indicating higher levels of anxiety. Previous analysis of the questionnaire has shown that it has good internal consistency (between .92 and .94 for adults) as well as good reliability scores (test-retest r = 0.75 over a one-week interval). It has also shown validity scores ranging from .47 to .58 when compared to other measures of anxiety.

Beck Depression Inventory

Depression was assessed using the Beck Depression Inventory (BDI; Beck, Ward, Mendelson, Mock, & Erbaugh, 1961), a measure containing twenty-one sets of four statements that participants choose one or more from to indicate how they have been feeling throughout the previous week (for example, "I do not feel sad"; "I feel sad"; "I feel sad all the time and I can't snap out of it"; "I am so sad or unhappy that I can't stand it"). The inventory is a very commonly used measure of depression, with analyses of the measure showing strong internal consistency (0.91) as well as sufficient reliability (test-retest r = 0.93 after one week).

Perceived Stress Scale

The Perceived Stress Scale (PSS; Cohen, Kamarck, & Mermelstein, 1983) was administered to assess the level of stress participants felt they were experiencing. The scale consists of fourteen items (i.e., “In the last month, how often have you felt nervous or ‘stressed’?”) that participants answer on a 5-point Likert scale ranging from “Never” to “Very Often”. The scale has been found to be sufficiently reliable, with test-retest reliability of at least .84. Its validity has been verified when tested against similar measures, with correlations ranging from .52 to .76.

Exercise Dependence Scale

Exercise addiction was assessed using the Exercise Dependence Scale-21 (EDS-21; Hausenblas & Symons Downs, 2002), a 21-item questionnaire that categorizes respondents as at-risk, nondependent-symptomatic, or nondependent-asymptomatic, as well as identifying physiological dependence. The scale assessed dependence along seven dimensions (i.e., tolerance, withdrawal, intention effect, lack of control, time, reductions in other activities, continuance), with a score of at-risk in three or more dimensions indicating dependence. Respondents answered statements such as “I exercise to avoid feeling irritable” on a 6-point Likert scale (1 = “Never”, 6 = “Always”). The scale has shown strong internal reliability (up to .93) as well as good test-retest reliability (.92 after seven days).

Health Questionnaire

A cardiovascular screening questionnaire was used to assess the overall physical health of the participants. Any conditions or medications that increased participant risk or interfere with the methods of the experiment were not included in subsequent parts of the study.

Exercise Background and Methods

Participants answered questions about how often they engaged in aerobic activity and what types of aerobic activities they did. Those who ran three or more times weekly were asked whether they use running to cope with stress. They also answered questions about their running background and their typical running routine, including how long they have been running, what days they normally run, what time during the day, typical distance or longevity, typical speed, what their commitment level is, how competitive they are, and whether they are in training.

Physical Activity Affect Scale

Affect was measured using the Physical Activity Affect Scale (PAAS; Lox, Jackson, Tuholski, Wasley, & Treasure, 2000), a 16-item measure designed to assess changes in affect along two dimensions (positive affect, negative affect). Respondents indicate how they are feeling (e.g., “Upbeat”) on a 5-point Likert scale ranging from 0 (“Do not feel”) to 4 (“Feel very strongly”). Internal consistency of the scale ranges from .85 to .90 for each of the dimensions. Analyses of the scale used on both physically active and non-active populations indicate minimal differences in the ability of the scale to detect changes in affect (Carpenter, Tompkins, Schmiege, & Nilsson, 2010).

Daily Log

A log of each participant’s day was recorded for both of the days participants wear the device, including all activities the participant engaged in during the day and when during the day they experienced the most stress. The log included an hourly schedule for the participants to record what activities they engaged in and when, as well as a rating on a 5-point Likert scale to indicate how stressed they felt during that time period.

Math Task

Mild stress was induced through a mental math task. The task consisted of a long series of three-number simple addition problems, similar to those used by Glass and Singer (1972). Participants were given five minutes to correctly answer as many problems as they could. Performance was assessed based on the number of problems completed and the number answered correctly. Simple addition was chosen because it required only a short time to train participants on the procedure, and they could easily administer it to themselves outside of the laboratory.

Physiological Data Collection

Physiological stress response and recovery were recorded using an ambulatory monitor (Bioharness 3 Remote Physiological Monitor, Zephyr Technology; Annapolis, Maryland). The monitor recorded heart rate, respiration rate, skin temperature, posture, and activity level. The data was used to measure the heart rate, recovery, and HRV of participants during the 4-hour assessment period each day. Data was stored on a memory flash card attached to a chest strap worn by participants. ECG was sampled at 250 Hz and recorded using a high pass filter at 15 Hz and a low pass filter at 78 Hz.

Respiratory parameters included respiratory rates detected from 3 BPM to 70 BPM (0.05 Hz to 1.166 Hz). Cardiac parameters included HR (beats/min) and estimates of heart rate variability (HRV): high-frequency domain (HF) of spectral analysis and the time-series root mean square successive difference (RMSSD) in heart period series.

Respiratory and cardiac data were processed using the Bioharness analysis software (Zephyr Technology). Further, power spectral analysis of HRV data was measured using a fast-Fourier transformation accomplished with Heart Rate Variability Software (HRV; Department of Applied Physics, University of Kuopio). The FFT algorithm calculated the frequency domains that characterize the high-frequency (HF) power spectrum (0.15Hz – 0.40Hz). Detrending of the R-R series was conducted using "smooth priors" and "Eye" models and an Alpha value of 1000. From this analysis, high-frequency power spectrum was calculated for each ten-minute segment before four scheduled diary assessments and a five-minute segment during the math task. HF was presented using normalized units (nu).

Procedure

Initial data collection occurred through an online survey. Participants answered questions about their stress levels, and then completed the screening for the at-home portion of the study. The screening included questions about cardiovascular health, exercise dependence, running method, and running background. Participants with sufficient cardiovascular health who ran at least three times per week, were not highly competitive 'elite' runners, were not currently involved in any official training (i.e., track team), were not exercise dependent, and used running to cope with stress were invited to join the running group. Participants with sufficient cardiovascular health who did not engage in aerobic exercise regularly were invited to join the non-running group. See Figure 1.

The at-home experimental procedure took place over a 4-day period. This period was structured so that the days on which participants wore the Bioharness monitor occurred during the workweek (i.e., Monday-Friday). Participants who ran on their first day of monitoring did so between Monday and Thursday, with their non-running day occurring between Tuesday and Friday. Those who ran on their second day of monitoring did so between Tuesday and Friday, with non-running day assessment taking place between Monday and Thursday. On the Day 1, participants will met with trained research assistants (RAs) in the Stress and Coping Lab on the UWM campus. RAs trained participants in how to turn on, put on, take off, and turn off the Bioharness. Participants were also trained on how to start and stop the timer and how to stop the alarms on the timing device. During this meeting, participants also complete the first of three math tasks. They were asked to complete as many three-digit addition problems as they were able to in a timed five-minute period. This initial math task was used to train participants in how to complete the task (as they were on their own during subsequent tasks). It also provided participants with an idea of their baseline performance. They were asked to improve their performance when they completed the math task again, with the task serving as an acute stressor during the rest of the study. Once participants were comfortable with the equipment and had completed the math task they left the lab, taking the Bioharness, timer, and daily assessments with them, as well as contact information for the RA in case of any questions or concerns.

On Day 2, participants wore the Bioharness and carried the timer during the same 4-hour period between the hours of 9:00am and 4:00pm as in Day 3. During this period the participants were prompted four times at irregular intervals (to avoid anticipation of the prompt) by the timer to answer a short series of questions. These questions included what they had been doing for the previous 10 minutes and the 16 items from the PAAS. On the third prompt they also completed the 5-minute timed math task, with instructions to attempt to improve their performance from the laboratory baseline. On average, the prompts occurred 50 minutes apart. After the 4-hour period was completed, participants removed and turned off the Bioharness. At the end of the day they completed a daily log with information about what they did during the day.

The procedure for Day 3 was the same as Day 2, with participants wearing the Bioharness and carrying the timer during the same 4-hour period as in Day 2. The difference between Days 2 and 3 occurred only in the running group, who will completed a run on one of the days and not on the other according to their normal running schedule. They were instructed to complete their run as they normally do (i.e., time of day, distance, intensity, etc.). The order of run and rest days was counterbalanced, so not all runners will run on day 2 and rest on day 3. The non-running group did have this difference between days 2 and 3. On day 4 participants, returned to the lab and met with the RA to drop off the equipment, their questionnaires and daily logs, and to be debriefed.

Data Analysis

The study consisted of a one-within-subjects, one-between-subjects design (running group versus non-running group, day 2 versus day 3). The running and non-running groups were assessed using multivariate analysis of variance (MANOVA) to determine differences in affect, stress levels, or physiological activity. Differences between the running and non-running groups on perceived stress, anxiety, and depression were also assessed. Within participant affective and physiological changes between assessment days were tested using repeated-measures ANOVA. Differences between day 2 and day 3 were assessed for the running group (relative to changes in the yoked, non-running participants) to determine if there is a change in reactivity (i.e., affect, physiology) from running days to non-running days to determine whether day to day changes were a result of normal fluctuation rather than due to the effects from running. Physiology was assessed using the 10-minute period pre-assessment and the 5-minute period during the math task, and was examined for differences in HR and HRV. Assessments from each prompt were averaged for an indication of differences between total sessions from Day 2 to Day 3. Individual prompts were also analyzed for changes that occured throughout each day as well as for differences between prompts at the same time on each day (i.e., differences between Prompt 1 on Day 1 and Prompt 1 on Day 2). Reactivity to the acute stressor (math task completed on the third prompt each day) was tested separately from the other prompts to determine how participants respond to the acute stressor. Performance on the math task was assessed for differences between performances on Day 2 and Day 3, and for differences between monitoring days and the baseline assessment from Day1.

Results

Screening Survey

An online screening survey was completed by 498 undergraduate psychology students at the University of Wisconsin-Milwaukee. Participants were predominantly female (79%) and Caucasian (72%), with an average age of 21.59 years (SD=4.6). Runners made up 42% of the sample.

The runners and the non-runners (controls) were compared on their self-reported scores of perceived stress, anxiety, and depression. A significant difference was found for perceived stress scores (F=11.47, p=.001, η_p^2=.03), with the runners scoring lower than the controls ($M_{runners}$=32.13, SD=.49; $M_{controls}$=39.73, SD=.59). The runners also scored significantly lower than the controls on the anxiety scale (F=5.67, p=.02, η_p^2=.01; $M_{runners}$=8.39, SD=.52; $M_{controls}$=6.46, SD=.63). The difference between the runners and the controls on depression was not significant (F=3.03, p=.08, η_p^2=.01; $M_{runners}$=7.89, SD=.53; $M_{controls}$=9.10, SD=.45).

Two-Day Study

A total of 22 participants completed the two-day physiology monitoring portion of the study. Two of the participants had to be removed due to equipment recording errors. There were 10 participants in both the running group and the control group. The sample used for analysis was mostly female (70%) and Caucasian (80%), and ranged in age from 18 to 35 (M=21.55, SD=3.78).

Physiology

The physiological data used in analysis was recorded during the 10-minute period prior the self-report assessment, and the 5-minute period during completion of the math task.

The difference in heart rate from the Running Day to the Rest Day across running groups approached significance (F=4.05, p=.06, η_p^2=.18). Broken out by day, there was no difference in the heart rates of the runners and the controls on Running Day (M_{runners}=85.65, SD=4.25; $M_{controls}$=87.22, SD=4.25; F=.07, p=.79, η_p^2=.004), but the runners showed significantly lower heart rates than the controls on the Rest Day (M_{runners}=75.16, SD=3.42; M_{controls}=85.15, SD=3.42; F=4.27, p=.05, η_p^2=.19). See Figure 2.

Physiological data also showed differences between measurement intervals, but only in two variables. The frequency-domain measurements of HRV were significant, but only on the Running Day. The low-frequency normalized units (LFnu) were significantly lower during the math task than at the other intervals during the day (F=4.34, p=.05, η_p^2=.19; M_{math}=57.87, SD=4.85; M_{other}=64.25, SD=4.45). For the high-frequency normalized units (HFnu), values were significantly higher during the math task (F=4.43, p=.05, η_p^2=.20; M_{math}=41.87, SD=4.82; M_{other}=35.56, SD=4.43).

Other physiological assessments, including root mean square of successive differences in heart rate (RMMSD), percent of NN50 (pNN50), and the frequency-domain assessments of HRV (LFms and HFms) were not significantly different between running groups, days, or measurement interval (see Table 2, Table 3).

Self-reports

No differences were found between the runners and the controls for stress reported during the two days of monitoring (*F*=.39, *p*=.54, η_p^2=.02). There were also no differences between the Running Day and the Rest Day (*F*=1.34, *p*=.30, η_p^2=.06), or between measurement intervals (*F*=1.55, *p*=.21, η_p^2=.081).

There was a significant effect of measurement interval for positive affect (*F*=6.38, *p*=.001, η_p^2=.26), with significant differences occurring between the first interval and the third interval (*F*=18.18, *p*<.001, η_p^2=.50), and between the second interval and the third interval (*F*=13.92, *p*=.002, η_p^2=.44), indicating that all participants reported less positivity just prior to the math task. At the third interval (math task), participants reported significantly lower positive affect (*M*=10.95, *SD*=.89) than during the first (*M*=12.93, *SD*=.69) and second (*M*=12.65, *SD*=.92) intervals. There were no significant differences based on day (*F*=.38, *p*=.54, η_p^2=.02) or based on running group (*F*=1.65, *p*=.21, η_p^2=.08).

The difference between runners and controls approached significance for the measure of negative affect (*F*=3.76, *p*=.06, η_p^2=.17), with the runners scoring lower than the controls ($M_{runners}$=5.01, *SD*=.98; $M_{controls}$=7.73, *SD*=.98). There was no difference based on day (*F*=1.21, *p*=.29, η_p^2=.06), or based on measurement interval (*F*=2.07, *p*=.12, η_p^2=.10). However, the interaction effect between day and running group approached significance (*F*=3.91, *p*=.06, η_p^2=.18). Follow-up analysis for this effect showed that scores for the runners did not significantly differ based on day (*F*=.26 *p*=.62, η_p^2=.03). However, the controls did show a significant difference (*F*=9.23, *p*=.01, η_p^2=.51), reporting higher negative affect on the Running Day (*M*=9.53, *SD*=1.28) than on the Rest Day (*M*=5.93, *SD*=1.24). See Figure 3.

Math Task

Performance on the math task was assessed by both how many problems participants completed, and what percentage they completed correctly. Overall, there was not a significant difference in the number of problems completed between the Running Day and the Rest Day (F=.078, p=.78, η_p^2=.01), or for the number completed between the runners and the controls (F=.726, p=.41, η_p^2=.04). The interaction effect for day by running group approached significance (F=4.08, p=.058, η_p^2=.19). Follow-up analysis for this effect showed that the controls did not significantly differ on the number of problems completed between the Running Day and the Rest Day (F=.939, p=.36, η_p^2=.09), but the runners completed a significantly higher number of problems on the Running Day (*M*=135.4, *SD*=12.06) than on Rest Day (*M*=121.8, *SD*=11.49; F=6.89, p=.03, η_p^2=.43). Differences between the runners and the controls were not significant on the Running Day (F=2.79, p=.11, η_p^2=.13) or on the Rest Day (F=.0002, p=.99, η_p^2=.00). For the percent of problems correct, there were no significant effects for day of completion (F=.04, p=.84, η_p^2=.002), running group (F=2.99, p=.10, η_p^2=.14), or for the interaction (F=1.69, p=.21, η_p^2=.08; see Table 4). See Figure 4.

Discussion

The findings from the survey portion of the study were consistent with previous research, with the exception of the depression variable, which showed no difference between the runners and the controls. Participants who ran on a regular basis reported lower levels of both anxiety and perceived stress, which supports the hypothesis that regular physical activity can improve psychological health. These findings supported the hypothesis that runners would show lower general levels of stress and anxiety than people who did not regularly engage in cardiovascular exercise.

Results from the two-day monitoring portion of the study provided some evidence to support the hypothesis that the runners would show long-term physiological benefits and lower reported stress levels than the controls. The physiological data showed differences in heart rate between the running groups. Overall, runners showed a lower heart rate than the controls across both days of monitoring. This is consistent with previous research that shows individuals who engage in cardiovascular exercise (like running) on a regular basis have lower resting heart rates than those who do not (Cantwell, 1985).

The self-reported affect data also showed differences between the runners and the controls. The runners reported lower levels of negative affect than the controls on both days, and across all measurement intervals. They also showed consistent negative affect across the both days, while the controls reported higher negative affect on the Running Day than on the Rest Day. This difference may be due to the runners' belief that running reduces their negativity, as it is widely accepted in the running community that regular exercise has psychological benefits. As the runners who were recruited for the study also reported using the activity as a method of coping, they may also believe they experience less negativity because they feel they are effectively coping with it.

There was also some evidence to support the hypothesis that runners would show short-term benefits in proximity to a run. Findings regarding performance on the math task provided the strongest support for the hypothesis for these benefits. While there were no overall differences between groups or between days, there was a significant interaction effect. The controls showed no difference in either the number of problems completed or the percentage correct from Running Day to Rest Day. However, the runners completed a higher number of problems on the running day, but without a difference in accuracy between the two days. This indicates an improvement in performance, as they were able to complete more problems without decreasing their accuracy.

The physiological data showed differences between the runners and the controls in heart rate changes. Runners had significantly lower heart rates on the Rest Day than they did on the Running Day, but there was no significant difference between the two days for the controls. The higher heart rate on the running day is most likely due to the run itself, as the heart rate increases with physical activity. The higher heart rates of the runners on the Running Day may also explain the differential math task performance in the runners. A possible link between increased heart rate and increased math performance can partially be explained by the theory of social facilitation (Zajonc, 1965), which states that people will perform better on simple, familiar tasks in the presence of others, but will perform worse on difficult, unfamiliar tasks. Variations on this theory suggest that it is not merely the presence of others that affects performance, but the physiological arousal that occurs as a result of their presence (Guerin, 1993; Blascovich, Mendes, & Hunter, 1999). In the current study, the elevated heart rate in the runners on the Running Day may have contributed to their enhanced performance, as simple addition of single-digit numbers is a familiar, easily performed stress task.

Positive affect also showed differences between the math interval and other measurement intervals. Participants reported significantly lower positive affect right before the math task was completed than they did in the previous assessments. This provides evidence that the math task acted as an effective stressor for the participants during the study procedure.

Limitations

Some of the non-significant findings in the study may be due to the small sample size. With only 10 participants in each group, differences that would be significant with a larger sample may not appear to be, because of the lack of power in the data. In the future, additional participants will be run with the goal of tripling the size of the sample (with n=30 per group).

The study was also limited by the absence of a self-report assessment immediately following the math task. While the assessment that is completed just before the math task may indicate how participants feel in anticipation of the minor stressor, however it does not provide information directly related to how participants felt during the task. Future assessments could also examine the physiological data during the recovery period after the math task to assess whether there are differences in how the runners and controls respond after completing the task, or if responses in runners differ from the Running Day to the Rest Day. The data showed that LFnu, and HFnu both differed significantly during the math task when compared to all other assessment intervals during the day. However, analysis of how *quickly* those values returned to their normal levels may show differences between the runners and the controls that are not apparent in the specific time periods assessed.

It is also possible that the results of the study were limited by the expectations of the participants. If the runners had previous knowledge that running is beneficial they may have responded differently on the Running Day than they did on the Rest Day. In addition, the runners and the controls may have responded differently on the self-report measures due to their belief about how they s*hould* be feeling, rather than how they actually felt.

Conclusions

Overall, the study did provide evidence for both short- and long-term benefits for people who run regularly over those who do not engage in regular cardiovascular activity. The inclusion of a behavioral variable (the math task) in the assessment of short-term benefits has not been included in previous research, but may provide important additions to the current literature, as well as direction for future research.

The long-term benefits for runners occurred on both the physiological and psychological levels. The runners showed lower heart rate than the controls, a factor that has shown strong indications for cardiovascular health (i.e., Palatini, 2004). They also showed decreased levels of negative affect, anxiety, and perceived stress, indicating that beyond the physical benefits, they also experience less psychological stress than those who do not exercise regularly. They also saw short-term benefits in their behavior, demonstrated by their better math task performance on the Running Day. While these findings provide support for previous research about the long-term benefits of regular exercise, they also indicate that regular exercisers can gain short-term benefits in behavioral performance, which contributes to an emphasis on the importance of regular cardiovascular activity.

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Appendix A

Experimental Procedure Outline

Day 1:

- Participant meets with RA in the lab
  - Trained to operate Bioharness and timer, and is instructed on how to complete EMA assessments
  - Complete initial math task
  - Take equipment and assessments, as well as contact information in case of questions or concerns

Day 2:

- Participant completes first day of EMA assessment
  - Wear Bioharness for 4-hour period between 9:00am and 4:00pm
  - Complete EMA assessment (report of current activity and completion of PAAS) at each of 4 prompts from timer
  - Complete math task at prompt 3, attempting to improve on performance from Day 1
  - Complete daily log at the end of the day, with information about daily schedule
  - Running group members who run on first assessment day will run some time outside of 4-hour assessment period

Day 3:

- Participant completes second day of EMA assessment
  - Wear Bioharness for 4-hour period between 9:00am and 4:00pm (same period as on Day 2)
  - Complete EMA assessment (report of current activity and completion of PAAS) at each of 4 prompts from timer
  - Complete math task at prompt 3, attempting to improve on performance from Day 1
  - Complete daily log at the end of the day, with information about daily schedule
  - Running group members who run on second assessment day will run some time outside of 4-hour assessment period

Day 4:

- Participant returns equipment and assessments to lab and is debriefed

Appendix B

University of Wisconsin – Milwaukee
Consent to Participate in Online Research

Study Title: Short-Term Changes in Responses to Stress in Runners

Person Responsible for Research: Dr. Raymond Fleming, UWM Psychology Department & Molly A. O'Connor, Psychology Graduate Student

Study Description: The purpose of the study is to examine short-term changes in stress response experienced by runners in proximity to exercise sessions. This study will examine physiological, affective, and cognitive responses to emotion during two four-hour periods in the daily life of individuals who run on a regular basis and others who do not regularly engage in aerobic exercise. A biopsychosocial approach to understanding behavior will be employed. That is, different systems that influence behavior (i.e. physiology, cognitive, and emotional) will be measured simultaneously.

Approximately 500 participants will participate in this portion of the study. If you agree to participate, you will be asked to complete a survey that will take approximately 60 minutes to complete. The questions will ask about thoughts, feelings, behaviors, and emotions that you experience in your life. Based on the information provided on this survey, some participants will be contacted to participate in the experiment portion of the study.

The second portion is a naturalistic study involving physiological measurements of heart rate and respiration during your daily life. All participants will be asked sets of questions periodically through the day. Not all willing participants will be selected and contacted. If selected for the naturalistic study, a research assistant will contact you by e-mail to schedule a meeting time within two weeks. The experimental portion will last approximately 9 hours over 2 days and provides an opportunity for research credit in the amount equivalent to the time spent involved in the study.

Risks / Benefits: Risks to participants are considered minimal. There will be no costs for participating. You will be awarded 1 hour of research credit for the online survey portion and a potential of 9 more hours of research credit for the naturalistic experiment. Extra credit for the participation in this study may not be guaranteed. Your instructor has final discretion for awarding extra credit.

Confidentiality: Every measure will be taken to keep your responses confidential. The internet site is public space. As an online participant in this research, there is always the risk of intrusion by outside agents, i.e., hacking, and therefore the possibility of being identified. In order to receive research credit and be contacted for further participation you will be asked to provide your name and phone number. Your course instructor will be given notice of your research participation. Data from this study will be saved on a password protected computer for 2 years. Only Dr. Raymond Fleming and his research team will have access to the information. The only instance where your information will be disclosed is if there is suspected threat to self or others. In this instance, the appropriate authorities will be notified to ensure your or others safety.

Voluntary Participation: Your participation in this study is voluntary. You may choose to not answer any of the questions or withdraw from this study at any time without penalty. Your decision will not change any present or future relationship with the University of Wisconsin Milwaukee.

There are alternatives for extra credit other than participation in this study. Contact the UWM psychology department at 414-229-4746 or speak with your course instructor for possible alternatives.

Who do I contact for questions about the study: For more information about the study or study procedures, contact Dr. Raymond Fleming at 414-229-3980 or mundo@uwm.edu

Who do I contact for questions about my rights or complaints towards my treatment as a research subject? Contact the UWM IRB at 414-229-3173 or irbinfo@uwm.edu

Research Subject's Consent to Participate in Research:

To voluntarily agree to take part in this study, you must complete the attached survey. Completing the survey indicates that you have read this consent form and have had all of your questions answered, and that you are 18 years of age or older.

Thank you!

Appendix C

UNIVERSITY OF WISCONSIN – MILWAUKEE
CONSENT TO PARTICIPATE IN RESEARCH
STUDENT CONSENT

1. General Information

Study title: Short-Term Changes in Responses to Stress in Runners

Person in Charge of Study (Principal Investigator):

My name is Dr. Raymond Fleming, Ph.D. I am a professor in the Department of Psychology at UWM.

2. Study Description

You are being asked to participate in a research study. Your participation is completely voluntary. You do not have to participate if you do not want to.

Study description:

The purpose of this study is to:

The purpose of the study is to examine short-term changes in stress response experienced by runners in proximity to exercise sessions. Differences that exist between regular runners and non-aerobic exercisers, as well as those within runners based on how recently they have run, may be important for understanding both short- and long-term effects of exercise.

This research is being done based on previous studies that indicated both long- and short-term benefits on physical and psychological health from regular engagement in exercise. This study will help us learn more about long-term differences between exercisers and non-exercisers, as well as the scope and duration of the short-term benefits of single exercise sessions.

The study will be conducted in the Psychology Department at UWM and in the naturalistic environment. Approximately 80 undergraduate students will participate in this portion of the study. Your participation in this part of the study will take approximately 9 hours over 4 days.

Criteria for inclusion in this portion of the study include being an adult (at least 18 yrs.), being able to give consent, and being an English speaker. Recruits for the running group should have run at least three times per week for the previous three months but not be highly competitive (e.g., elite runners), and report using running to cope. Recruits for the non-running group should not engage in aerobic exercise on a regular basis.

Exclusion criteria require participants to be free from medical complications that may place the individual at risk (i.e., cardiovascular disease, high blood pressure) or medications that affect the central nervous system, cardiac, respiratory or musculo-skeletal systems that could bias the collection of cardiovascular data. Exclusion criteria apply to both the online survey and laboratory portions of the study. Moreover, potential threat to self will be assessed and may lead to exclusion.

3. Study Procedures

What will I be asked to do if I participate in the study?

If you agree, you will be asked to participate in a naturalistic study immediately after giving your signed consent. The certain activities which you will be asked to participate in include wearing a non-invasive physiological device that is comfortably worn under a loose garment. The experiment will last approximately 9 hours over the course of 4 days, with two 4-hour physiology monitoring sessions. You will be asked to answer a set of several questions (e.g. “How relaxed do you feel right now?”) throughout your day. You may ask to stop the experiment at any time. During the two 4-hour periods, you are asked to go on with your daily activities.

The questionnaire will ask you several brief questions about your mood and emotional experience. This activity is important for the study because it helps us understand how your mood changes throughout the day. Each set of questions should take approximately 90 seconds to complete.

The physiological measurements that will be recorded during this study are extremely safe and include heart activity (e.g., heart rate), respiration, and movement. These measurements are important because they will help us understand how your body reacts to emotion and stress. Physiological recordings will be continuously recorded during each 4-hour time-period.

4. Risks and Minimizing Risks

What risks will I face by participating in this study?

The potential risks for participating in this study are minimal – no greater than what you would experience in your daily life.

1. There is a very small risk that you may feel embarrassed or uncomfortable talking with the research team or answering questions. If you are distressed at anytime throughout the experiment, you may decline to answer a question or will be allowed to take a break. You can always follow-up on certain topics of interest with a research member, Norris Health Center, and UWM Psychology Clinic.

2. You will be asked to engage in your daily life and answer several sets of questions throughout your day. The questions are non-invasive, and are securely-digitally coded.

Furthermore, the physiological equipment is non-invasive, meaning that it does not damage the body or body tissue in any way.

5. Benefits

Will I receive any benefit from my participation in this study?

There are no direct benefits to you other than research credit

Are subjects paid or given anything for being in the study?

Each participant who completes both the survey and experimental parts will receive 10 research credit hours (credit for 1 hour for the survey, credit for 9 hours for the naturalistic study) that may be applied to participating undergraduate courses. Extra credit for the participation in this study may not be guaranteed. Your instructor has the final discretion for awarding extra credit.

6. Study Costs

Will I be charged anything for participating in this study?

You will not be charged anything for your participation in this study

7. Confidentiality

What happens to the information collected?

All information collected about you during the course of this study will be kept confidential to the extent permitted by law. We may decide to present what we find to others, or publish our results in scientific journals or at scientific conferences. Information that identifies you personally will not be released without your written permission. Only Dr. Fleming and his research team will have access to the information.

However, the Institutional Review Board at UW-Milwaukee or appropriate federal agencies like the Office for Human Research Protections may review your records.

You will be identified by your name and phone number which you provided on the online survey. You will also be given an anonymous identification number which will be used to label further information and data. Your name and phone number will not be written on any document from this laboratory study.

All information will be stored in a locked cabinet in a restricted access room in Pearse B-78 at UWM. Any digitized data will be stored on a double-password protected computer. All information will be handled and analyzed in Pearse B-78. All information collected from this study will be kept for 2 years, and then will be destroyed. The only instance where your information will be disclosed is if there is suspected threat to self or others. In this instance, the appropriate authorities will be notified to ensure your or others safety.

8. Alternatives

Are there alternatives to participating in the study?

There are no known alternatives available to you other than not taking part in this study.

Other studies in the Psychology Department at UWM may be available where you could be awarded research credit for your participation.

9. Voluntary Participation and Withdrawal

What happens if I decide not to be in this study?

Your participation in this study is entirely voluntary. You may choose not to take part in this study. If you decide to take part, you can change your mind later and withdraw from the study. You are free to not answer any questions or withdraw at any time. Your decision will not change any present or future relationships with the University of Wisconsin Milwaukee.

If you decide to withdraw or if you are withdrawn from the study before it ends, we destroy all data up to that point.

Refusal to participate in this study will not affect your grade or class standing.

10. Questions

Who do I contact for questions about this study?

For more information about the study or the study procedures or treatments, or to withdraw from the study, contact:

Dr. Raymond Fleming
Psychology Department
224 Garland Hall
2441 E. Hartford Ave.
Milwaukee, WI 53211
414-229-3980

Who do I contact for questions about my rights or complaints towards my treatment as a research subject?

The Institutional Review Board may ask your name, but all complaints are kept in confidence.

Institutional Review Board
Human Research Protection Program
Department of University Safety and Assurances
University of Wisconsin – Milwaukee
P.O. Box 413
Milwaukee, WI 53201
(414) 229-3173

11. Signatures

Research Subject's Consent to Participate in Research:

To voluntarily agree to take part in this study, you must sign on the line below. If you choose to take part in this study, you may withdraw at any time. You are not giving up any of your legal rights by signing this form. Your signature below indicates that you have read or had read to you this entire consent form, including the risks and benefits, and have had all of your questions answered, and that you are 18 years of age or older.

____

Printed Name of Subject/ Legally Authorized Representative

____ _____________________

Signature of Subject/Legally Authorized Representative Date

Principal Investigator (or Designee)

I have given this research subject information on the study that is accurate and sufficient for the subject to fully understand the nature, risks and benefits of the study.

____ ____________________

Printed Name of Person Obtaining Consent | Study Role

____ ____________________

Signature of Person Obtaining Consent | Date

Appendix D

Beck Anxiety Inventory

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

BDI

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 the PAST WEEK, INCLUDING TODAY! Check the statement you pick. If several statements in the group seem to apply equally well, check each one. **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 any more.
   [ ] 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.

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 now than I ever am.
[ ] 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.
[ ] l 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

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. Although some of the questions are similar, there are differences between them and you should treat each one as a separate question. That is, don't try to count up the number of times you felt a particular way, but rather indicate the alternative that seems like a reasonable estimate.

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 dealt successfully with irritating life hassles?

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

5. In the last month, how often have you felt that you were effectively coping with important changes that were occurring in your life?

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

6. 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

7. 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

8. 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

9. 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

10. 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

11. 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

12. In the last month, how often have you found yourself thinking about things that you have to accomplish?

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

13. In the last month, how often have you been able to control the way you spend your time?

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

14. 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.____

Appendix H

Cardiovascular Health History Questionnaire

Please answer the following questions about your cardiovascular health, possible medications you are currently taking, and the history of cardiovascular health in your family, and your fitness level. 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 CARDIOVASDULAR 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, indicate 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, indicate 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 (please, circle all that apply and write who this family member is, e.g., sister/brother/aunt/uncle, etc.):
   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, indicate the name of this disease)_____________________________ (*Family member:*_____________________)
   i. NONE OF MY RELATIVES HAS 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 per day do you smoke per day?_______________________________
8. How much caffeine/caffeinated beverages have you had TODAY?
    a. How many cups of coffee have you had today?__________________________________
    b. What is the amount of coke have you had today?_________________________________
    c. Please, list other caffeinated beverages/foods you have had today____
9. How much caffeine/caffeinated beverages do you USUALLY consume per day?
    a. How many cups of coffee do you have per day?__________________________________
    b. What is the amount of coke you have per day?_________________________________
    c. Please, list other caffeinated beverages/foods you may have during the day____

Appendix I

Physical Activity Affect Scale

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

0 1 2 3 4
Do Not Feel Strongly **Feel Very**

1. Energetic ________
2. Peaceful ________
3. Tired ________
4. Miserable ________
5. Calm ________
6. Enthusiastic ________
7. Fatigued ________
8. Relaxed ________
9. Worn-Out ________
10. Discouraged ________
11. Upbeat ________
12. Crummy ________

Appendix J

	Runners	Controls	Diff.
Gender	70% female	70% female	$X^2(1, N=20)=0.00, p=1.00$
Ethnicity	90% Caucasian	70% Caucasian	$X^2(3, N=20)=2.25, p=.52$
Age	22.6 years	20.5 years	$X^2(8, N=20)=9.00, p=.34$

Table 1: Demographic differences between runners and controls.

Appendix K

Measure		F	Sig.	η_p^2
Heart Rate	Day	4.05	0.06	0.18
	Interval	0.08	0.98	0.01
	Running	1.67	0.21	0.09
RMSSD	Day	0.63	0.44	0.03
	Interval	0.94	0.45	0.05
	Running	0.08	0.78	0.00
NN50	Day	1.06	0.32	0.06
	Interval	.32	.86	0.02
	Running	0.10	0.76	0.01
pNN50	Day	1.58	0.23	0.22
	Interval	0.12	0.97	0.01
	Running	0.04	0.95	0.00
LFms	Day	0.38	0.55	0.02
	Interval	0.82	0.52	0.04
	Running	0.08	0.78	0.00
HFms	Day	0.02	0.90	0.00
	Interval	1.21	0.31	0.06
	Running	1.07	0.31	0.06
LFnu	Day	1.54	0.23	0.08
	Interval	0.84	0.50	0.05
	Running	0.72	0.41	0.04
HFnu	Day	1.59	0.22	0.08
	Interval	0.83	0.51	0.04
	Running	0.69	0.41	0.04

Table 2: Omnibus F-tests for main effects of physiological variables.

Appendix L

Measure		F	Sig.	η_p^2
Heart Rate	Day*Run	1.81	0.19	0.09
	Interval*Run	0.60	0.66	0.03
	Day*Interval	0.63	0.65	0.03
	Day*Interval*Run	0.85	0.50	0.05
RMSSD	Day*Run	0.08	0.78	0.00
	Interval*Run	0.48	0.75	0.03
	Day*Interval	0.46	0.76	0.03
	Day*Interval*Run	1.14	0.35	0.06
NN50	Day*Run	1.05	0.32	0.06
	Interval*Run	0.24	0.92	0.01
	Day*Interval	0.63	0.64	0.03
	Day*Interval*Run	1.28	0.29	0.07
pNN50	Day*Run	1.24	0.28	0.07
	Interval*Run	0.31	0.87	0.01
	Day*Interval	0.43	0.78	0.02
	Day*Interval*Run	1.17	0.33	0.06
LFms	Day*Run	0.04	0.84	0.00
	Interval*Run	0.91	0.46	0.05
	Day*Interval	0.33	0.86	0.02
	Day*Interval*Run	0.77	0.54	0.04
HFms	Day*Run	0.00	0.96	0.00
	Interval*Run	1.33	0.26	0.07
	Day*Interval	0.65	0.63	0.03
	Day*Interval*Run	0.59	0.67	0.03
LFnu	Day*Run	0.20	0.66	0.01
	Interval*Run	0.24	0.92	0.01
	Day*Interval	0.99	0.42	0.05
	Day*Interval*Run	1.41	0.24	0.07
HFnu	Day*Run	0.19	0.67	0.01
	Interval*Run	0.27	0.89	0.02
	Day*Interval	0.99	0.42	0.05
	Day*Interval*Run	1.39	0.25	0.07

Table 3: Omnibus F-tests for interaction effects of physiological variables.

Appendix M

		Mean Problems Completed	Mean Percent Correct
Runners	Running Day	135.4	98.6
	Rest Day	121.8	98.2
Controls	Running Day	111.7	98.9
	Rest Day	122.0	99.2

Table 4: Mean performances on the math task.

Appendix N

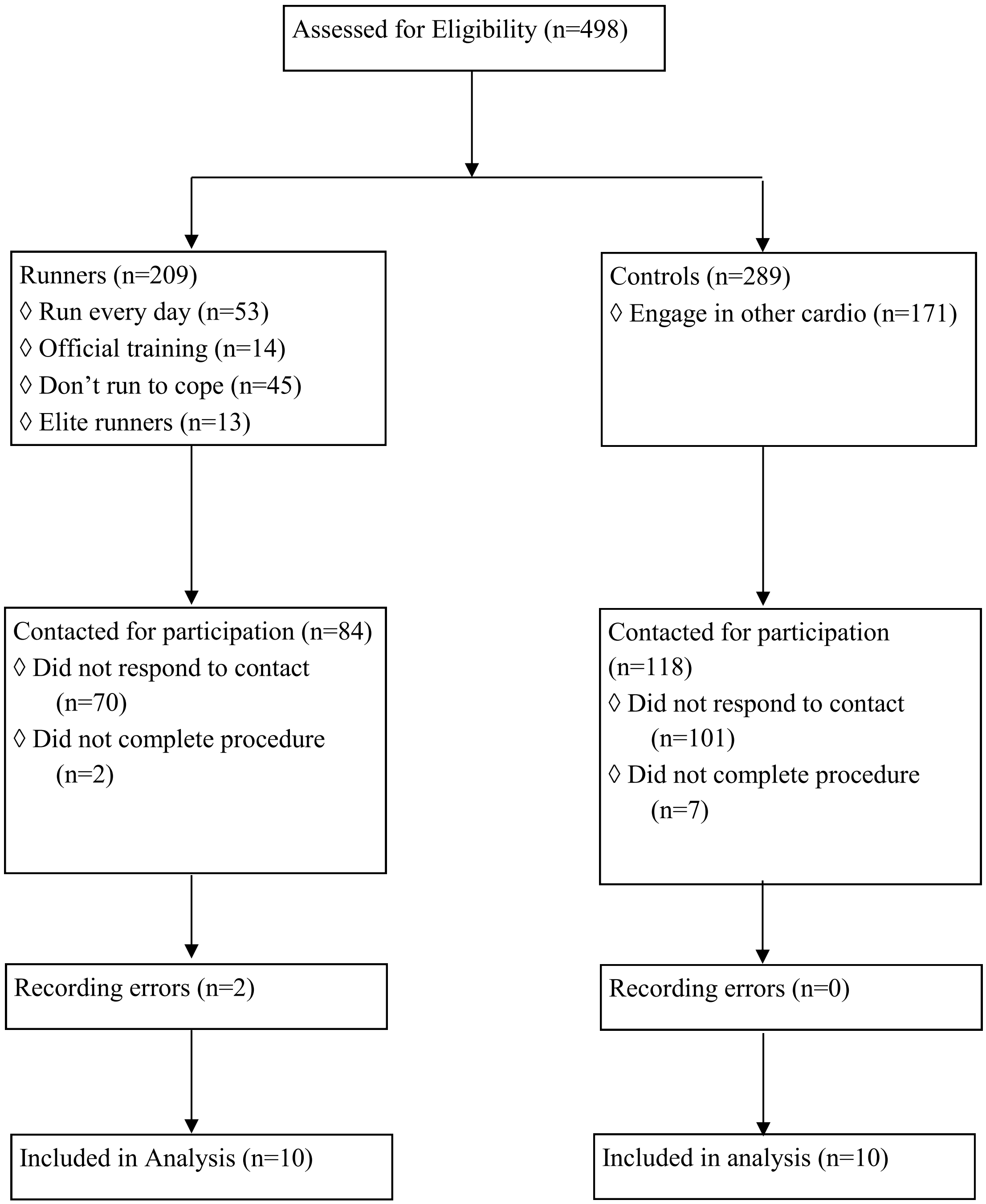

Figure 1: CONSORT table of included participants.

Appendix O

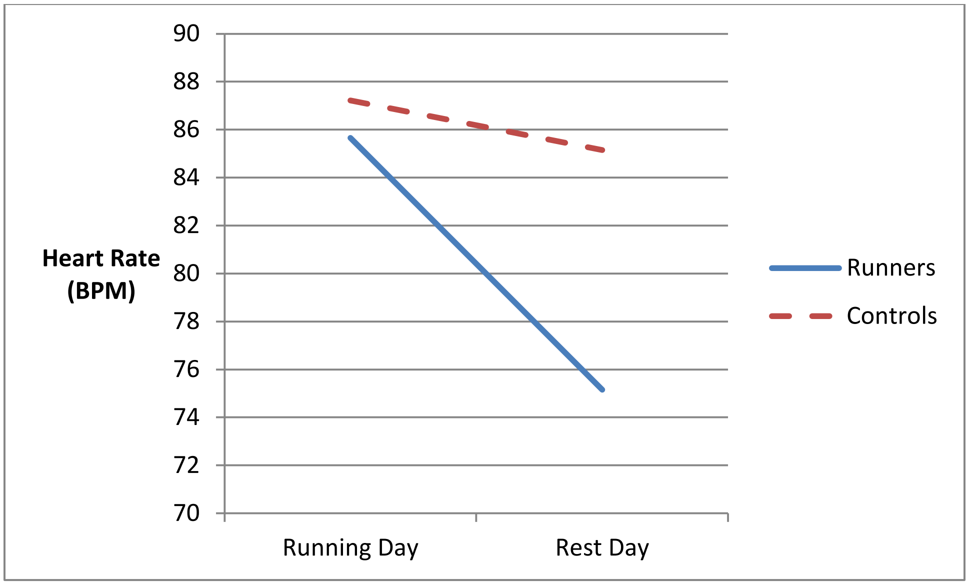

Figure 2: Average heart rate for day by running group.

Appendix P

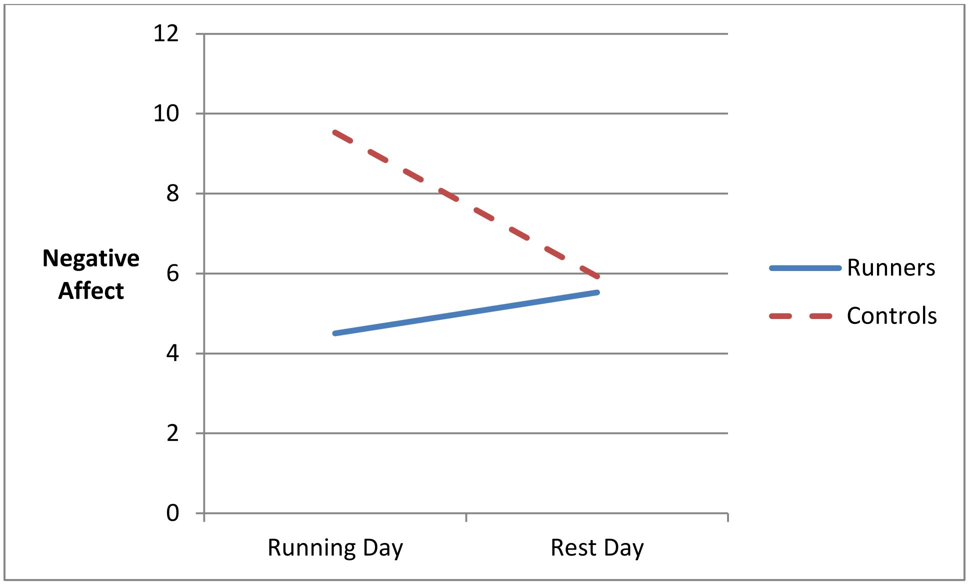

Figure 3: Average negative affect for day by running group.

Appendix Q

Figure 4: Math problems completed for day by running group.

Curriculum Vitae

Molly A. O'Connor

Education

University of Wisconsin-Milwaukee, Milwaukee, WI
Ph.D., Psychology
Major: Experimental Health and Social Psychology — May 2014
Minors: Quantitative Methods, Psychopathology
Dissertation*: Short-Term Changes in Responses to Stress in Runners*

M.S., Psychology — May 2011
Thesis: *The Desired-Exerted Control Relationship in Stressful Situations*

University of Minnesota-Duluth, Duluth, MN
B.A.Sc., Psychology — May 2008
B.A., Spanish, *cum laude*

Honors and Awards

University of Wisconsin-Milwaukee Graduate Student Travel Award — May 2012
University of Minnesota-Duluth Honors Program — 2004-2008
University of Minnesota-Duluth Undergraduate Research Opportunities Program Grant — 2007

Teaching Experience

Associate Lecturer for Psych 205, Personality — Spring 2014
University of Wisconsin-Milwaukee, Milwaukee, WI
- Prepared and led discussion of topics in personality theory
- Developed learning assessments and assignments
- Managed and organized discussion sections and teaching assistants

Associate Lecturer for Psych 101, Introduction to Psychology — Spring 2012, Fall 2013
University of Wisconsin-Milwaukee, Milwaukee, WI
- Provided overview and discussion of basic theories and research topics in psychology
- Developed learning assessments and assignments
- Facilitated learning with in-class demonstrations and supplemental online assignments

Associate Lecturer for Psych 230, Social Psychology — Fall 2012, Spring 2013
University of Wisconsin-Milwaukee, Milwaukee, WI
- Prepared and led discussion of topics in social psychology
- Developed learning assessments and assignments
- Managed and organized discussion sections and teaching assistants

Teaching Assistant for Psych 610, Experimental Design Spring 2011-2014
University of Wisconsin-Milwaukee, Milwaukee, WI
- Prepared and led discussion sections for graduate and undergraduate students
- Instructed students in advanced statistics, multiple linear regression, logistic regression, and factor analysis
- Instructed students in statistical packaging software (SPSS)
- Taught statistics through the lens of psychology research methods

Teaching Assistant for Psych 510, Advanced Psychological Statistics Fall 2010-2013
University of Wisconsin-Milwaukee, Milwaukee, WI
- Prepared and led discussion sections for graduate and undergraduate students
- Instructed students in basic and advanced statistics, sampling theory, and psychological testing procedures
- Instructed students in statistical packaging software (SPSS)
- Taught statistics through the lens of psychology research methods

Teaching Assistant for Psych 230, Social Psychology Spring 2010
University of Wisconsin-Milwaukee, Milwaukee, WI
- Prepared and led discussion sections for graduate and undergraduate students
- Instructed students in topics and theories in social psychology

Teaching Assistant for Psych 205, Introduction to Personality 2008-2009
University of Wisconsin-Milwaukee, Milwaukee, WI
- Prepared and led discussion sections for graduate and undergraduate students
- Instructed students in topics and theories in personality psychology

Teaching Assistant for Psychological Statistics
University of Minnesota Duluth, Duluth, Minnesota 2007-2008
- Provided assistance for students in introductory psychological statistics
- Proctored and graded class exams

Research Experience

ASPCA Statistical Consultant, Milwaukee, WI
- Analyzed existing data set using cat behavior in shelters to predict cat behavior in homes
- Assessed shortened version of feline personality questionnaire compared to previous long version for differences in predictability and utility
- Provided statistical outputs and interpretation for future publication of findings

Undergraduate Research Opportunities Program, Duluth, MN
- Funding received from University of Minnesota
- Examined link between personality and likelihood to seek psychotherapy
- Presented at the 2008 National Conference for Undergraduate Research in Salisbury, Maryland

Americorps, Duluth, MN

- Year-long internship
- Worked with existing database examining link between mentoring and child's behavior
- Results used to update questionnaire given to children in program

SDT Research Group, Duluth, MN

- Examined self-determination theory and its link to training for marathons
- Presented at the 2008 Midwestern Psychological Association Conference in Chicago, Illinois

Publications

Under Review

Fleming, R., O'Connor, M., Nakajima, M., & Stearns, S. (2014). Effects of architectural layout on neighborhood satisfaction. *Manuscript submitted for publication.*

Toussaint, L., Lange, L., O'Connor, M., Nakajima, M., & Fleming, R. (2014). Control-oriented coping buffers stress responses in evacuees from a technological accident. *Manuscript submitted for publication.*

Presentations

O'Connor, M., Stojanovic, M., Smith, O., & Fleming, R. (2012, May). Predictions of neighborhood satisfaction. *Poster presented at the 2012 Convention of the Midwestern Psychological Association, Chicago, IL.*

Shoji, K., O'Connor, M., & Fleming, R. (2012, May). Indirect effects of coping strategies with hypothetical stressful events on PTSD symptoms. *Poster presented at the 24th Annual Convention of the Association for Psychological Science, Chicago, IL.*

O'Connor, M., Toussaint, L., Lange, L., Nakajima, M., & Fleming, R. (2010, May). Use of an ipsative scoring method on a measure of coping. *Poster presented at the 2010 Convention of the Midwestern Psychological Association, Chicago, IL.*

O'Connor, M., Weinstein, B., & Fleming, R. (2010, May). Effects of social support on traumatic evacuation stress. *Poster presented at the 2010 Convention of the Midwestern Psychological Association, Chicago, IL.*

LaCaille, L.J., LaCaille, R.A., Prokop, J., Overgaard, S., Cole, C., O'Connor, M. (2008, May). Achievement goals predict motives to run and endurance racing performance. *Poster presented at the 20th Annual Convention of the Association for Psychological Science, Chicago, IL.*

O'Connor, M., Lacaille, L.J. (2008). Coping strategies, personality, and help-seeking behavior. *Poster presented at the 22nd National Conference on Undergraduate Research, Salisbury, MD.*

Professional Affiliations

American Psychological Association		Since 2009
American Psychological Association of Graduate Students		Since 2009
	Campus Representative	2009-2010
Association of Graduate Students in Psychology, UWM		Since 2008
	Secretary	2009-2010
	Treasurer	2010-2011
Association for Psychological Science		Since 2008
Midwestern Psychological Association		Since 2009