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The Benefit of Recreational Physical Activity to Restore Attentional Fatigue: The Effects of Running Intensity Level on Attention Scores

J.C. Norling, Ph.D.
Lyndon State College

Jim Sibthorp, Ph.D.
Yana Suchy, Ph.D.
James C. Hannon, Ph.D., C.S.C.S.
Edward Ruddell, Ph.D.
University of Utah

Abstract

The primary aim of this study was to examine the effects of running intensity level and physical activity level on the recovery of attentional fatigue while controlling for duration, environment, and activity type in a sample of recreational runners. Attention Restoration Theory served as the theoretical frame for the study. Relationships among these and related variables were evaluated at the group level in an experimental, between subjects design. The data allowed hypothesis testing about differences between group means at four levels of intensity: self-regulated, low, high, and comparison to a resting control group on the dependent variable attention. High intensity running restored attention significantly more than the control group. Implications for theory, and recreation research and practice are discussed.

KEYWORDS: Attention, Intensity, Running, Recreation, Restoration, Physical activity

About the authors: **J.C. Norling, Ph.D.**, Lyndon State College, Mountain Recreation Management Department, P.O. Box 919, Lyndonville, VT 05851 | 802-626-6356, jonathan.norling@lyndonstate.edu

Jim Sibthorp, Ph.D., University of Utah, Department of Parks, Recreation, and Tourism, 250 S. 1850 E., RM 200, Salt Lake City, Utah, 84112 | 801-581-5940, jim.sibthorp@health.utah.edu

Yana Suchy, Ph.D., University of Utah, Department of Psychology, 380 S. 1530 E., Rm. 502 Salt Lake City, Utah, 84112-0251 | 801-585-0796, yana.suchy@psych.utah.edu

James C. Hannon, Ph.D., C.S.C.S, University of Utah, Department of Exercise and Sport Science, 250 S. 1850 E. Rm. 206, Salt Lake City, Utah 84112 | Phone: 801-581-7646, Fax: 801-585-3992, james.hannon@hsc.utah.edu

Edward Ruddell, Ph.D., University of Utah, Department of Parks, Recreation, and Tourism, 250 S. 1850 E., RM 300, Salt Lake City, Utah, 84112 | 801-581-8542, edward.ruddell@health.utah.edu

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Introduction

The benefits of physical activity (PA) have gained increasing importance in the parks, recreation, and leisure literature (Gobster, 2005; Henderson & Bialeschki, 2005; Sallis & Linton, 2005). Specifically, the restorative benefits of PA have several positive outcomes that relate to recovery from mental fatigue. For example, research findings suggest that PA can positively influence mood states (Rocheleau, Webster, Bryan, & Frazier, 2004), mental health and anxiety reduction (Paluska & Schwenk, 2000), and brain function (Dustman, Emmerson, & Shearer, 1990). In a sample of college students Misra and McKean (2000) reported that PA has been shown to positively influence cognitive functioning as suggested by improved performance on tests involving response speed and mental flexibility. In addition, higher intensity bouts of cardiovascular PA for 30 minute durations have been shown to improve cognitive control (Hillman, Snook, & Jerome, 2003).

The primary aim of this study was to examine the effect of recreational PA on recovery from attentional fatigue. Attention Restoration Theory (ART) (R. Kaplan, Kaplan, & Brown, 1989) was the theoretical frame for this study. The principles of ART explain why a recreation participant may achieve restoration from mental fatigue. Although ART explains person and environment interactions that can lead to attention restoration, the theory may be broader than its environmental roots and may explain why recreational PA may be an integral source of restorative experiences. Specifically, this study was conducted at a campus recreation center and examined the influence of running intensity level and PA level on attention change while controlling for duration, the running environment, and activity type in a sample of mentally fatigued recreational runners.

Literature Review

The Problem of Directed Attentional Fatigue

The strain of maintaining focused attention coupled with processing many levels of conflicting stimuli can result in compromised attentional processes attributed to directed attentional fatigue (Banich, 2004; S. Kaplan, 1995). Attention restoration is commonly considered a reversal of the effects of directed attentional fatigue caused by sustained concentration over time (R. Kaplan et al., 1989) and allows for increased critical thinking, concentration, and sustained focus on work (S. Kaplan, 2001). University students are required to process multiple stimuli in changing contexts, placing increasing demands on the brain's attentional system (Astin, 1975, 1984; Belch & Gebel, 2001). According to Cimprich (1992a), heightened mental anxiety associated with academic stress has been shown to influence attentional processes related to learning and academic performance. For example, significantly higher levels of stress are apparent after taking exams than during nonexam times in studies with college and medical school students (Chalmers, Blake-Mortimer, & Winefield, 2002; Sivonová, Zitnanová, Hlincíkoá, Škodácek, Trebaticka, & Durackova, 2004). For these reasons, Adlaf, Gliksman, Demers, and Newton-Taylor (2001) suggest that university students may be at high risk for compromised mental well-being due to the rigors of the academic environment.

Attention Restoration Theory

One of the more popular explanations for the reversal of directed attentional fatigue is ART (R. Kaplan et al., 1989). ART has been widely cited in studies that highlight the benefits of the environment to restore directed attentional fatigue and to achieve mental restoration (Banich, 2004; Hartig, Kaiser, & Bowler, 2001; Hartig, Mang, & Evans, 1991; R. Kaplan, 2001; S. Kaplan, 1995). Fundamentally, this theory posits that environments with perceived restorative qualities may provide a medium through which a person's attention is shifted from volitionally and intentionally focused attention to a more relaxed involuntary attention. Such a shift allows the brain to relax and rejuvenate. Although not specifically addressed by current ART research, recreational PA pursuits might be naturally rich with psychological nutriments necessary for restorative experiences. ART suggests that there are four necessary properties that an environment must provide for restored attention to occur. These include *being away* (cognitive distance and disengagement from stimuli causing attentional fatigue), *fascination* (a shift from voluntary to involuntary attention), *extent* (connectedness and scope leading to the experience of a whole other world), and *compatibility* (goal alignment and environmentally supportive conditions). The environmental psychology literature suggests that spending time within and/or viewing environments that are perceived as restorative can influence stress reduction (Ulrich, 1993; Ulrich et al., 1991) and restore attentional capacity (Hartig, Kaiser, & Bowler, 2001; Kaplan, 2001; Kaplan, et al., 1989; Kaplan, 1995b). While likely an important factor, researchers have not focused specifically on the effect of recreational PA to reverse directed attentional fatigue. In this study the aforementioned ART properties were not manipulated in the experimental design, however, the theory was used as a conceptual framework towards an explanation regarding how differences in running intensity level influenced attention restoration. Therefore, to isolate the effect of running intensity level the running environment was held constant.

Physical Activity Level and Attention Restoration

The importance of PA with regard to health benefits has been well documented. For instance, participation in regular PA has been associated with lower mortality rates, decreased risk of developing heart disease and diabetes, and improved mental health (CDC, 2007). A review of the leisure-related PA literature suggests that recreational PA may support attention restoration, as noted be ART, by helping a participant disengage from attention fatiguing stimuli leading to improved mental wellness. For example, activities considered recreation have been related to decreased tension and greater energy (Heywood, 1978). Specifically, recreational PA considered leisure has been shown to reduce stress and enhance well-being, and has been described as a coping mechanism to deal with daily hassles (Heintzman & Mannell, 2003; Henderson & Bialeschki, 2005; Iso-Ahola, 1999; Iwasaki, Mackay, & Mactavish, 2006).

In response to the need for PA standards, the American College of Sports Medicine (ACSM) and the American Heart Association (AHA) released an updated joint position stand outlining the type of PA and PA level required to promote and maintain health. Specifically, the recommendation stated that all healthy adults

aged 18-65 years old need moderate-intensity aerobic PA for a minimum of 30 minutes on five days each week or vigorous-intensity aerobic PA for a minimum of 20 minutes on three days each week (Haskell et al., 2007). Level of PA can be calculated as a MET (metabolic equivalent unit) minutes per week. METs have been shown to be reliable and valid ways to classify energy costs (Ainsworth, Haskell, Leon, Jacobs, Montoye, Sallis, 1993).

It is important to note that PA level is considered a different construct than fitness level, but that one may be considered an indicator of the other. For example, in a longitudinal study conducted over 25 years, in participants ages 13-27, Kemper (2006) noted that a 10% difference in the MET-score was positively related to a 0.3% difference in VO2max. The present research draws a clear distinction between the two constructs and measures and tests only PA level.

PA Intensity Level and Attention Restoration

The health benefit of attention restoration due to PA should depend on PA intensity level, which may either facilitate or negate the properties of ART. For instance, some research finding suggest that more vigorous bouts of aerobic exercise are required for improved cognition (Etnier, Salazar, Landers, Petruzzello, Han, & Nowell, 1997; Powers & Howley, 2004). In addition, Hillman and colleagues (2003) found moderate to vigorous levels of PA intensity improved cognitive functioning using attentional executive control tasks and comparing neuroelectric and behavioral performance at baseline with post exercise performance. Other research findings suggest high intensity exercise facilitates cognitive reaction time (Hogervorst, Riedel, Jeukendrup, & Jolles, 1996; Tomporowski, 2003).

However, some studies have suggested that higher levels of PA intensity have been shown to increase anxiety, as is the case during maximal exercise testing, and can decrease cognitive performance (O'Connor, Petruzzello, Kubitz, & Robinson, 1995). Lower intensity physical activities, such as walking, have been shown to improve mood and cognition (Ekkekakis, Hall, VanLanduyt, & Petruzello, 2000; Ekkekakis & Petruzzello, 1999; Potter & Keeling, 2005). Szabo (2003) suggested that self regulation of workload is a key variable in restorative PA outcomes, and not due to extrinsically imposed and arbitrarily determined levels of PA intensity and duration in contrived laboratory contexts. Alternatively, the restorative effects of PA might not be so evident depending on the presence of confounding variables, including fitness level and PA level (Heckler & Croce, 1992; Simonsick, 2003; Tomporowski, 2003), and the duration of the PA (Grego, Collardeau, Vallier, Delignieres, & Brisswalter, 2004).

Research Purpose and Hypotheses

Despite alternative explanations for attention restoration attributed to PA participation, we believe that PA intensity level will evoke the necessary properties of a restorative experience as suggested by ART, and thus, PA intensity level should be related to the restoration of fatigued attention. Therefore, the purpose of this study was to examine the influence of running intensity level and the moderating effect of PA level on attention restoration while holding constant duration (30 minutes), environment (the CRC indoor running track), and activity type (run-

ning) in a sample of mentally fatigued, recreational runners. The following hypotheses were tested: (1) Running will facilitate attention restoration more than a resting control group, and (2) Running intensity level will facilitate attention restoration depending on PA level.

Methods

Sample

Healthy, college age, recreational runners between the ages of 18 and 30 were recruited for this study. Flyers were placed around campus and at the CRC. Recreational runners were defined as those participants who described that they ran and/or participated in aerobic PA as a leisure pursuit, or form of recreation or exercise, at least three times a week. To adjust for error associated with the sample a between subject design and random assignment to running intensity level groups were implemented. The sample consisted of recreational runners (N = 121). The average age was 24.08 (SD = 3.46), consisting of 60 females (49.6%), and 61 males (50.4%). All data were collected between the dates of June 5th - July 6th, 2007. Participants opted for a choice of testing times that were 2 hours in duration, within five specified time blocks, and between the hours of 7:30 a.m. and 7:30 p.m.

The converted IPAQ (2001) scores were used as a measure of PA level. The IPAQ was selected due to costs associated with the study and ease of administration. Forty-one participants met the medium active standard (33.9%), 80 participants met the highly active standard (66.1%), and no participants in this sample met the low activity category. Participants who participated in the 2-hour testing were given a $20 gift card to a local sporting goods store.

Setting

All running interventions were conducted at the CRC 200 meter indoor, oval running track (7 1/2 laps equals one mile) located on the upper level of the facility, with open, balcony views of amenities on the lower level, including free and circuit weights, cardio machines, two indoor tennis courts, and basketball court. The choice to use the CRC indoor running track over an outdoor setting was made to best assess the effect of PA intensity level. The indoor environment more easily controlled for possible confounds that would be associated with the outdoor setting, for example, temperature, rain, snow, sun, insects, terrain, tread conditions, air quality, traffic, noise, the presence of animals and humans, and other potential nuisances.

All pretesting and posttesting occurred at the CRC in a racquetball court, upstairs from the indoor running track. A participant lounge area was located at the entrance to the main fitness area and provided several sofas, a television, and views of the recreation facility; this lounge area was used for the control group.

Procedures

Study procedures included filling out a questionnaire designed to gather demographic information about the sample, undergoing a mentally fatiguing task, a pretest measure of attention, systematic assignment to one of the intervention groups, and a posttest measure of attention. Attention restoration was measured

by pretest and posttest attention scores.

Before pretesting attention, participants were mentally fatigued for approximately 30 minutes. Fatiguing tasks included filling out a questionnaire (discussed in the measurement section), taking part in a demanding computer generated switching task (approximately 15 minutes) on DirectRT Precision Timing Software (version 2.0.25), and completing a 5-minute practice session to familiarize participants with the measure of attention (Conner's Continuous Performance Test II; Conners, 2000). Next, the pretest of attention was administered.

Following the CPT II pretest recreational runners were systematically assigned (randomly started systematic assignment) to one of three running intensity groups with differing heart rate (HR) intensity zones calculated by percentages of heart rate max (HRmax) defined as low, high, or a self-regulated (undefined zone), or assigned to a control group (resting HR). The duration was fixed to 30 minutes for all participants.

After the pretest, the researcher administered the intensity intervention consisting of one of the four manipulations of intensity. The researcher fit the participant with a Polar, Inc. heart rate monitor (HRM) pre-set to the specified HR zone with the alarm set to beep if the HR went above or below that range. In the case of the control group and the self-regulated running intervention, the HRM was not set for a specific zone, the alarm was turned off, and HR averages were determined for the 30-minute duration. HRMs were randomly assigned to each participant.

Following the intervention, the researcher allowed the participant to cool down for approximately 5 minutes and return to a resting HR. While the participant was cooling down the researcher asked one interview question regarding rate of perceived exertion. The HRM was removed from the participant and the heart beats per minute data were recorded.

The posttest was then administered. The posttest took 15 minutes to complete. Concluding the posttest the participants were debriefed and a gift certificate issued in thanks for participation.

Measurement

The Connors Continuous Performance Test II. Attention was measured by the Conners' Continuous Performance Test II (CPT II; Conners, 2000), which provides an objective, performance-based index of several aspects of attention. The CPT-II has been standardized and has excellent psychometric properties (Connors, 2000, 2003), and has been extensively validated as a measure of sustained attention (Greenberg & Waldman, 1993; Lin, Hsiao, & Chen, 1999; Riccio, Reynolds, Lowe & Moore, 2002; Miranda et al., 2008).

The CPT II test is taken while seated at computer. Letters are presented rapidly, one at a time, within specific time blocks. CPT II respondents are required to press the space bar or click the mouse whenever any letter except the letter 'X' appears on the computer screen. The inter-stimulus intervals (ISIs) are 1, 2 and 4 seconds with a display time of 250 milliseconds. The unique CPT paradigm is a test structure consisting of 6 blocks and 3 sub-blocks, each containing 20 trials (letter presentations). The presentation order of the different ISIs varies between blocks.

The CPT II obtains scores on 12 separate variables that make up the three dimensions of attention (inattention, impulsivity, and vigilance). The inattention variables consist of: number of omissions, commissions, hit reaction time, hit reaction time standard error, variability, detectability, hit reaction time, interstimulus change, and hit standard error inter stimulus change (Conners, 2000). The researchers in the present study used a composite dependent variable—inattention change—by calculating the difference between pretest and posttest composite T-scores. Given the systematic assignment any differences in these change scores should be attributable to the assigned level of running intensity.

International Physical Activity Questionnaire. At the beginning of each testing session date, time, air temperature, HRmax, HR zones, HR average were recorded. A pretest questionnaire was administered to collect demographic data (age and gender) and PA level using the last seven days, self-report International Physical Activity Questionnaire (IPAQ, 2001). The scoring protocol to determine a continuous score for the IPAQ-short form is expressed as a MET (metabolic equivalent unit) minutes per week (Ainsworth, Haskell, Leon, Jacobs, Montoye, Sallis, 1993). For purposes of this study the data were converted to a three level categorical variable using IPAQ guidelines (IPAQ, 2005). The IPAQ was selected because it provided an easily administered and non-invasive indicator of PA level.

Rate of Perceived Exertion Scale. The Rate of Perceived Exertion Scale (RPE; Borg, 1998) was administered at the conclusion of each running or control group intervention to assess rate of participant's perceived exertion level and was used as a validity check on the running intensity levels.

Running Intensity Level. Running intensity level was operationalized as heart rate level. HR was controlled for and measured by the Polar Vantage XL HR Monitor. Prior to the study the HRMs were recalibrated by Polar, Inc. A total of five HRMs were used during the study, and assigned randomly to the participants. HRmax was derived from the following equation: [208 - (0.7 x age)] (Tanaka, Monahan, & Seals, 2001). Following the specified intervention the HR data were recorded to determine each participant's average HR and percentage HRmax for each of the manipulated interventions. Running intensity had four levels (1) participant self-regulated intensity (2) low intensity (60-70% HRmax), (3) high intensity (81-90% HRmax), and (4) control group (resting HR while sitting in the CRC lounge area). Low and high training zones are suggested levels of HR intensity based on percentages of HRmax determined by Sleamaker and Browning (1996).

Design

A between subjects, experimental design was used. The following hypotheses were tested: (1) Running will facilitate attention restoration more than a resting control group, and (2) Running intensity level will facilitate attention restoration depending on PA level. The sample size for the study was 121; approximately 30 participants per cell. Hypothesis one was tested with a planned comparison of means which analyzed contrasts between running groups (self-regulated + low + high intensity heart rate intensities) versus the control group. Hypothesis two was tested with an *F* test using two-way ANOVA. The variables were heart rate intensity level and PA level. The manipulated variable was HR intensity level. PA

level was operationalized as a three level categorical variable (as specified by IPAQ, 2005) and included in the ANOVA procedure to test for an interaction effect between heart rate intensity level (hypothesis two). In other words, it was thought that the influence of HR intensity on attention restoration might depend on the PA level of the participant. Group means and standard deviations were calculated, as were the effect size statistics for partial eta squared (η^2).

Inclusion Criterion

Participant's data that were outside the designated HR zone more than 20% of the time were excluded from the analysis. The exclusion criterion was determined by the participant's HR average for the duration of the intervention, to be calculated from the start of the 6th minute to the end of the 30th minute, to equal 25 minutes. The average did not include the first 5 minutes of running to allow for the participant's HR to reach the specified zone. All study participants met this inclusion criterion.

Decision to use Inattention Change Score as Dependent Variable

This study assessed attention restoration (inattention change) by the difference between pretest and posttest change scores on the CPT II. Inattention change had an overall positive change (M=1.82, SD=3.76). However, the validity of the inattention change scores to appropriately represent degree of attention restoration was based on the effectiveness of the systematic assignment of participant to group to balance the inherent individual difference among the groups. The effectiveness of the systematic assignment was assessed through comparing the inattention pretest scores by group using an ANOVA. The assigned group was *not* a significant predictor of pretest scores (p<.05), thus utilization of the change score from pretest to posttest to represent degree of attention restoration seemed appropriate.

Results

Preliminary Data Analysis

The data were cleaned and screened according to the procedures noted by Tabachnik and Fidell (2001). First, univariate outliers were assessed for the CPT II variable used as the dependent variable – inattention change. In accordance with Tabachnik and Fidell (2001) z-scores in excess of 3.29 (p < .001, two tailed test) were assessed as potential outliers - one univariate outlier was identified. Upon further examination this participant was found to have both the highest HR average (192.36 beats per minute) and the highest percentage of HRmax (99%) for the entire sample. Based on conceptual and statistical criteria this participant's inattention change score was removed from further analysis.

HR data were collected for a running duration equal to 30 minutes, and the HR data were then analyzed from minutes 6-30. Notably, the high intensity running group mean showed the highest HR mean (M=166.09, SD=3.78) followed closely by the self-regulated group (M=165.20, SD=14.34). The two groups were within .89 heart beats per minute for the duration of the testing; however, the

self-regulated intensity group had a larger standard deviation (14.34) versus the high intensity group (*SD*=3.78). The low intensity mean was 127.71 (*SD*=3.28), followed by the control group mean of 61.73 (*SD*=9.79).

The Rate of Perceived Exertion (RPE; scale range 6-20) by intensity group means were similar between the high intensity group (*M*=13.5, *SD*=1.36) and the self-regulated group (*M*=13.38, *SD*=1.45), followed by the low intensity group (*M*=9.84, *SD*=1.51), and lastly, the control group (*M*=6.13, *SD*=0.35).

Hypotheses Testing

Before hypothesis tests using ANOVA the homogeneity of variance assumption was evaluated using Levene's procedure, and the assumption of normality was evaluated by examination of the distribution of the dependent variable, both overall and within groups.

The following hypotheses were tested: (1) Running will facilitate attention restoration more than a resting control group, and (2) Running intensity level will facilitate attention restoration depending on PA level.

A planned comparison of means failed to support the hypothesis test that running had a significantly higher group mean score than the control group (hypothesis 1). The test statistic was *not* significant ($F(1,115)=2.797$, $p=.097$), and the standard error was .775.

To test hypothesis two, a two-way ANOVA was run. The interaction between PA level and HR intensity level was not significant. The main effect of PA level was not significant. However, ANOVA results (Table 1) indicated a significant main effect between heart rate intensity level and attention change. The $F(3,112)=3.24$ was statistically significant ($p=.025$). The partial eta squared value (.08) suggested a very small effect size, and the observed power was .731. As displayed in Table 2 all intensity levels influenced positive CPT II inattention change scores. The high intensity group had the highest average inattention change improvement (*M*=3.36, *SD*=4.16), followed by the self-regulated group (*M*=1.81, *SD*=3.40), the low intensity group (*M*=1.27, *SD*=3.96), and the control group (*M*=.83, *SD*=3.80).

A Tukey post hoc multiple comparison of means revealed significant ($p=.044$) mean differences between high running intensity and the control group (2.531), but not between high intensity and self-regulated or low intensity groups. There were not statistically significant mean differences between the self-regulated group mean and low, high, or the control group means. There were not statistically

Table 1: ANOVA Results: Intensity, PA Category, and Inattention Change

Between Subjects	Sum of Squares	MS	*df*	*F*	*p*
Intensity	132.16	44.05	3	3.24	.025*
PA Category	13.40	13.4	1	.98	
PA Category x Intensity	35.21	11.74	3	.86	
Error	1525.09	13.62	112		

* p<.05
Note: For Intensity Partial eta squared =.08; Power = .731
Change score is the difference between the pretest and posttest score on the CPT II inattention measure.

Table 2: Inattention Change Means by Intensity Groupe

Intensity Level	N	Mean	*SD*
Low	31	1.27	3.96
High	30	3.36	4.16
Self-Regulated	29	1.81	3.40
Control	30	.83	3.11
Total	120	1.82	3.80

*Inattention Change represents the difference between the pretest and posttest score on the CPT II; Positive change scores indicate improved performance.

significant mean differences between the low group mean and the self-regulated, high, or the control group means.

Discussion

This study examined the effect of recreational PA on the reversal of attentional fatigue. Attention Restoration Theory (ART; R. Kaplan et al., 1989) served as the theoretical frame for the study. Specifically, the role of HR intensity and the moderating effect of PA level were examined while controlling for a 30-minute duration, a CRC indoor running track environment, and running activity type in a sample of mentally fatigued recreational runners. The following hypotheses were tested: (1) Running will facilitate attention restoration more than a resting control group, and (2) Running intensity level will facilitate attention restoration depending on PA level.

The results of the present study indicated that high intensity running significantly restored attention more than the control group. Running overall (low, high, and self regulated groups together) did *not* significantly restore attention more than the control group.

Implications for Attention Restoration Theory

The principles of Attention Restoration Theory (ART; R. Kaplan et al., 1989) explain why a participant may achieve restoration from mental fatigue. Although ART explains person and environment interactions that can lead to attention restoration, the theory may be broader than its' environmental roots and may explain why recreational PA may be an integral component of restorative experiences. ART suggests that participants, first, must be fascinated (ART property - *fascination*) enough with an environment that they switch from directed, focused attention to a state of involuntary attention. This shift is necessary for the individual to get away from mentally fatiguing stimuli and described by ART as *being away*. Another dimension of ART is *extent*. From a restorative environments perspective *extent* suggests that a landscape or scene would need to have scope, legibility, and hang together in a way that might lead the viewer into a whole other world experience. The last ART dimension is *compatibility* that suggests a person by environment goal compatibility match.

When considering the ART properties, *goal compatibility* may have been a reason high intensity runners experienced the highest levels of attention restoration. Specifically, in the present study, participants wore HRMs to control for intensity, and both high and low running groups were asked to stay within a specified HR zone. Higher intensity running may have provided a goal match with a relatively fit sample, whereas resting in the CRC lounge may not have matched participant recreational PA expectations.

Consistent with ART's *being away* property the high intensity runners may have escaped mentally fatiguing thoughts that lead to attention restoration. The *being away* experience may have been related to running in a desired and controlled higher intensity zone that was compatible with their running goals for this one-time study. If the HR zone was compatible with the runners desired intensity then the runners may have used less "associative thinking" (Goode & Roth, 1993), or attention focused on maintaining a pace, and more "dissociative thoughts," or thoughts associated with surroundings or wandering thoughts. If so, the *fascination* property of ART may have been engaged.

Why the self-regulated group did not achieve significantly different results than the control group may have been related to the wide range of HR means not seen in the low and high controlled HR zones. Participants were not instructed to run for any specific purpose, including attention restoration. Allowed to self-regulate the PA experience, runner's individual goals may have contributed to the running intensity level they choose – for example, to obtain a good workout and not attention restoration. Consequently, some self regulated runners did intervals (speeded up and slowed down), or sprinted at the end of the run, while others appeared to run at a more relaxed and consistent pace. This phenomenon resulted in fluctuations of HR intensity within a set duration. These issues may have effected attention restoration.

Low intensity runners, however, described frustration with running at too slow a pace or reported that their HRM zone was too low to run at a consistent pace. These runners were forced to alternate between walking and running to stay within the range. Consequently, they may have been referring to their HRM more than self-regulated or high intensity runners. For low intensity runners, the goal incompatibility coupled with voluntary attentional focus on the HRM may have contributed to less attention restoration than self-regulated or high intensity running groups.

College Students and the Reversal of Attentional Fatigue

The findings that higher intensity running, at a controlled HR zone, for a 30-minute duration restored attention more than the control group is important for college students and may be considered a strategy to reverse the effects of attentional fatigue. College student are required to synthesize and integrate complex concepts which activate the frontal areas of the brain. Posner and colleagues (Posner, 1992; Posner, Badgaiyan, Parks, Levine, & Long, 1998) found that during tasks requiring understanding concepts, meaning, awareness, and planning for action, the frontal network is engaged. Over time attentional fatigue may result and can lead to diminished cognitive functioning (McClain, 1983; Parasuraman, Warm, & See, 2000).

Although high intensity running may restore attention at controlled durations other physiological variables may influence restored attention and could interact with running intensity level. Aerobic PA, such as running, has been shown to increase blood supply, oxygen, neurotransmitters (acytelcholine) and hormones (epinephrine, and norepinphrine) that are involved with brain function and cognitive processes (Dustman et al., 1990; Tomporowski, 2003). A neurotransmitter is a chemical that is used to relay, amplify and modulate electrical signals between a neuron and another cell. For example, low levels of noradrenaline are related to the likelihood of errors during target searches in continuous performance tasks (Aston-Jones, Rajkowski, Kubiak, & Alexinsky, 1994). Furthermore, Coull, Middleton, Robbins, and Sahakian (1995) found that clonidine has been shown to decrease sustained attention, increase attentional lapses, and impair visual information processing. Lastly, although untested in this study, the effects of repeated daily doses of high intensity running efforts could lead to increased fatigue and could influence attention restoration results. Therefore, the combination of physiological and psychological factor may each aid in the reversal of directed attention fatigue and further research could isolate and control for such factors.

Limitations

Limitations existed within the study, including the operationalization of PA level, reliability of the measures, and sample size. The self-report, last 7-days, International Physical Activity Questionnaire (IPAQ, 2001) was used as a measure of PA level. The IPAQ (2005) guidelines for data processing were used to transform data into a categorical variable with three levels (low, medium, and high). The sample of recreational runners did not have any participants in the low category, resulting in a PA variable with only two levels (medium and high). PA level was assessed as a moderating variable - no significant interaction or main effect were found. Therefore, the nonsignificant interaction with PA level may have been due to several reasons: (a) a statistically, nonsignificant effect due to lack of variability across the three IPAQ (2001) levels, (b) the IPAQ is a self report measure and PA level may have been inaccurately assessed by participants, (c) measurement of the CPT II inattention variable was inaccurate, or (d) a combination of these or other factors.

Measurement limitations may have existed with the CPT II (Conners, 2000). The CPT II has not appeared in the PA literature and may be considered a useful measurement option. Further testing using the CPT II will offer greater insight regarding the usefulness of the measure.

The sample size for the study may have also had an impact on results. There were 121 participants in the sample consisting of a nearly equal number of males and females systematically assigned to three running interventions and a control group. A power analysis was conducted prior to testing suggesting that a sample of 120 would offer power above .80. Notably, significant one-way ANOVA results for intensity on inattention change offered a small partial eta squared effect size and power just below .80. Therefore, increasing sample size is suggested.

Implications for Future Leisure Research

The significant results of intensity on inattention change using the CPT II as a measurement tool suggests a number of interesting possibilities for future research. First, further using the CPT II in PA research may address reliability and validity concerns with this measurement tool in exercise and recreation contexts. While controlling for extraneous confounds the stability of the inattention variable can be assessed further.

The experimental design used age predicted specified HR zones based on the formulae of Tanaka and colleagues (2001) and controlled intensity with an HR monitor. To more precisely determine HRmax, future studies could determine participant fitness VO_2max and/or HRmax derived from treadmill testing (Gant, Williams, King, & Hodge, 2004; Glaister, 2005).

Although not measured in this research, operationalizing and measuring fitness level might offer additional findings about the interaction of fitness level with intensity level on attentional recovery. For example, participants with higher fitness levels have been show to perform better on a number of different measures of attention and executive function (Kramer, Colcombe, McAuley, Scalf, & Erickson, 2005). Alternatively, Hall, Ekkekakis, and Petruzzello's (2005) findings suggest that when a participant can no longer maintain a physiological steady state, due to approaching VO2max or lactate threshold, other metabolic factors can influence cognition in a negative way. In other words, low and high levels of fitness may influence both psychological and metabolic response to a constant workload.

A number of confounding variables may have influenced the results and could be controlled for and analyzed as predictors, such as level of hydration (Doppelmayr, Finkernagel, & Doppelmayr, 2005; Grego et al., 2005), measuring the presence of blood lactate (Glaister, 2005; Seiler & Sjursen, 2004), and controlling for the effects of caffeine (Laurent et al., 2000).

Although duration was held constant at 30 minutes, future research could look at the effects of different durations along with intensity levels to determine possible interactions between these variables.

Further consideration of the mentally fatiguing task issued to the participants before the pretesting is warranted. A review of the PA literature suggests that inducing mental fatigue prior to pretesting has not been previously explored. In the present study, using DirectRT software and a switching task may have contributed to increased attentional fatigue. Thus, the participants may have been taking the pretest of attention at a somewhat fatigued state. However, another speculation is that the participants were exposed to too many attentional tasks. By the time participants took the CPT II posttest they had been screened, filled out a pretest questionnaire, briefed on the study, taken the mentally fatiguing switching task, the CPT II pretest, been briefed on the HRM and the running intervention, run at a specified HR zone, completed two post run interview question, and then took the CPT II posttest. Therefore, the necessity of the mentally fatiguing task could be questioned as an additional confound, and could have contributed to the small effect size.

Potential studies could manipulate the environmental setting. The context of the present study was an indoor running track; however, some research has indicated that mood improves while running in outdoor and park settings (Bodin & Hartig, 2003; Butryn & Furst, 2003). Others have suggested that simply spending time in a natural environment can restore attention (Hartig et al., 1991; S. Kaplan, 1995, 2001). Recent recreation and leisure research indicates a growing interest in the study of PA with specific focus on the attributes of park environments that may facilitate increases in PA (Bedimo-Rung, Gustat, Tompkins, Rice, & Thomson, 2006; Brownson, Hoehner, Brennan, Cook, Elliott, & McMullen, 2004; Burton, Turrell, Oldenburg, & Sallis, 2005). Therefore, implementing a control group, at resting HR, in a restorative natural setting could offer additional insight about the influence of green environments.

As informed by ART, PA goals need to be compatible with the expectancies of the participants. For instance, the low intensity running did not contribute to significantly different results versus the control group and may have been a function of mismatched goal expectancy. Importantly, for the individual who is involved with recreational PA programming it would be inaccurate to suggest that low or self-regulated intensities do not have any benefit – inattention change scores improved for both groups in this study, but not significantly so versus the control. However, the results do indicate that a vigorous, high intensity run, at a controlled HR zone, for 30 minutes, facilitated attention restoration and may have provided a better challenge-skill match. Thus, practitioners should be aware of participants' goal expectancies and needs.

In conclusion, the attentionally fatigued college student may improve attentional processes via participation in acute bouts of running at a vigorous intensity level within a controlled HR zone. The findings from the present study suggest that recreational PA in a campus recreation center setting, depending on intensity and duration, may provide physiological and psychological nutriments that both excite and refresh the brain that may lead to improved attentional performance.

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