Effect of Acute Exercise on Cognitive Function

Katherine Low, Davielle Shelman, & Ashley White

Thursday 1:00-5:00 pm

Alexandra McFarland

Abstract:

Physical exercise has numerous benefits to the human body (Radak et al., 2001). Experimenters hypothesized that short bouts of aerobic exercise would have a positive effect on cognitive function. The Stroop Test was used to measure cognitive performance. For the experimental group, the test was administered before and after 5 min of aerobic exercise at or above 60% of maximum heart rate, and for the control group, where no exercise was performed, tests were given consecutively. The mean difference in time (sec) to complete the Stroop test for the experimental group was 5.389 sec (with outlier) and 5.704 sec (without outlier) as compared to the control group, whose mean difference was 5.1 sec. The results indicated that there was no statistical significance in the average difference in Stroop Test completion times between the control and experimental groups. In conclusion, further research is needed to determine if short bouts of exercise have an effect on cognitive function.

Introduction:

Significance:

The effects of acute exercise on cognitive function are important for the athletic and military communities, where reaction time and decision making are closely tied to effectiveness and overall performance. Acute physical activity could affect the mental processes of athletes on the field, as well as the decisions of military personal (Brisswalter et al., 2002; Lieberman et al., 2005). For example, military findings have determined that exercise decreases the affects of stress in military personal, and physical fitness overall increases the chances of mission success due to both physical and psychological preparedness (Thomas et al., 2004). Findings could be used to determine ways to improve cognitive function for both groups or to look into the source of error and deterioration of performance.

Literature Review:

It is well known that exercise has many positive benefits such as, an improved self image, enhanced social skills, and alleviated symptoms of depression and Alzheimer's disease (Colcombe & Kramer 2003; Radak et al., 2001; Taylor et al., 1985). It has also served as a favorable adjunct for alcoholism and substance abuse programs (Taylor et al., 1985).

Similarly, the connection between cognitive function and exercise is not a new interest. For many years, the idea that better long term cognitive function is related to physical activity levels has encouraged many to engage in healthy lifestyle practices (Scarmeas & Stern, 2003). It has been found that improved cognitive ability is yet another positive attribute of endurance training (Taylor et al., 1985; Colcombe & Kramer 2003; Etnier et al. 1997; Brisswalter et al., 2002). For instance, aerobically trained individuals scored higher than sedentary subjects on a variety of cognitive tasks (Colcombe & Kramer 2003; Brisswalter et al., 2002).

In another example, Weuve, et al. (2004) began a long-term study in 1986 to monitor the leisure activities for a group of mature women who regularly performed cognitive assessments to determine progress or presence of cognitive decline. This study showed that there were marked improvements in cognitive function for those groups with higher activity levels. In addition, a meta-analysis conducted at Wake Forest University looked at over 176 different studies and concluded that there was in fact a small correlation between activity level and cognition, although the strongest correlation was linked to a general fitness level as opposed to a chronic exercise regimen or acute bouts of exercise (Etnier et al., 2007).

In contrast, Emery et al. (2003) performed an experiment on cardiac rehabilitation patients who combined exercise with music to improve cognitive performance, specifically verbal fluency. In this study, only those who were exposed to music in addition to their exercise showed improvement. Again in contrast, Churchill et al. (2002) argued that although positive correlation has been found in a number of studies researching the benefit of aerobic exercise, the cross-sectional nature of such studies and their inability to address other factors, such as nutrition and lifestyle, makes them unreliable. However, Churchill et al. (2002) do not argue that a beneficial relationship exists between aerobic exercise and cognitive functioning.

A relationship between acute exercise and cognitive function has also been investigated as a result of the connections between long-term exercise programs and cognitive function. A review of the literature done by Brisswalter et al. (2002) has discovered negative, positive, as well as no relationship at all between exercise and cognitive function. This diverse array of results is most likely due to the variety of exercises used and the mixture of cognitive tasks (Brisswalter et al., 2002). Positive benefits are explained by an activation of the central nervous system, with the hypothesis that exercise induced physical arousal leads to a narrowing in mental focus (Magnie et al., 2000).

An additional study by Sibley, et al. (2006) looked at the effects of an acute bout of exercise on cognitive aspects of the Stroop performance. The subjects consisted of 76 college age students, 39 male and 37 female between the ages of 19-35, who comprised both the experimental and control groups. The experimental participants performed self-paced aerobic exercise for 20 minutes by running on a treadmill while the control group participants were provided with reading material so that both groups had a 20 minute interval between testing. After the 20 minute interval both groups immediately took the Stoop test in a quiet, secluded room. The Stroop test calls into effect different cognitive processing theories such as the maintenance of goal-oriented processing theory and inhibition which are both used to overcome interference or the susceptibility to performance deterioration under conditions of multiple distracting stimuli. This study found that exercise may facilitate cognitive performance by improving the maintenance of goal oriented processing in the brain. Overall, it has been found that acute exercise has an inverted U-effect on the performance of a cognitive test (Brisswalter et al., 2002).

Hypothesis:

Based on previous research, we anticipated that there would be similar improved outcomes in cognitive performance for those that participated in the short-term exercise session prior to the Stroop Test. Low, Shelman, and White expected that the experimental group would have a smaller mean time difference, approximately 5 seconds less, between Stroop Test 1 and 2 than those in the control group therefore exhibiting higher cognitive function as a result of exercise participation.

Methods and Materials:

Experimenters acquired 40 volunteers between the ages of 18 and 29, by randomly selecting students in the Western Washington Biology Building, to determine the effect of exercise on completion of cognitive exercises. Each subject was called in individually and randomly assigned to either the control group or the experimental group. The control subjects were then read a script (*Fig.1*) by the proctor in a quiet, secluded room and asked to complete a timed (sec), simple cognitive exercise (demonstrating Stroop Effect).

The Stroop Effect (*Fig. 3*), named for its creator J. Ridley Stroop (Chudler, 2006), is a test where participants are told to name the color of the word as opposed to reading the word itself (which will also be a color). For example if the word "BLUE" is printed in red ink, participants should then say "RED" (*Fig. 2)*.

Script for Test Giving

1.) Right now we are going to give you a short test. Your results will be kept anonymous, so there is no pressure. However, please attempt to do your best, as your results will influence our experiment.
2.) For this test you are required to say the color of the word, not what the word says. For example, for the word this word (show flashcard of the word red colored blue) you should say "Blue." (*Fig. 2*)
3.) You will be timed for this test.
4.) You will be given this test two times.
5.) The two tests will vary slightly, just remember to say the color of the word, not necessarily read the word out loud.
6.) Leave no mistakes uncorrected.

Are there any questions?

Let's begin…

Note to test giver:

Each subject should be given one sentence of encouragement at the end of each test, "Good job/Great job/Good work" are all appropriate phrases.

Talk slowly and clearly.

Figure 1: Script read by experiment proctors to test subjects prior to participating in the Stroop Test

Figure 2: Pre-test shown to participants to clarify how to do the Stroop Test. In this case participants were expected to say "Red".

Figure 3: The Stroop Effect displayed on a computer screen in front of participants to test cognitive function

The Stroop Effect was used to determine cognitive function because it is closely tied to two cognitive theories: the speed of processing theory and the selective attention theory. The speed of processing theory operates on the idea that interference occurs when naming the color because the word is read faster than the color named. The selective attention theory focuses on the premise that it take more attention to focus on the color and avoid reading the word. This experiment has also been used in a large number of other studies and therefore has a strong background in testing cognitive function (Young, 2007).

Experimental subjects were called in and read the same script in a quiet, secluded room as the control subjects with a small variance explaining their participation in exercise before the second portion of the test. These subjects were asked to use the sitting bike to complete 5 minutes of aerobic exercise (no less than 60% of maximum heart rate maintained) immediately after taking Stroop Test 1 and immediately prior to completing Stroop Test 2. The 60% heart rate value was calculated by using the Fox and Haskell equation (Finn, 2001). These subjects were also timed.

In this experiment, the independent/causative variable was participation in exercise and the dependent/outcome variable was average difference in time (in seconds) taken to complete the cognitive exercise. Final data was found by subtracting the initial Stroop Test 1 time (sec) from the secondary Stroop Test 2 time (sec) and averaged. These values were compared using an independent t-test assuming equal variance, where statistically significant findings will have a P-value of less than 0.05. Experimenters hypothesized that the experimental group (those persons participating in the exercise prior to cognitive test) would have smaller difference in test completion times than the control group.

Table 1: Independent T-test comparing mean time (sec) for difference between Stroop Test 1 and Test 2 for Control and Experimental Groups

t-Test: Two-Sample Assuming Equal Variances

	CNTRL	EXPER
Mean	5.1	5.389
Variance	31.68947	20.32453
Observations	20	20
P(T<=t) two-tail	0.858728	

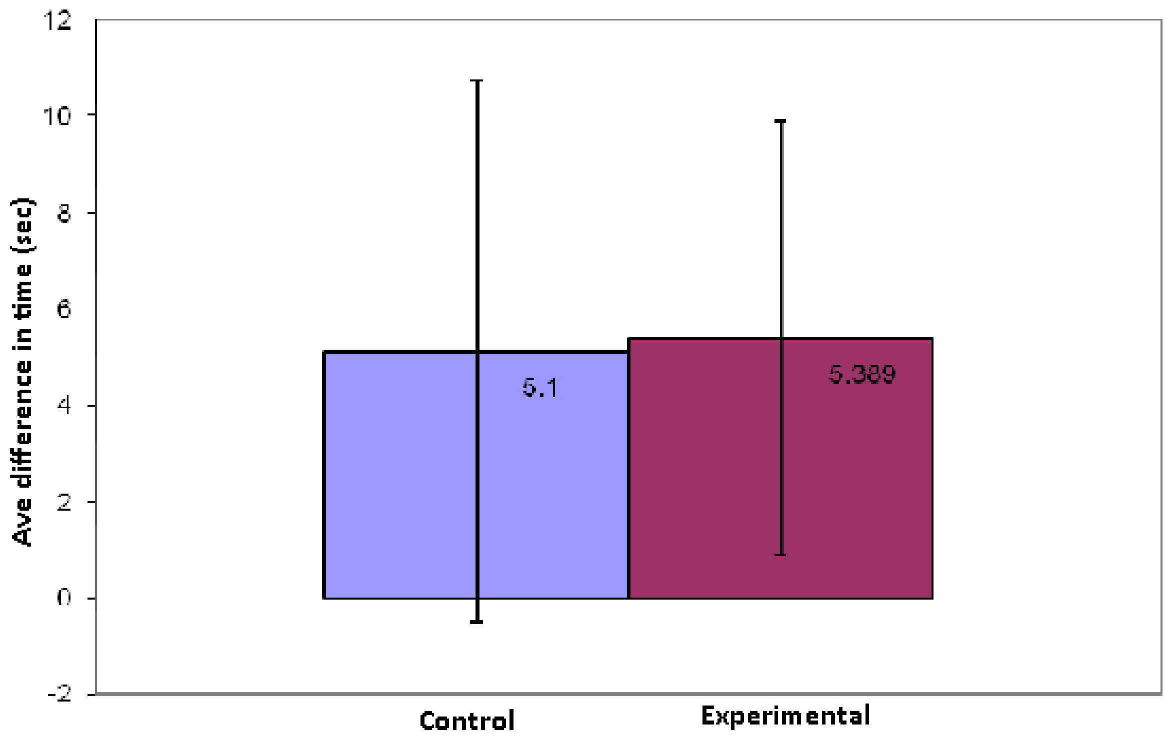

Figure 4: Graph comparing mean time (sec) difference between Stroop Test 1 and Test 2 for the Control and Experimental Groups

Table 2: Independent T-test comparing mean time (sec) difference between Stroop Test 1 and Test 2 for Control and Experimental Groups without outlier

t-Test: Two-Sample Assuming Equal Variances

	CNTRL	*EXPER*
Mean	5.1	5.704211
Variance	31.68947	19.35611
Observations	20	19
P(T<=t) two-tail	0.711934	

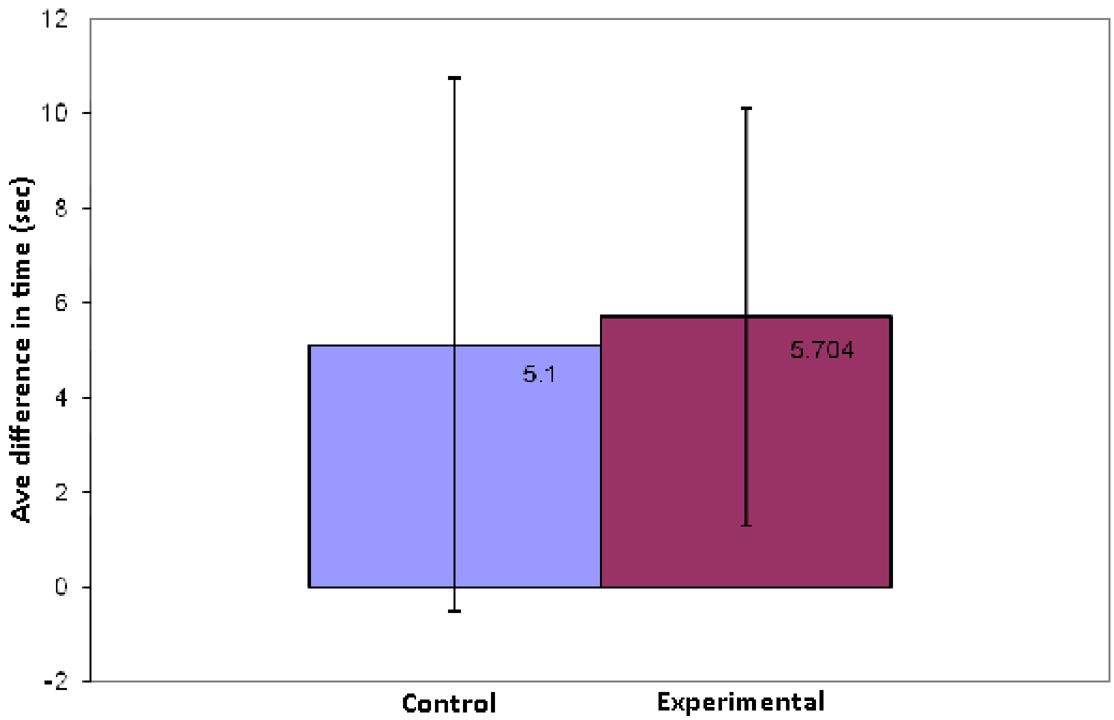

Figure 5: Graph comparing mean time (sec) difference between Stroop Test 1 and Test 2 for the Control and Experimental Groups without outlier

The mean time difference for the control group was 5.1 sec, while the experimental group was 5.398 (with outlier) (*Fig. 4)* and 5.704 (without outlier) (*Fig. 5)* with both independent T-Test P-values at numbers greater than 0.05 (*See Tables 1 &2)*

Low, White, & Shelman hypothesized that the experimental group (participants that performed exercise in between Stroop: Test 1 and 2) would have a smaller mean time difference (sec) than the control group (participants who did not exercise and took the tests consecutively).

Discussion:

The results of this experiment proved that there was no significant difference in mean time in seconds between both subject groups (*Fig. 4 & 5).* Both Independent T-Test P-values were significantly greater than 0.05 (Tables 1 & 2) and therefore, according to this study there was no relationship between acute bouts of aerobic exercise and cognitive function.

The results of this study do not correlate with those results found in the Sibley, et al. (2006) study. The study done by Sibley, et al. (2006) found that there is indeed a connection between goal-oriented processing and exercise which is particularly interesting because of its similarities to the study conducted in this paper. The different outcome could be attributed to small differences in experimental procedures such as interval wait time for the control group.

In addition, Magnie et al. (2000) found that acute exercise also had a positive effect on brain responses that are the results of thought or perception, known as P300 and N400. In their study, both N400 and P300 amplitude increases, following a bout of maximal exercise (Magnie et al., 2000). However, in looking at a review of the literature, they state that the relationship between exercise and cognitive function has not yet been clarified and further long term studies are needed (Brisswalter et al., 2002 & Magnie et al., 2000).

Because the Stroop Test deals with the speed of processing theory and selective attention theory those participants with learning disabilities, specifically dyslexia, will not experience the same Stroop Effect. Figure 4 and Table 1 address the statistical comparisons between the experimental and control group with the outlier, a dyslexic participant, and therefore have a less significant difference, whereas, Figure 5 and Table 2 exclude the outlier.

Sources of Error:

As with any research experiment, error is inevitable. Sources of error for this experiment included; subject's behavior during the Stroop Test, differences in holding the heart rate monitor, and controlling for wait time. While taking the second part of the Stroop Test, some of the subjects would squint in order to only see the color of the word and not the word itself, therefore, decreasing the overall Stroop Effect. Keeping the heart rate monitor uniform across all subjects was also difficult because many participants, at times, allowed their arms to slump away from the heart rate detector making it hard to detect the correct heart rate. Another error that occurred with the heart rate detector was that subjects held the hand grips in slightly different fashions, some being more effective than others. Lastly, the amount of time between taking Stroop Test 1 and 2 was not controlled for between the experimental and control groups. The experimental group had a five minute cognitive respite while exercising whereas the control subjects were given no break between tests.

Further Research:

For further investigation, experimenters recommend that the Stroop Test be avoided due to its susceptibility to error. The wording of the instructions would also be changed to eliminate the word “test” as a way to alleviate test anxiety, as this would impair their results. Future studies should look into the varying effects of different heart rates, duration of exercise, types of exercise, or addition of rest between exercise and test taking for the experimental group. Further research is needed to fully understand the effects of short bouts of acute exercise on cognitive function.

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