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SELECTIVE ATTENTION IS RESISTANT TO HIGH INTENSITY EXERCISE AND MUSICAL DISTRACTION

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Abstract: BACKGROUND: The effects of high intensity exercise on cognitive performance are not fully understood. Music can affect physiological responses to exercise which may also impact cognitive performance. The aim of this study was to determine if music could impact cognitive performance after a bout of high intensity exercise. METHODS: Twelve subjects (n=7 males, n=5 females, 20.3 ± 1.7 y; 72.2 ± 14.9 kg; 1.70 ± 0.09 m) completed the Stroop test after a short (12 min) bout of high intensity interval exercise while listening to either Classical, Rock, or No Music. Subjects completed the Brunel Music Rating Inventory after listening to Classical or Rock music during a control (no exercise) session. Order of testing was randomized. RESULTS: There was no significant difference in Stroop effect between musical conditions without exercise (No Music 166.6 ± 118.17 ms; Classical 138.42 ± 86 ms; Rock 139.67 ± 74.47 ms). There was also no significant difference in Stroop effect between musical conditions with exercise (No Music 132.39 ± 88.93 ms; Classical 137.05 ± 61.74 ms; Rock 102.6 ± 83.1 ms). There was also no significant difference in Stroop effect between control and exercise for the different music conditions. There was, however, a significant interaction effect of music and exercise on heart rate response ($p<0.01$), with exercise HR being significantly lower during either music condition (Classical [146.41 ± 12.59ms], Rock [148.92 ± 12.30ms]) than without music (151 ± 16.66ms). CONCLUSIONS: The results of the present study suggest that selective attention is resistant to the effects of a short high intensity interval exercise bout and the distraction of either classical or rock music. The results also suggest that music may lower average heart rate during high intensity interval exercise.

Keywords: High Intensity Interval Training, Stroop, Selective attention

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1. Introduction

During most forms of sporting competition, it is important for the athlete to make split-second decisions while also working at high intensities [12]. The Inverted-U relationship between exercise intensity and cognitive function was initially proposed by Gutin [6]. Researchers have since demonstrated that moderate intensity exercise provides cognitive benefit [11,3,14]. However, when exercise at high intensity is studied, the results are not as uniform [3]. Smith et.al [17] showed that high intensity exercise can slow reaction times and significantly raise omission error and decision error rates when compared to moderate intensity exercise. In contrast, high intensity exercise has been shown to benefit cognitive performance in areas such as selective attention and short term memory tasks [1]. Piepmeier et al. [14] showed little relationship between cognitive performance and exercise intensity. The neuronal mechanisms behind these findings are still not fully understood [11]. In order to elucidate these mechanisms, it has been suggested that future research be highly specific regarding inclusion criteria such as fitness, exercise intensity, and exercise mode in order to create a more consistent testing population between studies [3].

The impact of music on the human body is complex and is still being studied in multiple areas such as psychology, therapy, and performance [7]. Though great strides have been made over the years, the effects of music on the human body and mind are not completely understood. However, notable physiological responses (heart rate, blood volume, skin conductance, muscular tension, etc) have been reported in the literature [7] suggesting that music does have a significant effect on human physiology.

‘Sedative’ music has been defined as music having slower tempi, softer, more legato characteristics. ‘Stimulative’ music is the opposite; fast paced, louder, and wider pitch ranges [7]. These different categories could be broadly applicable to calm classical music and hard rock music. Adjusting these musical characteristics has demonstrated capabilities of influencing individuals’ mood, energy level, or even emotional states [13]. However, due to the complex nature and extreme variation of music itself, some have criticized the “Sedative” and “Stimulative” labels as too vague. This variation in musical characteristics is reflected in the literature, where musical selections for exercise and cognitive performance studies vary considerably in genre, as well as amount of time subjects are exposed to music. Another issue with musical science is the subjective nature of music. Cultural, developmental, biochemical, and musical exposure levels all vary from person to person, so the same song may have different effects not only between two subjects, but potentially even on the same subject over time. These variables make it extremely difficult to tightly control the effect of different music genres on physiological and cognitive responses during high intensity exercise [7].

There is a dearth of research on the effect of music as a potential ergogenic aid that may improve cognitive performance in individuals working at high intensities. There is no consensus on the effect of music on the autonomic nervous system, however there is some evidence of improved nervous system function [5]. Szmedra & Bacharach [19] found music had significant benefits on heart rate, rate pressure product, systolic blood pressure, relative perceived exertion, lactate accumulation, and norepinephrine accumulation after trained athletes completed a submaximal exercise test. While this study analyzed the physiological markers of exercise, the aim of the present study was to determine if music improved or impaired cognitive performance after a bout of high intensity exercise. It was hypothesized that different genres of music would have different effects on cognitive performance. The Stroop Test was used to measure selective attention of the subjects [18]. This test has been associated with frontal lobe activation [4]. This area of the brain can be linked to tasks such as problem solving, motor control, and executive function [4] which are all important for athletic performance.

2. Methods

2.1. Subjects

A convenience sample of 12 undergraduate students completed this study. Subject characteristics are presented in Table 1. Subjects completed a pre-participation survey and provided voluntary informed consent. Ethical approval by the Longwood University Institutional Review Board was obtained prior to the commencement of the study. Volunteers who indicated the presence of cardiovascular disease risk factors/ symptoms or color blindness were excluded. All subjects regularly performed either resistance training or cardiorespiratory training for at least 30 minutes per week. All but one subject listened to music during exercise.

Table 1. Subject characteristics.

Age (y)	20.3 ± 1.7
Weight (kg)	72.2 ± 14.9
Height (m)	1.70 ± 0.09

Note: Data are presented as mean ± SD; n=7 males; n=5 females.

2.2. Protocol and Procedures

The subjects reported to the Exercise Physiology Lab on four separate occasions with a minimum of 24-hours between visits. The initial visit to the lab was a control session which all subjects attended at the same time. During the control session subjects remained seated while listening to each musical selection (no music, sedative, stimulative) for approximately 12 minutes to simulate the amount of time of subsequent workout sessions. After listening to the music condition for the appropriate length of time, the music continued as the subjects completed the Stroop Test online (http://ezyang.com/stroop/) then completed the Brunel Music Rating Inventory (BMRI) [9]. Subjects reported to the lab three more times to complete each exercise condition. Exposure to music conditions was randomized. Exercise sessions consisted of a 12-minute-high intensity interval training workout ("No Equipment HIIT Cardio Home Workout-Quick and Intense HIIT", from the YouTube channel "Fitness Blender") that contained body weight exercises such as push-ups and jumping jacks. The video workout did not have a musical soundtrack; the only sound came from the voice of the instructor and the movements of the instructor on screen. The exercises were simple in nature, could be done with no equipment, and were demonstrated by the instructor, making it easy for the subjects to follow along. Subjects were instructed to complete the workout at their own self-selected interpretation of high intensity.

Heart rate was measured telemetrically (FirstBeat,Jyväskylä, Finland) throughout the workout and Stroop Test. A subject was considered to have reached high-intensity exercise if he or she reached at least 77% of age-predicted maximum heart rate. This stipulation was met in all trials. All subjects were given verbal encouragement during the workout. Directly after the completion of the workout (within 30 seconds) the subjects reported to an assigned laptop and completed the online version of the Stroop test to assess selective attention performance. Briefly, the Stroop test protocol involves a color word flashing randomly on the screen. The color word may not match the color of the word. Subjects are required to identify the color shown rather than read the color word. For example, if the word "yellow" flashed on the screen and it was colored yellow, the correct answer would be yellow. If the word "yellow" flashed again but was colored green, the correct answer would be green. The "R", "G", "Y", and "B" keys on the subject's computer were used to indicate the answer. The test was completed when the subject answered 20 words correctly. No talking was allowed during the Stroop test, however, the musical condition of the session was maintained until all subjects had completed the Stroop Test. All subjects completed the Stroop test within 3 minutes after the completion of the workout. The Stroop effect (ms) can be defined as the difference in response time for matched and mismatched color words and can be attributed to the neural interference upon receiving two different color stimuli [18]. This was presented by the software upon completion of the test. The order of exposure to control (no music), sedative, and stimulative music was randomized.

2.3. Music Selection

The playlists for the sedative and stimulative conditions are presented in Table 2. The order that the music was played was randomized each session using the “Shuffle” command on the music streaming platform. The sedative playlist consisted of all instrumental classical music pieces with low tempos (BPM average = 69.85) and a general calming and smooth timbre. The stimulative playlist (BPM average = 148) was fully composed of instrumental hard rock pieces in order to sonically contrast the legato and consonant nature of the classical music. Subjects completed the BMRI [9] for each music condition during the control session to determine the differences in musical enjoyment between the sedative and stimulative music conditions. Music of both categories was lyric-free on the basis that lyrics have been shown to decrease productivity and concentration [16]. Additionally, no “instrumental” versions of popular songs with lyrics were used. This was to discourage association with lyrics that may have been previously heard by the subjects, and by extension, disallow the subconscious singing of songs while testing. All music was played at a consistent volume.

Table 2. Music playlists

Sedative Music
Je Te Veux (*Eric Satie)*
String Quartet no. 2: Nocturne *(Alexander Borodin)*
Clair De Lune *(Claude Debussy)*

Lacrimosa *(Mozart)*	
Gymnopedie no. 1 *(Eric Satie)*	
Moonlight Sonata - 1st mov. *(Beethoven)*	
Nocturne Opus no. 9 *(Chopin)*	
Als Die Alter Mutter Op 55.4 *(Antonin Dvorak)*	
Stimulative Music	
Thunderhorse *(Dethklok)*	
YYZ *(Rush)*	
The Call of Ktulu *(Metallica)*	
Into the Lungs of Hell *(Megadeth)*	
Psychobilly Freakout *(The Reverend Horton Heat)*	
Eruption *(Van Halen)*	
Soothsayer *(Buckethead)*	

Note: Playlist is presented as Song Title (Musical group or composer).

2.4. Statistical Analysis

Results were analyzed using SPSS 22.0 software (IBM, Armonk, NY), and are presented as means (SD), unless otherwise indicated. A series of 2x3 (exercise x music) repeated measures ANOVAs were conducted to test the significance of within-subjects factors on dependent variables including reaction time on the Stroop Task, as well as Heart Rate Response. Significance was set *a priori* at alpha < 0.05. Where appropriate, *post-hoc* analyses were conducted and Bonferroni adjustments were made to reduce the likelihood of Type II errors.

3. Results

There was no significant difference in Stroop effect between musical conditions with or without exercise (Figure 1). Music condition had no effect on HR at rest (control) or during exercise (Figure 2). Additionally, there was no significant difference between music conditions in mean heart rate response to either rest of exercise in response to music between control and exercise (Figure 2). There was a significant interaction effect of music and exercise on heart rate response ($p<0.01$), with exercise HR being significantly lower during exercise with either sedative or stimulative music. BMRI results showed that most subjects preferred the stimulative compared to the sedative, though many preferred another genre as their top choice. However, BMRI rating had no effect on HR or Stroop effect.

Figure 1. *Stroop Effect between musical conditions with and without exercise*

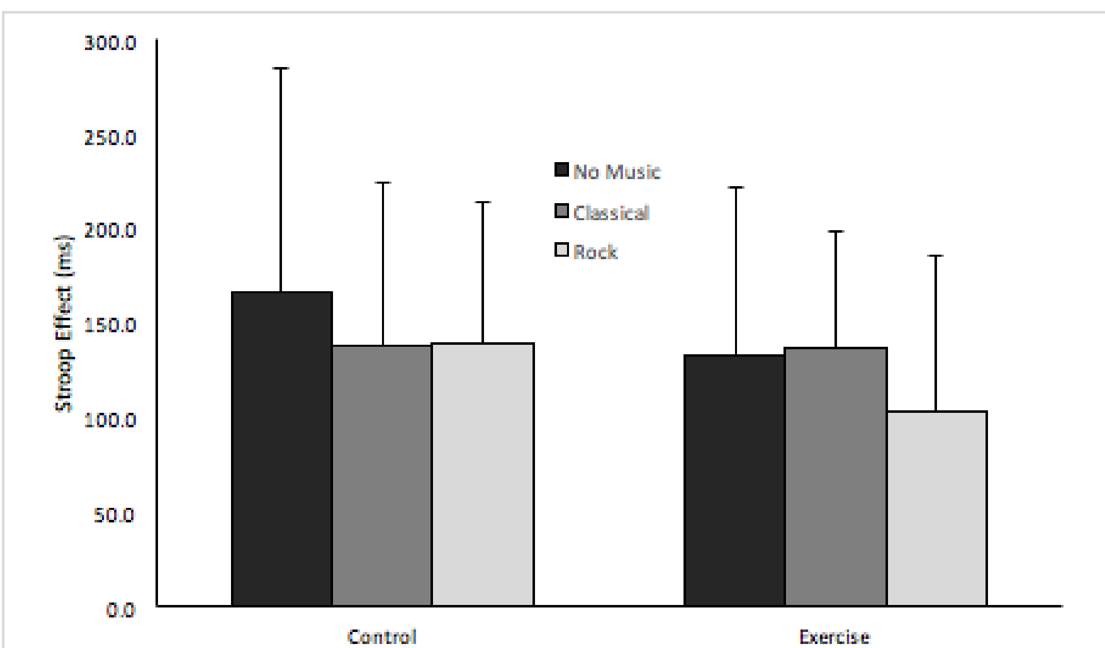
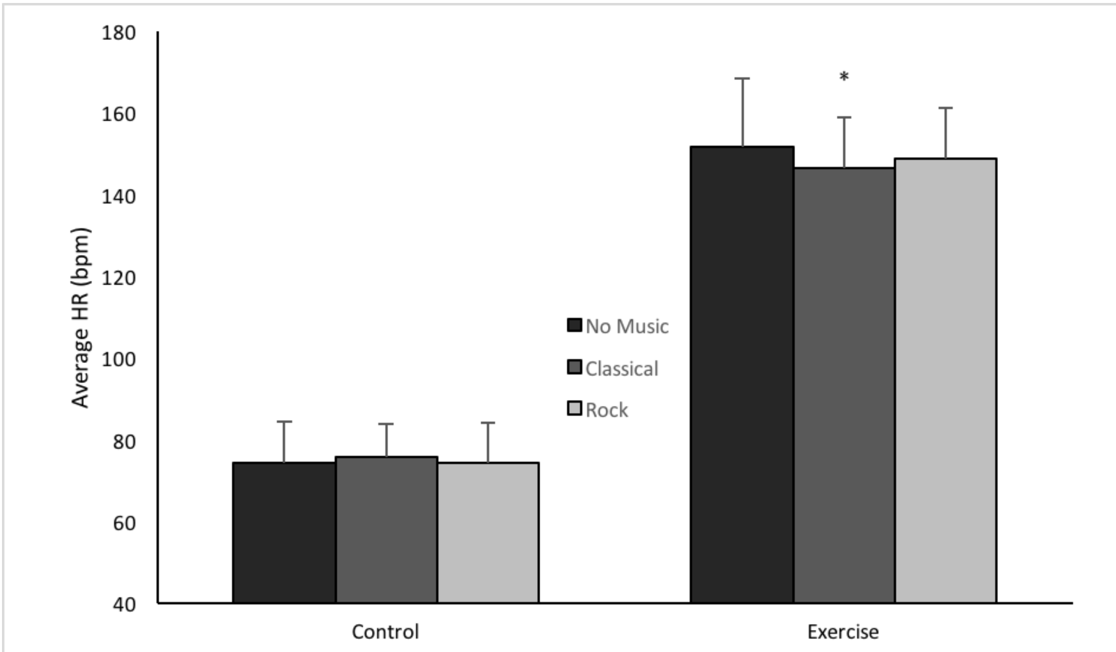


Figure 2. *Average Heart Rate between musical conditions with and without exercise*



4. Discussion

The results of the present study suggest that selective attention is resistant to the effects of a short high intensity interval exercise bout and the distraction of either sedative or stimulative music. The lack of response to the differing musical genre refutes some of the existing literature. Selective attention is more resistant than the researchers initially thought. It was hypothesized that performance on the Stroop task would decrease in the presence of music (especially hectic, hard rock) due to the addition of a distracting auditory stimulus alone. It appears that the music in this study was not enough to impair cognitive performance, at least from the measure of selective attention. Future research should consider this and experiment with new musical variables such as volume, genre, and selection process. The results also suggest that music may lower average heart rate during high intensity interval exercise. This supports the findings of some previous literature [19], though the existing body of work still appears to be divided on the effects of music. If music could be used to lower the heart rate during high intensity exercise performance may be improved due to slower onset of fatigue. However, these results are independent of the neural benefits or detriments of music that could affect motivation or self-efficacy [2].

In previous research involving music and performance, there have been a series of methods for determining the musical selections. The major distinction lies in self-selected vs. non self-selected music. In self-selected trials, subjects choose music that aligned or was opposite to individual preferences. Anaerobic work with preferred vs. non-preferred music has been shown to have motivational benefits, but it remains to be seen if any tangible performance gains can be achieved [2]. A drawback of the self-selected design is that it potentially creates large variation in the type of music each subject is exposed to. In non-self-selected models, the musical dynamics (beats per minute (BPM), timbre, consonance/dissonance) can be controlled. However, the individual preference will almost certainly shift between subjects. Due to the complex and not fully understood relationships between music, exercise performance, and cognitive performance, it is important to consider all of these factors when designing an experiment. In the present study, it was necessary to control each playlist in order to meet the “sedative” or “stimulative” criteria. The sedative playlist consisted of all instrumental classical music pieces with low tempos (BPM average = 69.85) and a general calming and smooth timbre. The stimulative playlist (BPM average = 148) was fully composed of instrumental hard rock pieces in order to sonically contrast the legato and consonant nature of the classical music. The popularity of these musical genres among college students can be called into question. However, the present study was more concerned with presenting two contrasting music genres in order to determine the effects on selective attention. In an effort to determine the differences in musical enjoyment between the two conditions, the subjects completed the Brunel Music Rating Inventory survey [10]. While music preference had no influence on the results of the present study this additional variable may be able to further explain potential cognitive performance enhancements or detriments. Music of both categories was lyric-free on the basis that lyrics have been shown to decrease productivity and concentration [16].

It is worth noting that the Stroop test is by no means a complete measure of cognitive functioning, but rather specifically assesses selective attention. Future research should utilize other cognitive tests in order to obtain a more holistic analysis of cognitive function. Future research should explore other variables such as; self-selected vs non self-selected music, exercise with other media such as podcasts or audiobooks, and different volumes of the auditory stimulus and should incorporate longer and more intense exercise protocols and different exercise modalities. Anecdotal data from two subjects who completed the high intensity interval workout followed by the Stroop test two times in a row showed a substantially larger Stroop effect after the second exercise bout (i.e. identifying the correct color took longer in mismatched color word pairs). This observation suggests that a longer duration of high intensity exercise may have greater negative effects on selective attention. Mechanisms for this effect remain to be elucidated.

Many people enjoy listening to music during exercise. The results of this study suggest that heart rate response to exercise is reduced when listening to music but that music does not affect selective attention. Exercise participants should be able to continue to make rapid decisions in response to changing stimuli while listening to either sedative or stimulative music. The significant lowering of the heart rate in the presence of music regardless of the type may have implications for future research regarding stress, anxiety, cardiac rehabilitation, or human performance.

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