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SELECTIVE ATTENTION IS RESISTANT TO HIGH INTENSITY EXERCISE AND MUSICAL DISTRACTION

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Jones D., et al. The effects of high-intensity exercise on cognitive performance are not fully understood. Music can affect physiological responses to exercise which may also affect cognitive performance. The aim of this study was to determine if music could impact cognitive performance after a bout of high-intensity exercise. Eleven subjects completed the Stroop test after a short (14 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. The order of testing was randomized. There was no significant main effect of either exercise ($F(1,2) = 0.585$, $p = 0.524$) or music ($F(2,4) = 1.939$, $p = 0.258$) on Stroop reaction time, nor was there a significant interaction effect of exercise and music on Stroop reaction time ($F(2,4) = 0.045$, $p = .956$). There was a significant main effect of exercise on heart rate response ($F(1,2) = 564.005$, $p < 0.01$). Mean heart rates were consistently higher during exercise (HRex= 148.2 ± 14.7) than during control sessions (HRcon= 76.1 ± 9.1). There was no other significant main effect for music ($F(2,4) = 2.537$, $p = 0.194$) or interaction effect of music and exercise ($F(2,4) = 2.980$, $p = 0.161$) on heart rate response. 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 the average heart rate during high-intensity interval exercise.

Key Words: high intensity interval training, stroop, selective attention

INTRODUCTION

During most forms of sporting competition, it is important for the athlete to make split-second decisions while also working at high intensities, for example in a soccer match when deciding which teammate to pass to or in a basketball game anticipating jumping into the passing lane to steal the ball (Lemmink & Visscher, 2005). The Inverted-U relationship between exercise intensity and cognitive function was initially proposed by Gutin (1973). Researchers have since demonstrated that moderate intensity exercise provides cognitive benefit (Browne, et al., 2017; Kashihara, Maruyama, Murota & Nakahara, 2009; Piepmeier et al., 2014). However, when exercise at high intensity is studied, the results are not as uniform (Brown, et al., 2017). Smith et al. (2016) argued 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 (Alves et al., 2014). Piepmeier et al. (2014) showed little relationship between cognitive performance and exercise intensity. The neuronal mechanisms behind these findings are still not fully understood (Kashihara et al., 2009). 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 (Brown et al., 2017).

The impact of music on the human body is complex and is still being studied in multiple areas such as psychology, therapy, and performance (Hodges, 2016). 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 (Hodges, 2009) 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 (Hodges, 2016). 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 (Maranto, 1993). 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 (Hodges, 2016). As a result of these variables, it is nearly impossible to completely control music and its effects within a study. An experimenter can either control the musical dynamics by playing the same songs, which would in turn cause each participant to have a unique reaction and opinion to the music. Or the experimenter could allow the participant to select the music within set parameters of enjoyment or motivation levels, which would result in different auditory stimuli between each participant. One must look at each study to determine which method is best for that situation, acknowledging the flaws each would exhibit.

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 (Ellis & Thayer, 2010). Szmedra and Bacharach (1998) 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 the Szmedra and Bacharach (1998) 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 (Stroop, 1935). 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. This test has been used previously to effectively evaluate selective attention after exercise (Alves et al., 2014; Hogervorst, Riedel, Jeukendrup, & Jolles, 1996; Whyte, Gibbons, Kerr & Moran, 2015). This test has been associated with frontal lobe activation (Chayer & Morris, 2001). This area of the brain can be linked to tasks such as problem solving, motor control, and executive function (Chayer & Freedman, 2001) which are all important for athletic performance.

METHODS

Subjects

A convenience sample of 12 undergraduate students completed this study. No power analysis was run, as this was a pilot study that did not have the funding necessary to support a large number of participants. Subject characteristics are presented in Table 1. Subjects completed a pre-participation survey and provided voluntary informed consent. The survey included questions about weekly exercise frequency in days per week (3.166 ± 0.83) and exercise session length in ranges of minutes: 30-45 minutes (n=4), 45-60 minutes (n=2), and >60 minutes (n=6). The total weekly training volume in this study ranged from 30-60 minutes per week up to 360 minutes per week. Additionally, most common type of exercise was surveyed; Resistance training (n=7), Cardiovascular exercise (n=5), or team sports (n=0). 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 their regular exercise outside of this study.

Table 1

Subject Characteristics

Characteristics	*M ± SD*
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.

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 at tables in the lab while listening to each musical selection over the lab speakers (no music, sedative, stimulative) for approximately 12 minutes to simulate the amount of time of subsequent workout sessions. After the appropriate length of musical exposure, the subjects completed the Stroop Test online (http://ezyang.com/stroop/) with the music still playing, as they would go on to do in an exercise session. The subjects then completed the Brunel Music Rating Inventory (BMRI) (Karageorghis, Bigliassi, Guérin & Delevoye-Turrell, 2018). The BMRI is a survey that assesses music affinity for each participant in the form of a Likert scale. Questions regarding the specific rhythm, tempo, genre of music, melody, sound of the instruments, and the beat each musical condition were rated on a Likert scale, with "1" being "not motivating at all for exercise" and "7" being "strongly motivating for exercise". The possible max score was 42. A higher score equates to greater music affinity/preference. Though music preference has still proved difficult to control for, this method has shown promising results (Karageorghis et al., 2018). 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. This workout was chosen specifically because the video did not have a musical soundtrack; the only sound came from the voice of the instructor and the movements of the instructor on screen. This would make it possible to play the music that was specifically selected for the study, which lasted through the entirety of both the workout and the Stroop test (Except during a "no music" session). 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. Due to the variability in training status, subjects were instructed to complete the workout at their own self-selected interpretation of high intensity. Subjects were encouraged to exert maximum energy with subsequent verbal encouragement. Additionally, 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 and surpassed in all trials.

Heart rate was measured telemetrically (FirstBeat Technologies OY, Jyväskylä, Finland) throughout the workout and Stroop Test 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. 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 can be defined as the difference in response time for matched and mismatched color words in milliseconds. For example, if the average response time for matched color word pairs is 50 ms, while the average response time for mismatched color word pairs is 75 ms, the "Stroop Effect" would be 25 ms. This delay can be attributed to the neural interference upon receiving two different color stimuli, and the ability to limit the effect of this interference is called "Selective Attention" (Stroop, 1935). 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.

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. As part of the control session subjects completed the BMRI (Karageorghis et al., 2006) directly after each musical condition concluded in order to determine the differences in musical enjoyment between the sedative and stimulative playlists. Music of both categories was lyric-free on the basis that lyrics have been shown to decrease productivity and concentration (Shih, Huang & Chiang, 2012). 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 of 70 decibels.

Statistical Analysis

Results were analyzed using SPSS 22.0 software (IBM, Armonk, NY), and are presented as mean ± SD. 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.

RESULTS

For all repeated measures ANOVAs conducted, Mauchly's assumption of sphericity was met at $p > 0.05$. Mean Stroop reaction times during exercise with the various music conditions were: No Music 132.39 ± 88.93 ms; Classical 137.05 ± 61.74 ms; Rock 102.6 ± 83.1 ms). Without exercise, reaction times were: No Music 166.6 ± 118.17 ms; Classical 138.42 ± 86 ms; Rock 139.67 ± 74.47 ms. There was no significant main effect of either exercise ($F(1,2) = 0.585$, $p = 0.524$) or music ($F(2,4) = 1.939$, $p = 0.258$) on Stroop reaction time, nor was there a significant interaction effect of exercise and music on Stroop reaction time ($F(2,4) = 0.045$, $p = .956$; Figure 1). There was a significant main effect of exercise on heart rate response ($F(1,2) = 564.005$, $p < 0.01$). Mean heart rates were consistently higher during exercise (HR_{ex}= 148.2 ± 14.7) than during control sessions (HR_{con}= 76.1 ± 9.1D). There was no other significant main effect for music ($F(2,4) = 2.537$, $p = 0.194$) or interaction effect of music and exercise ($F(2,4) = 2.980$, $p = 0.161$) on heart rate response (Figure 2). BMRI results showed that most subjects preferred the stimulative (average score: 24.07 ± 13.52 AU) compared to the sedative (13.35 ± 6.95AU), though many indicated that they preferred another genre as their top choice. Despite this, there was no significant correlation between BMRI scores and Stroop effect (Pearson *r* = 0.-117, *p* = 0.724) or heart rate response (Pearson *r* = -0.215, *p* = 0.525).

Table 2

Music Playlists

Sedative Music	Stimulative Music
Je Te Veux (*Eric Satie)*	Thunderhorse *(Dethklok)*
String Quartet no. 2: Nocturne *(Alexander Borodin)*	YYZ *(Rush)*
Clair De Lune *(Claude Debussy)*	The Call of Ktulu *(Metallica)*
Lacrimosa *(Mozart)*	Into the Lungs of Hell *(Megadeth)*
Gymnopedie no. 1 *(Eric Satie)*	Psychobilly Freakout *(The Reverend Horton Heat)*
Moonlight Sonata - 1st mov. *(Beethoven)*	Eruption *(Van Halen)*
Nocturne Opus no. 9 *(Chopin)*	Soothsayer *(Buckethead)*
Als Die Alter Mutter Op 55.4 *(Antonin Dvorak)*	

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

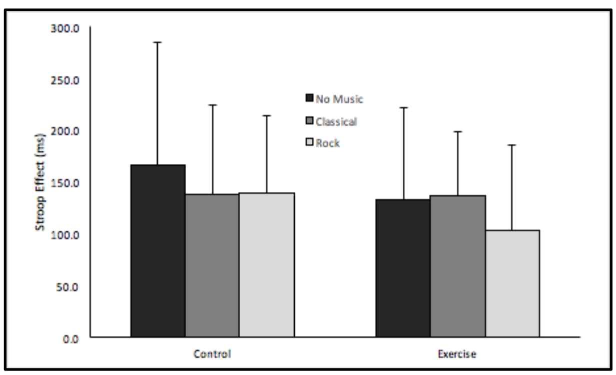

Figure 1. Stroop Effect between musical conditions with and without exercise.

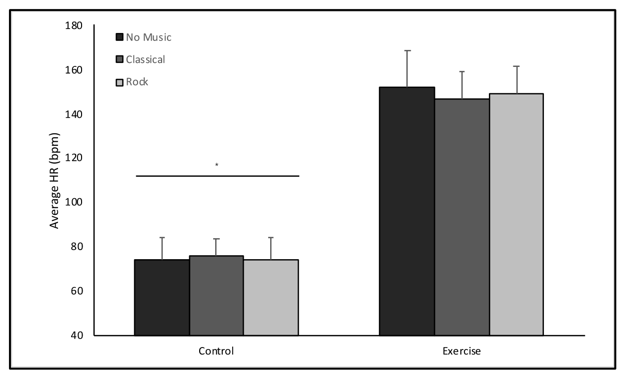

Figure 2. Mean HR was significantly higher during exercise compared to control; * *p* < 0.01, significantly different from exercise HR.

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, showing that selective attention has the potential to be more resistant to musical distraction than the conductors of the present study had hypothesized. 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 of an external stimulus 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 (Szmedra & Bacharach, 1998), though the existing body of work still appears to be divided on the effects of music (Hodges, 2016; Maranto, 1993). 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 (Ballmann, Maynard, Lafoon, Williams & Rogers, 2019). If the results of the present study could be replicated, they could have practical uses in a variety of intense training sessions, and may already be at play in settings such as spin classes, HIIT classes, or independent music listeners in the gym. It may be worthwhile for coaches to experiment with music in their team practices for the possible physiological benefit displayed by these results. In order to make future research more applicable to a sport competition setting, researchers should experiment with cognitive performance while actively performing exercise in order to more realistically simulate a live competition where decisions must be made.

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 implications, but it remains to be seen if any tangible performance gains can be achieved (Ballman et al., 2019). 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 yet 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 (Karageorghis et al., 2018). 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 (Shih et al., 2012).

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 also continue to explore a variety of auditory stimulation media and variables, for example; self-selected vs non self-selected music, exercise with other media such as podcasts or audiobooks, and different volumes of the auditory stimulus. Additionally, studies should incorporate longer and more intense exercise protocols and different exercise modalities in addition to tighter control of subject training status. One major limitation of this study was the inability to standardize the intensity of exercise between participants. While they all performed the same workout, the only requirement was to reach 77% of their max heart rate, which leaves a large window of intensities that meet the requirement and thus create variability in each individual's workout stimulus. This could have significantly different implications for each subject's physiology based on training status. Future studies should consider this and standardize exercise intensity. One way to do this may be to use maximal effort testing similarly to Ballmann et al. (2019). 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 anecdote came after two subjects were interested in doing a second workout after their data for the day had already been recorded. 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.

CONCLUSION

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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