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The Relationship Between Subjectively Motivational Music and Various Exercise Variables While Running At Maximal Speed

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Honors Thesis

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Introduction

For the past twenty years, an increasing amount of research has been completed to study the application of music in the exercise field (Karageorghis & Priest, 2012; Bishop et al., 2012). With the advancements in technology, music has become ever more incorporated into our emotional and social lives. Karageorghis & Priest (2012) explain that music "captures attention, raises spirits, triggers a range of emotions, alters or regulates mood, evokes memories, increases work output, heightens arousal, induces states of higher functioning, reduces inhibitions and encourages rhythmic movement - all purposes that have considerable application in the exercise domain" (p. 2).

There has been an increasing interest in research focusing upon the benefits of listening to music during exercise. Studies before the 1990s were inconsistent due to methodological limitations and the missing theoretical framework. Several experiments show benefits of motivational music during physical activity on various exercise variables (Karageorghis & Priest, 2012). Ahmaniemi (2007), in particular, studied the effect of song tempo and songs' motivational rankings on step count, while running at maximal speeds, specifically in individuals who identified themselves as runners. Research focusing on the motivational component of music in non-runners performing high-intensity exercise (i.e. running) is limited and may add knowledge that can be applied to the well-being and health of the general public and non-elite athletic individuals.

Literature Review

Physical Activity

Physical activity refers to all energy expended by movement, such as activities of daily living (ADLs), which involve bodily movements. Exercise, on the other hand, is a planned activity aimed to improve fitness and health. Physical activity and exercise are behavioral processes, while physical fitness is a set of characteristics, like strength or stamina, which determine capacity for physical activity. Fitness is related to one's physical activity levels, and exercise programs can be formed to improve specific aspects of fitness (Fox, 2003).

Physical Activity & Music

Due to its tendency to increase rhythmic movements, motivational music has been shown to also increase physical activity, and therefore, fitness levels (Bishop, 2012). Physical fitness is negatively correlated with oxygen consumption (VO_2), the amount of oxygen one's body transports and utilizes to do work (Raven, Wasserman & Squires, 2012). This motivational influence allows individuals to work at higher work rates, especially during repetitive endurance activities like running or cycling, allowing them to work at higher physical activity intensities, which improves physical fitness (Bishop, 2012). The Brunel Music Rating Inventory-3, and other tools, have been created and designed to assess the motivational qualities of music in exercise. It is a valid, consistent tool by which music can be selected with an appropriate exercise or training session, and standardizes music in experimental protocols involving exercise tasks (Karageorghis, 2008). Many health benefits have been associated with regular physical activity, such as reduced risk of coronary heart disease, stroke, obesity (Pate el al., 1995), improvements in strength, flexibility and balance (Seco et al., 2013).

Music in a Rehabilitation Setting

Music has been used in rehabilitation settings, where health professionals are concerned with the remediation of impairments and disabilities, and the promotion of mobility, functional ability, quality of life and movement potential through physical intervention (O'Sullivan, Schmitz, & Fulk, 2013). Numerous studies have explored the benefits of rhythm and how music can be used to assist in recovering motor, cognitive, and linguistic skills. For example, stroke patients have been shown to benefit from music therapy, through improvements in fine and gross motor skills, speed, and precision, and smoothness in movement (McIntosh et al., 1997). As previously mentioned music increases motivation, acts as an external timekeeper, and improves physical, psychological, cognitive and emotional function, aspects that may be useful within physical rehabilitation (Karageorghis & Priest, 2012).

Tempo

Music tempo has been shown to benefit patients with Parkinson's, a condition that impairs movement timing and may lead to gait instability and falls. Music has been shown to significantly improves gait velocity, cadence, and stride length, suggesting patients' rhythmic synchronization with music (McIntosh et al., 1997). The use of a musical cadence stabilized the internal rhythm generating system and reintegrated timing networks, even after the removal of the auditory stimulus (Hove et al., 2012). Karageorghis et al. (2011) have also observed the significance in self-selected music, as compared to music chosen by an experimenter. Rehabilitation patients may benefit from the use of self-selected music and tempo, which may promote engagement in physical activity and, as a result, their recovery.

There are several variables that influence motivation. intrinsic motivation, for example, is driven by one's interest or enjoyment, exists within an individual and is not influenced by external factors, such as rewards. Alternatively, extrinsic motivation is driven by an outcome, regardless of intrinsic motivation, and comes from outside the individual (Deckers, 2013). Music's motivational impact will be discussed related to ratings of perceived exertion (RPE), how difficult one finds work, heart rate, step frequency, and VO_2.

A song's tempo, measured in beats per minute (bpm) has been shown to be a motivational component in increasing physical activity levels (Waterhouse, Hudson & Edwards, 2010). Healthy individuals performing sub-maximal exercise not only worked harder with faster music, but also chose to do so and enjoyed the music more when it was played at a faster tempo (Waterhouse, Hudson & Edwards, 2010). The motivational relationship between preferred music and tempo may facilitate and promote a greater sense of autonomy, when the selected music and tempi are appropriate for a particular motor rhythm (Karageorghis, Jones, & Stuart, 2008). Findings show the motivational and ergogenic, work promoting, effects of music on exercise, suggesting that music can be used to promote engagement in increased exercise intensity levels, which may improve one's physical fitness.

Tempo use has also been shown to aid exercise recovery, one's return to normal, physiological levels after exercise. Significantly faster recovery times for blood pressure and heart rate have been observed when an individual listened to slow music after completing sub-maximal treadmill work, compared to when the same individual listened to fast music or no music. Savitha, Mallikarjuna & Rao (2010) also showed the benefits for post-exercise recovery: recovery time is independent of gender and a participant's music preference, and may benefit from the use of slow music

Song Preference

Kornysheva et al. (2010) used magnetic resonance imaging (MRI) to find that subjectively preferred rhythms and tempos boost activity in motor-related parts of the brain. When presented with auditory rhythms, individuals, who may have appreciated music rhythms since they had musical training, showed increased activity in parts of the motor system, implying that the motor-system-based internal simulation of rhythms can be heightened by preference. This study suggests a connection between increased activity in the ventral premotor cortex, a part of the brain believed to play a role in control of behavior with emphasis on the trunk muscles, during rhythms with a preferred tempo and the “tuning-in to” the beat of subjectively enjoyable music. This study also shows the applicability of preferred music, rhythms, tempos and other subjective factors, such as lyrical content and how self-selected music may help regulate and empower neuromuscular responsiveness. Such studies suggest the benefits of music preference during exercise because it may increase enjoyment, which may be associated with exercise program adherence, and the motor system’s readiness to engage in physical activity.

RPE

When using the RPE scale with exercise, subjects subjectively rank how difficult they find their work from 6-20, which theoretically correlates with heart rate and therefore exercise intensity. Potteiger, Schroeder, and Goff (2000) found that participants, who completed a graded cycling test while listening to music, experienced lower RPE, as compared to participants who did not listen to music. Preferred music increases exercise enjoyment, suggesting that music acts as a distractor (Dyrlund &Wininger, 2008). In incremental tests, preferred music has been shown to “push” subjects to work beyond their lactate threshold, or anaerobic threshold, a term associated with moderate- to high-exercise intensities. As exercise intensities increase, the rate of ATP hydrolysis in the active muscle increases to provide energy for the greater demands placed upon the body. This process increases concentrations of hydrogen ions, which increases blood acidity at which point an individual may find work strenuous (Raven, Wasserman & Squires, 2012). The lactate threshold is the exercise intensity at which point lactate is produced faster than it can be removed or metabolized (Raven, Wasserman & Squires, 2012). The “barrier” associated with the lactate threshold can be increased with training and frequent engagement in exercise intensities above one’s threshold. An increased threshold is associated with lower, more efficient, VO_2. When performing two separate tests of the same exercise intensity, participants reported lower RPE when music was being played, especially preferred music, and that their work rate had become easier (Karageorghis & Priest, 2012). Such findings portray the applicability of using music in the exercise domain, and music's ability to make exercise appear easier and more appealing, which may increase engagement in physical activity, and therefore, fitness levels.

Heart Rate

Music has been shown to impact heart rate (bpm). Heart rate fluctuates according to the body's need to maintain equilibrium between the requirement and delivery of oxygen and nutrients, which correlate with exercise intensity (Raven, Wasserman & Squires, 2012). Karageorghis & Priest (2012) observed that listening to fast music increased heart and lung function in participants maintaining a treadmill running speed of 8.8 km/hour. Fast tempos heightened participants' physiological arousal, although the highest achieved exercise heart rates may have represented different levels of exercise intensity for each participant. Self-selected pedaling cadences increased or decreased during a cycling test in response to an increment or decrement in music tempo (Waterhouse, Hudson & Edwards, 2010). Such findings may not be solely based upon synchronization, so a relationship between tempo and exercise intensity through psychomotor arousal is possible.

Purpose

The intention of the current study was to expand upon the research completed by Ahmanieimi (2007), with non-runners. Similar studies have shown that listening to preferred music during exercise is more beneficial in untrained populations because trained runners may have grown accustomed to an internal rhythm they have developed through their training

(Karageorghis & Priest, 2012). Studying music's impact in non-runners is important because they may better represent the general population, so results may be better applied to the public. Music has a powerful use in the exercise field, and its ability to be used to promote healthy, active lifestyle behaviors and increase physical fitness in the general public is promising.

The purpose of this study was to determine whether there are differences in steps/min/m, highest achieved exercise heart rate, average exercise heart rate, average running speed, estimated relative VO_2, and RPE, while listening to subjectively motivating music, as compared to non-motivating music, while running at max speed.

Hypothesis

It was hypothesized that there would be differences in steps/min/m, highest achieved exercise heart rate, average exercise heart rate, average running speed, estimated relative VO_2, and RPE, while listening to subjectively motivating music, as compared to non-motivating music, while running at max speed.

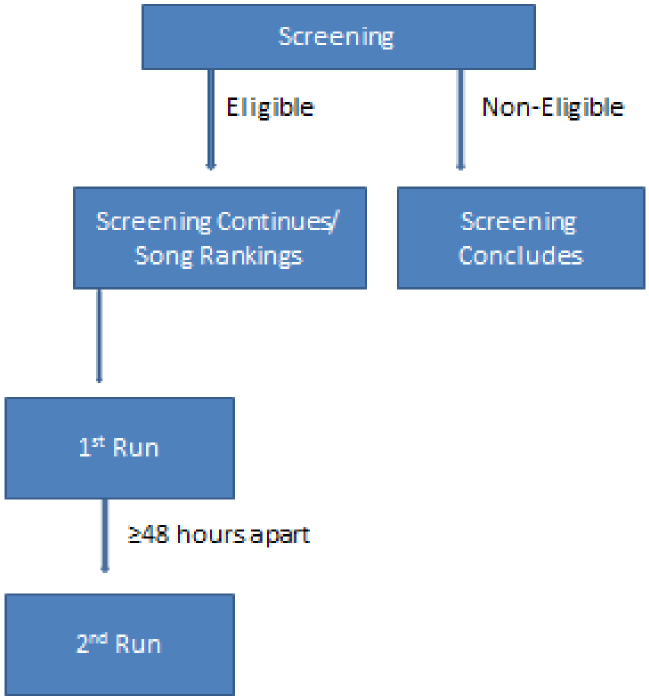
Methods

Participants

Inclusion Criteria: Participants between the ages of 18-35 years, who were enrolled at the University of Massachusetts Boston (UMB), identified themselves as "non-runners" (ran less than 20-30 km per week consistently for the past one to three years) (Bobbert et al., 2012), and had varying racial/ethnic backgrounds and body mass indexes (BMI), a measure of human body shape based on an individual's mass and height, were included in the current study.

Exclusion Criteria: Individuals unable to participate safely in regular physical activity, with heart conditions, including pacemaker or other internal medical devices, high blood pressure, diabetes or high blood sugar, asthma or other lung conditions, cancer, seizure, neurological or musculoskeletal conditions, and who did not read nor speak English were excluded. **Figure 1** depicts the sequence of events for participant's involvement in the study.

Figure 1. Sequence of Participants' Involvement



Recruitment

Participants were recruited by means of social and academic networks, such as University Facebook pages, on-campus organizations, word-of-mouth, flyers, and in-class announcements by the Primary Investigator (PI).

Screening

Screenings took place at UMB. A Physical Activity Readiness Questionnaire (PAR-Q) was completed by participants and used to determine the safety or possible risk of exercising for an individual based upon their answers to specific health history questions (The American College of Sports Medicine, 2013). Individuals, who answered 'yes' to one or more questions and had been concerned about their health, were advised to consult their physician before participation, while those who answered ‘no’ to all questions, have low risk of having any medical complications from exercise and were allowed to participate in the study.

Participants were asked, “How much do you run on a weekly basis?” and “have you run that amount over the last three years?” Meetings with volunteers, who did not qualify, concluded, while those who ran less than 20-30 km per week consistently for the past one to three years were termed as “non-runners” and were eligible to participate. These stipulations have been used in previous studies to define “runners” (Bobbert et al., 2012).

Eligible participants were given a list of nine songs, see **Table 1**. All songs had similarly fast tempos (beats/minute), between 147-169 bpm, as recommended by the American Council on Exercise for running activities (Foster, Pocari & Anders, www.acefitness.org). The songs were chosen for their tempo, variety in style, genre, artist, and release year, to allow for a greater appeal to all participants. Volunteers ranked each song’s motivational effect by answering the question: “How motivating, driving and inspiring do you find each song?” Ratings ranged from 1 to 10, ‘1’ for songs they found least motivational and ‘10’ for songs they found most motivational. Upon request, unfamiliar songs were played on a laptop.

Table #1. Descriptive Information of Song Selections

Song Title	**Artist**	**Beats/Min (bpm)**	**Genre**	**Release Year**	**Mean Motivational Ranking**
Dog Days Are Over	Florence and the Machine	150	Indie Rock	2010	5.7
Pump It	The Black Eyed Peas	153	Hip Hop	2006	7.1
Maniac	Michael Sembelo	159	Pop	1983	4.0
What I Like About You	The Romantics	160	Pop Rock	1980	6.5
Wake Up Call	Maroon 5	164	R&B	2007	4.7
I'm A Believer	Smash Mouth	165	Pop Rock	2001	5.6
Take On Me	A-Ha	169	Pop	1985	4.9
One Way Or Another	Blondie	161	Punk Rock	1979	5.1
Mean	Taylor Swift	164	Country	2011	3.4

Instrumentation

Step Count

A pedometer, New Lifestyle-100 (New-Lifestyles, Inc., Lees Summit, MO) was used to collect step counts. It is a small, light-weight device, which securely attaches to an individual's waist on their clothing that counts steps by detecting hip motion. It was reset to zero before each test and counted the subject's total step count for each run.

Heart Rate

A Polar heart rate monitor (Polar, China) was used to collect heart rate once per lap. It is a monitoring device, which measures heart rate in real time and consists of a chest-strap transmitter and a wrist receiver. The transmitter requires a band to be strapped around the subject's upper chest, fitting tightly against the skin at the chest plate, while the wrist receiver is worn around the participant's wrist and displays the subject's heart rate.

RPE

The RPE Scale was used to measure participants' perception of their exercise intensity upon the completion of each run (Borg, 1998). The chart ranges from 6-20, 6 representing no exertion at all and 20 representing maximal exertion. The values correlate with heart rate and positively correlate with exercise intensity (Borg, 1998).

Aerobic Fitness

Aerobic fitness was determined using the Balke 12-15 minute run test (Balke, 1963). Participants run at their fastest, self-selected pace that they can maintain for the entirety of the test, completing as many laps as possible and must pass the quarter mile line within 12-15 minutes. Time and total distance ran was used to determine each runner's average running speed, which was used to calculate estimated relative VO_2, ml/kg/min, with the 2010 ACSM guidelines' metabolic equation for running, for speeds greater than 134 m/min (>5.0 mph) or jogging speeds of 80-134 m/min (3-5 mph): [Velocity(m/min) * 0.2] + 3.5, and walking, for speeds of 50-100 m/min (1.9-3.7 mph): [Velocity(m/min)*0.1] +3.5 (American College of Sports Medicine, 2013). Participant #7 completed both tests at walking speeds, 50-100 m/min (1.9-3.7 mph);

therefore, their estimated VO_2 was calculated with the ACSM metabolic equation for walking in the first statistical analysis.

A small, light-weight Mp3 player, iPod Classic (Apple, Cupertino, CA),was placed in an upper arm band that the subject wore while running. A digital electronic stopwatch was used to measure participants' running time.

Experimental Design

At UMB's outdoors track, data was collected on two separate days, at least 48 hours apart, on days with minimal wind, no rain, and ideal weather conditions, on a dry, smooth surface (Horwill, 1994). Equipped with a pedometer, a Polar heart rate monitor, and an Mp3 armband containing a music playing device, runners completed the test once while listening to a play-list of their most motivating ranked songs, and a second time on a separate day, while listening to a play-list of their least motivating ranked songs. Participants were randomly assigned which play-list they would listen to first, and were recommended to wear clothing suitable for running. Before each test, the PI attached the pedometer and Polar heart rate monitor, explained their purposes and how to use the wrist receiver. Resting heart rate was recorded after five minutes of sitting. Runners were encouraged to engage in a "warm up" activity, such as jogging in place or jumping jacks, though the recommendation was optional and was completed by approximately half the participants.

The PI restated the run's protocol and encouraged runners to maintain as fast a pace as possible, as stated in the Balke test. Participants chose a lane, were positioned at the starting line, chose their preferred Mp3 player volume, and had their pedometer reset to zero. Runners read aloud their heart rates displayed on the wrist band after the completion of each lap. The PI verbalized the participant's time after each lap, offered encouragement, signaled when participants could finish running and recorded the runner's time upon completion of their last lap. Once finished, runners selected the value on the RPE scale that corresponded to how difficult they found their run, the pedometer was removed and step counts were recorded. Participants were allowed to "cool down", and the PI safely removed all worn devices. The same procedure was followed for both trials. The PI recorded the runner's RPE score, running time, number of laps completed, number of lane used, heart rate per lap, and step count for both runs.

Statistical Analysis

Data were analyzed using SPSS statistical software (v. 18.0) and presented as the mean differences of each outcome variable, unless otherwise noted. Paired t-tests were used to compare changes between each participant's 1st and 2nd run for steps/min/m, highest achieved exercise heart rate, average exercise heart rate, average running speed, estimated relative VO_2, and RPE. A p-value of less than 0.05 was used to denote statistical significance. Outliers were identified and excluded in separate statistical analyses. Upon visual inspection, any data that appeared to be outside of the general characteristics or means of the 1st and 2nd runs, equal to two standard deviations away from the mean, were further inspected.

Results

Eleven participants, considered "non-runners" from 19 to 34 years of age, completed both running trials. Descriptive characteristics of the participants are shown in **Table 2**. The group of participants had fewer males, four, compared to the number of females, seven.

There were statistically no significant differences between participants' runs for steps/min/m, RPE, highest achieved exercise heart rate, average exercise heart rate, average running speed, and estimated relative VO_2. Specific analyses are outlined below.

Table #2. Participants' Descriptive Characteristics. N=11

	Mean ± (Std. Dev.)
Age (years)	23.5 ± (4.1)
Sex (female)	64%
Height (cm)	168.1 ± (10.1)
Body Weight (kg)	65.7 ± (14.3)
BMI (kg/m^2)	23.1 ± (4.0)

Analysis of Paired t-tests results of total sample

There were no statistically significant mean differences between participant's values in the "High" run (participant's highest ranked motivational songs), and "Low" run (participant's lowest ranked motivational songs), for any of the outcome variables. **Table 3** shows mean values for the outcome variables of both "High" and "Low" runs, their mean differences, their corresponding p-values and correlation coefficient (r) and p-values

There were high positive correlations ($r > 0.689$) and significant relationships ($p < 0.05$) between the "High" and "Low" outcome variables, steps/min/m, highest achieved exercise heart rate, average exercise heart rate, average running speed, and estimated relative VO_2, except between "RPE High" and "RPE Low", which had a low correlation (0.06) and a non-significant p-value (0.858). One would expect the outcome variables of both runs per participant to be similar since data from the same person was collected.

Table #3. Paired T-Tests and Correlations of Outcome Variables

	"High" run mean ± S.D.	"Low" run mean ± S.D.	Difference (p-value)*	Correlation r (p-value)**
RPE	15.5 ± 1.6	14.0 ± 2.0	-1.5 (0.08)	0.06 (0.86)
Highest Achieved Exercise Heart Rate (bpm)	189.2 ± 19.4	188.3 ± 17.6	-0.9 (0.68)	0.93 (0.00)
Steps/min/m	0.071 ± 0.012	0.075 ± 0.012	0.004 (0.20)	0.69 (0.02)
Estimated Relative VO_2(ml/kg/min)	36.4 ± 8.0	36.2 ± 8.2	-0.2 (0.75)	0.92 (0.00)
Average Running Speed (m/min)	2.9 ± 0.5	3.0 ± 0.5	0.09 (0.34)	0.83 (0.00)
Average Exercise Heart Rate (bpm)	171.5 ± 32.1	179.2 ± 15.7	7.7 (0.29)	0.74 (0.01)

* From paired T-tests

**From Pearson product moment correlation

Identifying/Excluding outlier - "Walker"

Due to participant #7, who completed both runs at walking speeds, the differences of means were calculated a second time, excluding Participant #7. There were no statistically significant differences between participants' "High" and "Low" runs for any of the outcome variables, steps/min/m, highest achieved exercise heart rate, average exercise heart rate, average running speed, RPE, and estimated relative VO_2. **Table 4** shows mean values for the outcome variables of both “High” and “Low” runs, their mean differences and p-values.

Table #4. Paired T-Tests of Outcome Variables excluding Participant #7

	"High" run mean ± S.D.	**"Low" run mean ± S.D.**	**Difference (p-value)***
RPE	15.6 ± 1.6	14.5 ± 1.2	-1.1 (0.17)
Highest Achieved Exercise HR (bpm)	194.2 ± 10.4	192.3 ± 12.0	-1.9 (0.39)
Steps/min/m	0.073 ± 0.012	0.071 ± 0.008	0.002 (0.41)
Estimated Relative VO_2(ml/kg/min)	37.4 ±7.7	37.5 ± 7.5	-0.2 (0.75)
Average Running Speed (m/min)	3.0 ± 0.5	3.1 ± 0.3	0.1 (0.34)
Average Exercise HR (bpm)	179.0 ± 21.1	182.5 ± 0.5	8.3 (0.58)

Identifying/Excluding outlier - “pedometer”

Participant #2’s step frequency appeared drastically different from the rest of the data. The normal mean for total step count for the “High” and “Low” runs were 2058 and 2071 steps, respectively, compared to Participant #2’s total step counts, 1204 and 1765 steps. Due to possible differences in BMI (Gardner et al., University of Dundee), the differences of means for all outcome variables were calculated a third time, solely excluding Participant #2. There were no statistically significant differences between participants' "High" and "Low" runs for RPE, highest achieved exercise heart rate, average exercise heart rate, average running speed, and estimated relative VO_2. There were statistically significant differences, $p = 0.01$, between participants' "High" and "Low" runs for steps/min/m, and trended towards significance, $p = 0.06$, in RPE. **Table 5** shows mean values for the outcome variables of both "High" and "Low" runs, their mean differences and p-values.

Table #5. Paired T-Tests of Outcome Variables excluding Participant #2

	"High" run mean ± S.D.	**"Low" run mean ± S.D.**	**Difference (p value)***
RPE	15.5 ± 1.7	13.8 ± 2.0	-1.7 (0.06)
Highest Achieved Exercise HR (bpm)	188.7 ± 20.3	187.5± 18.3	-1.2 (0.62)
Steps/min/m	0.074 ± 0.008	0.076 ± 0.013	0.002 (0.01)
Estimated Relative VO_2 (ml/kg/min)	36.1 ± 8.4	36.1 ± 8.6	0.0 (0.86)
Average Running Speed (m/min)	2.9 ± 0.57	3.00 ± 0.5	0.1 (0.34)
Average Exercise HR (bpm)	169.5 ± 33.1	177.8 ± 15.8	8.3 (0.31)

Discussion

The purpose of this study was to determine whether there were differences in steps/min/m, highest achieved exercise heart rate, average exercise heart rate, average running speed, estimated relative VO_2, and RPE, while listening to subjectively motivating music, as compared to non-motivating music, while running at max speed. There were no significant mean differences in steps/min/m, highest achieved exercise heart rate, average exercise heart rate, average running speed, estimated relative VO_2, and RPE while listening to subjectively motivating music, as compared to non-motivating music, while running at max speed. There was a significant mean difference ($p = 0.01$) in steps/min/m after excluding participant #2.

In the current study, no significant mean differences were found for highest achieved exercise heart rate nor estimated relative VO_2. Previous studies have shown an ergogenic effect of listening to music during exercise that may delay fatigue and increasing work capacity, resulting in higher-than-expected levels of endurance and power(Karageorghis & Priest, 2012). Karageorghis et al. (2009) found that motivational music had a greater ergogenic effect than oudeterous, non-motivational, music ($p<0.01$) during treadmill walking. Such ergogenic effects would be apparent through cardiovascular output, such as heart rate and VO_2. Listening to music has been shown to enhance work output across various exercise modalities (Elliott et al., 2005; Razon et al., 2009), but the magnitude is not consistent across studies (Edworthy & Waring, 2006). Several studies have also established that listening to music impacts exercise variables during moderate to vigorous-intensity physical activity (Bishop et al., 2012; Dyrlund &Wininger, 2008; Karageorghis & Priest, 2012).

Participants' step frequency was compared with the unit, steps/min/m, since participants ran for different times and distances. Ahmaniemi (2007) found a significant positive correlation between subjective motivational ratings and step frequency, while the present study found no significant correlations in steps/min/min including all data. The current study provided no support for previous literature regarding step frequency ($p = 0.20$); however, there was a significant mean difference ($p = 0.01$) in step frequency after excluding participant #2, which supports Ahmaniemi (2007). Daniels (2005) analyzed the stride rates of elite runners and determined 180 steps/min as the most economical running cadence. The current study's data shows trends towards a higher average step frequency in the "Low" run, 163.9 ± 21.7 steps/min, compared to the "High" run, 160 ± 16.0 steps/min. Although the current study used "non-runners", opposed to elite runners, the "Low" run's step frequency was closer to the economical 180 steps/min. The average stride length is approximately 42% of a person's height (Basset et al., 1996; Welk et al., 2000) and is affected by multiple factors, such as walking speed, height, age, and gender affect stride length (Welk et al., 2000). In this study, participants' heights and stride lengths were not taken into consideration, so the mean differences' significance for steps/min/m, may not have been determined; however, the trend toward increased steps/min in the "Low" run should be noted for safety reasons. While running, taking fewer steps suspends one's body in air for a greater amount of time, resulting in greater applied forces as the body makes contact with the ground, which may result in chronic injury (Welk et al., 2000). This study suggests that listening to non-motivating music may be safer for non-runners. Participant #2 was determined to be obese, according to their BMI. In Obese class I and II individuals, differences ($p<0.01$) have been shown between observed and pedometer step counts during moderate walking when the pedometer is worn at the hip, as the current study followed (Gardner et al., University of Dundee). This measurement issue may be responsible for participant #2's difference in data.

No significant mean differences were found for RPE. Data trends towards higher RPE values in the “High” run, trending towards significance ($p=0.08$), which conflicts with previous studies that show decreased RPE levels with the presence of motivational music (Potteiger, Schroeder & Goff, 2000; Dyrlund & Wininger, 2008). The current study may not have had power due to the low number of participants. It has also been shown that motivational music lowers RPE at the start of exercise, but its influence on RPE declines at higher exercise intensities (Karageorghis & Priest, 2012), which may explain the non-significant mean differences in RPE in the current study.

There was no significant differences in highest or average exercise heart rates nor VO_2, suggesting that the runners performed around the same amount of work in both runs. In sight of Daniels’ findings (2005), the “High” run may have had increased RPE trends since average steps/min was lower, and the runners’ motions may have been less economical. Since runners performed about the same amount of work in both runs, more effort may have been exerted during the “High” run, due to mechanical inefficiency, which may explain the increased “High” RPE trends; however, average exercise heart rate, a marker of cardiovascular efficiency and work output, was lower in the “High” run, 171.5 bpm, than the “Low” run, 179.2 bpm. Around the same amount of work was completed with fewer heart beats in the “High” run, so participants may have displayed increased efficiency in this regard.

The current study is important because it acts as an additional discussion piece in the limited, yet growing body of literature on the use of motivational music in the exercise and rehabilitation field in non-elite individuals. Research on the motivational aspects of music during exercise is important for its application in the rehabilitation setting and physical activity habits in the general public because music appears to greater benefit untrained or recreationally active individuals than highly trained individuals (Karageorghis & Priest, 2012). More research must be completed to examine the motivational effects of music on work output, RPE and cadence in low, moderate and high intensity exercise, tasks of varying duration and how music can alter mood states, which may lead to increased exercise adherence. The tendency for individuals to synchronize their rhythmic motions to music has great applicability in gait training with individuals with gait instability, such as Parkinson's and Alzheimer's patients. Synchronization to a musical cadence also promotes energy efficiency during repetitive endurance activities (Karageorghis & Priest, 2012).

There were several limitations of this study. The small sample size (n=11) could be a factor in the limited statistical mean differences found between the "High" and "Low" runs. Future studies should increase the number of participants, increasing the data's validity while reducing the standard deviations of the data. A larger sample size could increase the chance of discovering statistically significant differences between runs. All participants were students enrolled at UMB, so the selection may not be representative of a larger population. Participants' age range was somewhat varied, 19-34 years of age, and all volunteers participated in varying degrees of physical activity. Future studies should ensure more homogeneous qualities in participants to increase data validity (Mitchel & Jolley, 2012). Since the music was rated by the same person who completed the running tests, variations in step frequency, time and RPE may have been influenced by the commitment of the person to show that the rating is valid (Ahmaniemi, 2007). Future studies should offer a larger sample of songs to rank to prevent participants from recalling their rankings. In the current study, heart rate was measured once per lap and each participant's average running speed was recorded upon the completion of the test. The Polar heart rate monitor was capable of capturing runners' times and heart rates throughout both tests. Future studies should include this feature to monitor changes in pace and provide a larger and more accurate account of exercise heart rate.

Less than half the participants engaged in a warm-up before their runs. Warming-up, such as a light jog, decreases the risk of injury, increases blood flow to muscles and joints, increases core temperature, which provides more blood to extremities and therefore increases readily available oxygen and nutrients for muscles, optimizes performance through stimulation of contractile enzymes and psychologically prepares one for activity (Hamilton, Weimar, & Luttgens, 2011). Future studies should maintain consistent warm-up protocols for all participants. Participants were advised to wear comfortable clothing for running, although some were more aptly dressed than others, which may have restricted some participants' running capabilities or decreased their feeling of comfort. Shoe type and gender, can influence one's principal movement path, which may have hindered the validity of the current study (Maurer et al., 2012). Future studies should recommend specific clothing appropriate for running, and consider differences in gait patterns between sexes.

Music volume was selected by each participant according to their preference. Music volume has been shown to additionally alter outcome variables. For example, listening to loud, fast music, while bicycling, can lead to speed increases when compared to loud, slow music (Elliott et al., 2005). Future studies should use the same music volume with all participants. Participants' self-efficacy, one's confidence in performing an activity, was not taken into account; however, pre-existing physical self-efficacy scores have been shown to significantly correlate with running times (Gayton et al., 1989). Future studies should include self-efficacy scores, as to take into consideration different individuals' pre-determined abilities to participate in physical activity.

Sleeping recommendations were not specified and taken into account. Sleep deprivation increases stress hormone levels, depresses the body's thermoregulatory system and increases running difficulty, all which may impair a runner's performance (Bond et al., 1986). Future studies should note sleeping habits to ensure validity in data. Participants were not given dietary suggestions, nor were their eating habits recorded. Diet and its proximity in time to both runs may have influenced outcome variables, and should be taken into account in future studies. Because running times were recorded by the PI, data may have been hindered by random error. Future studies should use more accurate time-keeping devices to ensure better accuracy.

This study has several strengths, such as having both runs completed at the same location under similar conditions. All participants were allowed the opportunity to become familiar with the songs, ranked and ran to the same pool of songs, all of which have fast tempos ideal for running. Participants' runs were completed more than 48 hours apart, allowing time to recover. Participants were randomly assigned identification numbers, which specified the order in which they completed their "High" and "Low" runs, taking into consideration the learning curve, which could have altered data.

In conclusion, no significant mean differences were found between steps/min/m, highest achieved exercise heart rate, average exercise heart rate, average running speed, estimated relative VO_2, and RPE, while listening to subjectively motivating music as compared to non-motivating music, while running at max speed, except in steps/min/m ($p = 0.01$) after excluding participant #2. The results from this study do not match previous research, possibly due to several factors, such as a small sample size and the lack of consistent pre-run guidelines concerning clothing, eating, drinking, sleeping habits and warm-ups. Past studies used runners, compared to non-runners; therefore, the results from this study may be correct for the participant population. Further research is needed to study the relationship between motivational music and exercises variables, utilizing music volume, large homogenous samples, other self-paced exercise and participants' pre-existing self-efficacy levels. Future studies will add to the limited knowledge regarding music in the exercise domain, which may help improve the physical activity habits of elite and amateur athletes, the general public and patients in a rehabiliton setting.

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