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The Effect of Auditory-Motor Synchronization on Physiological Responses and Perceived Exertion During Treadmill Running

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THE EFFECT OF AUDITORY-MOTOR SYNCHRONIZATION ON PHYSIOLOGICAL RESPONSES AND PERCEIVED EXERTION DURING TREADMILL RUNNING

by

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Synchronous, asynchronous, and no music were compared to determine the effect of synchronization of musical tempo and running cadence on physiological and perceptual responses to exercise. Eight subjects, three males and five females, participated in one assessment trial and three experimental trials. During the assessment trial, subjects performed a VO_{2max} test, and researchers then calculated running cadence at a velocity approximating 70 percent of VO_{2max}.

During the three experimental trials, subjects ran for 20 minutes at approximately 70 percent of VO_{2max} on a motorized treadmill with synchronous, asynchronous, and no music, where the order of trials was randomly assigned to each participant. VO_2, blood lactate, heart rate, perceived exertion, and cadence were recorded every five minutes.

A two-way ANOVA revealed a significant main effect for time on RPE, HR, VO_2, and blood lactate. The effect of music condition was not significant, $p>.05$. Results and recommendations for future studies are discussed.

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CHAPTER I
INTRODUCTION

Research Problem

Numerous studies exist concerning the impact of music on psychological and physiological measures during exercise. However, many of these studies are anecdotal and fail to address the mechanisms by which music can facilitate greater efficiency during movement.

Researchers have utilized a variety of musical mediums, genres, and tempos in their studies (Abadie, Chance, O'Nan, & Lay, 1996; Annesi, 2001; Potteiger, Schroeder, & Goff, 2000; Tenenbaum et al., 2004; Yamamoto et al., 2003). However, results from study to study vary as much as do the numerous methodologies employed. For example, Abadie et al. (1996) studied the effect of viewing music videotapes versus no videotapes during cycling and found no significant differences in ratings of perceived exertion (RPE) between the two conditions. In other words, subjects generally reported no differences in their levels of exertion between the two conditions. Annesi (2001) studied the effect of music, television, and music/television conditions during exercise and found that subjects in the combination group exercised significantly longer per session over the 14-week exercise period compared to the other three groups. In addition, this combination group displayed significant increases in maximum volume of oxygen uptake (VO_{2max}) compared to the other groups. This increase in oxygen volume (VO_2) during the maximal exercise test indicates that subjects experienced an increase in their

maximum exercise intensities, which would coincide with longer exercise sessions. It is also important to note that the music group did not display an increase in adherence or in length of exercise sessions compared to the other groups.

Researchers have also examined the effectiveness of both self-selected music and assigned music from various genres, but the studies yield mixed results (Bharani, Sahu, & Mathew, 2004; Potteiger et al., 2000; Tenenbaum et al., 2004). Bharani et al. studied the effect of self-selected versus no music on maximum exercise capacity. Subjects participated in both conditions, running on a treadmill until reaching exhaustion. When listening to self-selected music, subjects ran longer and experienced higher peak heart rates (HR) and rate pressure-products (HR multiplied by systolic blood pressure). They also reported less perceived exertion during equivalent submaximal exercise. In this study self-selected music increased maximum exercise intensity while decreasing perceived effort.

It is difficult, though, to make comparisons among studies with identical dependent variables as methodologies often vary from study to study (Potteiger et al., 2000; Tenenbaum et al., 2004). For example, Potteiger et al. compared up-beat, classical, self-selected, and no music and found that no significant differences existed among conditions in subjects' HRs while cycling at 70 percent of VO_{2max} (70 percent of maximum intensity). However, all three music conditions yielded significantly lower RPE values compared to no music. In other words, although the music conditions did not affect HR, subjects reported less exertion when listening to various types of music while cycling.

In contrast, Tenenbaum et al. (2004) compared the effect of rock, dance, inspirational, and no music on HR and RPE during treadmill running at 90 percent of VO_{2max}; they found no significant differences in any of the variables among the four conditions.

However, it is important to note that the exercise intensities differed between the two studies, 70 percent versus 90 percent VO_{2max}. Physiological responses vary across levels of exercise intensity, so one cannot state with certainty that the results of the two studies are contradictory. Also, the two studies employed submaximal workouts while other researchers have studied the effect of music on maximal tests as previously discussed (Bharani et al., 2004). Therefore, it is difficult to formulate conclusions when comparing these studies as the researchers employed methodologies with such important differences.

Yamamoto et al. (2003) have studied the effects of listening for 20 minutes to "slow" and "fast" music prior to 45 seconds of supramaximal cycle exercise. For the suparmaximal exercise, subjects were instructed to perform as many revolutions as possible while the load was kept constant. Researchers measured the concentration of blood lactate, ammonia, and catecholamines as well as HR and power output (work). Results indicated no difference in mean power output during cycling after the "fast" music condition" compared to the "slow" condition. Similarly, results yielded no significant differences in HR between conditions during music-listening, cycling, and resting for 10 minutes post-exercise. In addition, there were no significant differences in levels of blood lactate, ammonia, and dopamine prior to and post-music-listening, and no differences existed during the 10-minute recovery period.

However, the researchers found a significant decrease in norepinephrine before the end of listening to "slow" music compared to prior to listening. A significant increase in epinephrine was found immediately before the end of "fast" music listening compared to pre-listening. No differences were found in norepinephrine and epinephrine between conditions during the post-exercise recovery period.

Norepinephrine and epinephrine constrict blood vessels, increase HR, and increase blood pressure. Thus, results of this study indicate that listening to music prior to exercise can effect sympathetic activation. However, this effect was not present post-exercise, nor did an effect of "slow" versus "fast" music exist concerning exercise performance. In other words, slow music prior to exercise induced physiological changes associated with relaxation while fast music had the opposite effect, but these physiological changes were not evident post-exercise.

Rationale for the Research

Numerous studies exist concerning the effectiveness of music on physiological responses and perceived exertion during exercise, but results are inconsistent (Karageorghis & Terry, 1997). In the majority of these studies, musical accompaniment is perceived as a motivator (Annesi, 2001), distraction agent (Bharani et al., 2004), or relaxation agent (Yamamoto et al., 2003). While these may all be viable uses of music, another catalyst exists which has a substantial impact on physiological responses.

This catalyst is auditory-motor synchronization. Researching the effectiveness of music-listening during movement while neglecting auditory-motor

synchronization would be analogous to students attending college to socialize while neglecting their academic education. Motivation, relaxation, and distraction are all certainly important uses of music during exercise. These uses should not be underestimated, and researchers should continue to study these areas further. However, it is also important to investigate the use of music where auditory-motor synchronization could possibly facilitate greater efficiency during exercise. Rather than focusing entirely on music that accompanies exercise, it may be useful to also study the effect of music that perhaps more directly facilitates movement.

Karageorghis and Terry (1997) reviewed a number of studies and noted that while synchronous music produces an increase in work output, the effect of asynchronous music is unclear. However, the word "synchronization" as utilized in this review article was associated with "fast" music while "asynchronous" music was defined as "slow." In order for auditory-motor synchronization to occur, the movement, for example, running cadence (steps per minute), would match the tempo (beats per minute) of the auditory stimuli. Therefore, an inaccurate representation exists when defining synchronous music as "fast" and asynchronous music as "slow" since one could feasibly exercise in synchrony to music at a tempo (beats per minute) equal to half the exercise cadence (steps per minute). For example, a person running at a cadence of 160 steps per minute could still synchronize his or her movement with music played at a tempo of 80 beats per minute (BPM) because every two steps (or every stride) would be cued by the beat. In addition, a person running at a cadence of 160 would have a difficult time synchronizing to music with a tempo of 200 BPM.

These examples illustrate that during exercise, "slow" music is not always asynchronous, nor is "fast" music always synchronous.

Based on the findings from the extant literature, a strong need for evidence-based research exists that examines the effectiveness of facilitative, synchronous music on physiological responses and perceived exertion during exercise.

Purpose

The purpose of the present investigation was to determine the effect of auditory-motor synchronization on VO_2, blood lactate, HR, and RPE during treadmill running at a velocity correlated with an intensity of 70 percent of maximum oxygen consumption.

Research questions for this study were as follows:

(1) Does a difference exist concerning the effect of synchronous, asynchronous, and no music on volume of oxygen consumption, blood lactate, heart rate, and rating of perceived exertion during treadmill running?

(2) Do physiological responses and perceived exertion change over time during an exercise session?

(3) Do interactions exist among treatment conditions and time during an exercise session concerning physiological responses and perceived exertion?

The Null Hypotheses for this study were as follows:

(1) No significant differences exist concerning the effect of synchronous, asynchronous, and no music on volume of oxygen consumption, blood lactate, heart rate, and rating of perceived exertion during treadmill running.

(2) No significant differences exist concerning changes in physiological responses and perceived exertion over time during an exercise session.

(3) No significant interactions exist among treatment conditions and time during an exercise session concerning physiological responses and perceived exertion.

CHAPTER II
REVIEW OF RELATED LITERATURE

Rational-Scientific Mediating Model

When examining the effect of music on movement, it is helpful to first possess an understanding of the mechanisms of auditory-motor synchronization. One can obtain this understanding by examining research classified in the first three levels of the Rational-Scientific Mediating Model (R-SMM) (Thaut, 2000). These levels consist of musical response models, non-musical parallel models, and mediating models.

First, it is necessary to identify brain structures involved in the perception and production of rhythm, structures that are also involved in planning, coordinating, and executing motor functions. Next, one must examine non-musical parallel models, for example, the naturally occurring rhythmical components of movement and the effect of velocity and motor timing on movement efficiency. If one finds similar patterns in studies between these two categories, it is only then appropriate to investigate research in mediating models. For example, one can study the strategies people employ during synchronization tasks as well as the effect of auditory stimuli on components of movement in healthy individuals. Then, if auditory-motor synchronization has been found to elicit greater efficiency during movement, it is appropriate to study the relationship between this improved efficiency and implications for improved physiological responses during exercise. Therefore, by utilizing the R-SMM, one is able to develop a firm foundation on which to build

evidence-based knowledge concerning the effectiveness of facilitative auditory stimuli on physiological responses during treadmill-running.

Musical response models. First, it is important to identify brain structures utilized in the perception and production of rhythm. Harrington, Haaland, and Knight (1998) studied brain structures involved in time perception in subjects with left, right, or no cerebral damage. Subjects listened to two pairs of tones and were asked to determine if the period of time between the notes in the second pair was longer or shorter than the time between notes in the first pair. Participants also performed a frequency discrimination task, which accounted for brain processes unrelated to time that were shared by both tasks. After controlling for the frequency task, results indicated that only patients with right hemispheric damage had difficulty with the time discrimination task. When the researchers utilized Magnetic Resonance Imaging (MRI) to identify the location of the damage, they found that patients with damage to the right prefrontal-inferior parietal region performed poorly on the rhythm perception task, suggesting that this region plays an important role in time perception.

Furthermore, when studying the performance of patients with Parkinson's disease compared to healthy controls on a motor timing task, Harrington, Haaland, and Hermanowicz (1998) found that patients with Parkinson's performed significantly worse on this task than the controls. People with Parkinson's disease experience cell death and dysfunction in the basal ganglia, a region of the brain involved in tasks including, but not limited to, motor control and cognition. The results of this study

indicate that the basal ganglia plays a role in motor timing tasks as the researchers controlled for demands of auditory perception.

The temporal lobe also plays a significant role in rhythmic processing and reproduction (Penhune, Zatorre, & Evans, 1998). This study was comprised of patients with epilepsy with portions of either their left or right temporal lobe removed. They were asked to imitate either an auditory or visual rhythm by pressing a key. Results indicated that participants with right temporal cortectomies performed worse than the other group on the auditory rhythm task but not on the visual task. These findings suggest that the right temporal lobe is involved in auditory perception tasks.

In another study, the cerebellum has been shown to play a key role in rhythmic processing (Molinari, Leggio, De Martin, Cerasa, & Thaut, 2003). Participants included those with atrophy of the cerebellum, those with focal damage to the cerebellum, and healthy controls. They were asked to tap in synchrony with auditory stimuli that changed in tempo.

Results indicated that participants who had atrophy of the cerebellum performed this task significantly less accurately than the other two groups. In addition, this group also had more difficulty perceiving changes in tempo compared to the other two groups. The major function of the cerebellum is the coordination of movement. Therefore, it is not surprising that people with atrophy (or general damage) to the cerebellum experienced more difficulty in auditory-motor tasks compared to those with more localized damage and to healthy subjects.

To summarize, identifying brain structures involved in time perception and execution is imperative as these structures are also essential in planning, coordinating, and executing movements, for example, the right prefrontal-inferior parietal region, basal ganglia, and cerebellum (Harrington, Haaland & Knight, 1998; Harrington, Haaland, & Hermanowicz, 1998; Molinari et al., 2003). In addition, the right temporal lobe plays a crucial role in time perception (Penhune et al., 1998).

Until recently, researchers have merely identified structures that play important roles in auditory-motor synchronization. However, identifying these structures does not allow one to determine what specific roles each structure plays during an auditory motor task. In addition, the relationships or functional connectivity among these structures is not defined simply via identification of the structures. Furthermore, identifying these structures does not necessarily imply that the structures drive the auditory-motor interaction. One can define these relationships by utilizing functional magnetic resonance imaging (FMRI). This technique uses MRI to measure hemodynamic response in relation to neural activation. In other words, FMRI allows researchers to identify the areas of the brain that are activated during a given function or task.

Chen, Zatorre, and Penhune (2006) utilized FMRIs to identify the functional connectivity between brain structures in an auditory-motor task. In this study 12 subjects clicked on a computer mouse in synchrony with an external, auditory stimulus. Each subject participated in five conditions. During each condition, the subjects tapped in synchrony to an auditory stimulus with an inter-stimulus interval (ISI) of 600 ms (meaning the onset of each presentation of the tone was separated by

600 ms). Each tone in every condition was of equal length. In the first condition, all tones were of equal amplitude, where no metric pattern existed. In subsequent conditions, researchers adjusted the amplitude of every third tone so that the accented versus unaccented tones created a triple meter. The amplitude of the accented tone was highest in the fifth condition, creating the most audible metric structure.

Results indicated that as the metric structure increased, subjects increased tap duration during the accented tone even though the duration of this tone was equal to the duration of the unaccented tones. FMRI data showed that as the metric structure increased, the activity increased in both the posterior superior temporal gyrus and the dorsal pre-motor cortex. Furthermore, the functional connectivity between the two regions also increased. Results of this study suggest that as metric structure becomes evident, the relationship between the auditory and pre-motor cortices is strengthened, where sensory cues affect motor planning.

In addition to examining brain structures that play roles in auditory-motor synchronization, it is also helpful to study synchronization at the spinal level by examining audio-spinal facilitation. Rossignol and Melvill Jones (1976) found that auditory stimuli specifically designed not to invoke a startle response still caused excitability in spinal motor neurons. They measured the effect of auditory tones presented at 110 decibels (dB) on the H-Reflex, a reaction of muscles following stimulation of sensory fibers. The authors electrically stimulated the popliteal nerve during both silence and the presentation of the auditory stimuli. They recorded the reflex using electrodes attached to either the lateral or medial head of the gastrocnemius. The amplitude of the H-Reflex increased as the amplitude or volume

of the auditory stimulus increased. The authors noted that even when the stimulus was presented at 90 dB, the amplitude of the H-Reflex doubled. Thus, they concluded that auditory stimuli, for example music, can be utilized to facilitate the priming of muscles for movement.

Non-musical parallel models. The next step is to review research in non-musical parallel models in the sensorimotor domain. Chen, Ding, and Kelso (2001) had subjects press and release a key on a keyboard in synchrony and asynchrony with a single tone presented at a constant tempo. The researchers examined the synchronization errors (SE), defined as the duration between the stimulus and response tap, during the given tasks and found that these errors were related to future errors in the same task. These results suggest a higher and more global level of cortical processing.

The cerebellum also plays a role in rhythmic production and perception. Ivry and Keele (1989) examined subjects' performing a rhythmic production task as well as perception tasks of duration and loudness. They found that subjects with cerebellar damage performed worse on the production and duration-perception tasks compared to healthy controls, subjects with Parkinson's disease, and subjects with cortical damage and peripheral neuropathy. These results suggest that the cerebellum is not only involved in motor timing, but time perception as well.

Mushiake, Inase, and Tanji (1991) studied brain activation areas in monkeys in both a visually guided an internally guided sequential motor task. Results indicated no differences between the two tasks concerning activation of the primary

motor cortex. In general, the supplemental motor area displayed more activation during the internally-guided task while the pre-motor area displayed more activation during the visually-guided task, indicating a greater necessity for motor planning during the visual task.

After examining brain structures and networks associated with movement, it is also beneficial to study neurons at the spinal level. Central Pattern Generators (CPGs) play an important role in rhythmical movement. A CPG is a neuron or group of neurons that displays rhythmical activity without sensory input. Two common examples of CPGs include those that produce the rhythmic movement of insects' wings in flight, as well as those that produce the swimming movements in fish.

Duysens and Van de Crommert (1998) reviewed a number of studies that provide evidence for the existence of CPGs in human gait. Evidence consists of flexor reflex afferents, rhythmic movements in patients with spinal-chord injuries (where patients lack supra-spinal input), and sleep-related periodic leg movement in patients with spinal-chord injuries. If people with spinal-chord injuries lack supra-spinal input, then this rhythmical activity must come from spinal neurons.

The authors also point to studies where electrical stimulation of the spinal-chord in patients with spinal-chord injuries elicits reciprocal electromyogram (EMG) activity in symmetric muscles. Electromyograms are records of electrical activity, displaying the electrical potential of muscle cells when they contract and when they are at rest. To measure this potential, electrodes are either inserted into the muscle tissue, or surface electrodes are placed on the skin. Therefore, even if one can't see a

muscle contracting, the presence of EMG activity indicates neural activity in that muscle.

In addition, the authors point to research where in vibration induced air-stepping, a procedure where a healthy subject suspends one leg horizontally in a weightless chamber, vibration of a muscle in the suspended leg induces rhythmical EMG patterns in both legs where EMG activity is symmetrically organized around the hips. The authors also discuss the innate ability of infants to move their legs in a simulated gait pattern when externally supported.

Rhythmic movement in humans, including gait, is comprised of three components: supra-spinal influence, Central Pattern Generators, and sensory feedback (Zehr & Duysens, 2004). Under typically occurring circumstances, gait is relatively automatic and requires few cognitive demands. However, cognitive demands increase during difficult conditions such as uneven terrain.

It is also important to understand that CPGs, like other neuro-circuits, can be modulated internally (within the circuit itself) or externally originating from higher-order control neurons, circulating neurohormones, or from sensory neurons (Katz, 1995). Furthermore, external modulation can affect many different levels of motor organization such as CPG circuits, motor neurons, and muscles. For example, timed sensory inputs (such as kinesthetic feedback from a treadmill) aid in the reconfiguration of spinal networks in patients with spinal-chord injuries (Marder & Bucher 2001). These findings not only suggest that CPGs play an important role in human gait, but that these CPG circuits can also be externally modulated through

afferent input. This afferent input can consist of kinesthetic feedback (e.g., a treadmill) or it can consist of auditory input (e.g., music).

In addition to studying CPGs, it is also useful to examine movement performed at various velocities. When Hof, Elzinga, Grimmius, and Halbertsma (2002) studied EMG patterns of subjects walking at five different velocities, they found that although EMG profiles varied among velocities, they exhibited similar patterns, thus, lending evidence to the role of CPGs in gait.

Nagasaki (1989) studied subjects' flexing and extending their elbows in order to align hand-held pointers with various targets at three velocities. Results indicated that at a medium velocity, subjects moved their arms with greater symmetry in velocity and acceleration than they did during the slow and fast conditions. These results indicate that muscles contract with greater symmetry, thus creating more efficient movements, at a given velocity.

Mediating models. Next, it is helpful to examine research mediating musical and nonmusical parallel models. For example, results of a study by Schepens and Delwaide (1995) indicated increased EMG amplitude of leg muscles during gait at the presentation of a loud, auditory stimulus. This finding supports that of Rossignol and Melvill Jones (1976) as previously discussed. Since auditory stimuli is capable of inducing changes in neuro-motor recruitment patterns, then one can utilize such stimuli to facilitate more efficient movement.

Before diving in to the intriguing possible effects of such auditory stimuli on movement parameters, it is first necessary to understand certain concepts and

strategies related to synchronization, for example, auditory feedback, music versus metronome-cuing, and period versus phase-correction. Research has shown that when tapping to an auditory stimulus, people tend to make negative synchronization errors (SEs), where the tap precedes the stimulus. This error is greater when tapping with a foot versus with a hand (Aschersleben & Prinz, 1995). In this same study, researchers discovered that when adding auditory feedback to the auditory synchronization task, the auditory and kinesthetic feedback combined to decrease this SE although the SE was not completely reduced to zero.

Thaut, Rathbun, and Miller (1997) studied synchronization at various tempos with a metronome compared to music with imbedded metronomic clicks. The authors measured SE and inter-response intervals (IRIs) of college students and elderly subjects. It is first important, though, to reiterate the definitions of some common terms concerning synchronization as defined by the authors before discussing the results of this study. Synchronization error (SE) is defined as the duration between the auditory stimulus and the response tap. The inter-stimulus interval (ISI) is the duration between each click/tone that comprises the auditory stimulus. Finally, the inter-response interval (IRI) is defined as the duration between response taps.

The authors found that for both the college and elderly groups, SE was significantly reduced in the music condition at one, two, and four Hz, where HZ is the number of clicks per second. At three Hz (180 BPM), SE was equal for both conditions although it was positive during the music condition, with the tap following the click, and negative during the metronome condition, with the tap preceding the

click. When examining effects on IRIs, music reduced variability at one Hz. IRI increased with the ISI, but it remained constant as a percentage of the ISI.

This leads to another important concept, phase versus period correction. During synchronization tasks, people employ different methods depending on the situation (Hasan & Thaut, 1999; Semjen, Vorberg, & Schulze, 1998; Thaut & Schauer, 1997). Thaut, Miller, and Schauer (1997) found that people tend to synchronize to period versus phase. This means that one does not synchronize to each auditory click or pulse but, instead, to the ISI, the duration between pulses. However, phase-correction is employed when perturbation levels of the ISI are greater than five percent of the SE.

To reiterate, when the ISI remains constant, people synchronize via period over phase corrections.

One might wonder why, in a paper concerned with exercise physiology, so much space and effort are devoted to describing synchronization strategies. At an elementary level, it is easy to mistake auditory-motor synchronization by equating the brain with an automobile driver sitting at a traffic light. In this inaccurate comparison, auditory-motor synchronization would not occur until the next "click" or "beat." The brain would wait patiently, and when it received the signal, it would spring into action and drive the motor response, for example, a finger tap or a step.

However, it is imperative to understand that we do not synchronize to each, individual tap but, instead, employ long-term, higher level synchronizations strategies as previously discussed (Chen et al., 2001). Furthermore, we synchronize to the period or duration between stimuli, the ISI, not to each presentation of the stimulus

(Thaut, Miller, & Schauer, 1997). In this accurate interpretation of the research, the auditory stimuli drive the motor response. For example, if one walks in synchrony to a stimulus with an ISI of .5 seconds and steps exactly halfway between each stimulus, the SE would equal .25 s, but the IRI would still equal .5 s. In this hypothetical scenario, the individual is synchronizing to the period but not the presentation of each stimulus, a small comfort for the marching band member unable to step to the drummers' beat.

McIntosh, Prassas, Kenyon, and Thaut (1998) confirm this concept by studying elbow flexion/extension synchronized to an auditory stimulus. When the auditory stimulus was moved from the endpoints to the midpoint of the motion, the spatial/temporal components of the movement remained stable. These results demonstrate that subjects synchronized to the duration between the stimuli rather than each individual presentation.

It is proposed that rhythm can facilitate precision of one's own internal timing (Kenyon & Thaut, 2003). Thus, because people synchronize to the duration between auditory stimuli, the stimuli cue the timing of the entire movement pattern, not just the endpoints. Because the timing of the entire pattern is more precise, the kinematics of the movement are also more precise. This is an imperative concept to understand because it is the difference between the cuing of an endpoint versus the entire movement, for example, a heel strike versus the kinematics of an entire stride. If auditory stimuli were only capable of cuing a heel-strike, the practical results/implications would likely be minimized to insignificance. However, because

auditory stimuli seem to, indeed, cue the entire stride, its use in exercise physiology studies is worth investigating.

This cuing of movement is evident through the examination of research concerning EMG activity and kinematics when movement is synchronized with external, auditory stimuli. Safranek, Koshland, and Raymond (1982) studied subjects' flexing/extending their elbows to hit various targets with hand-held pointers. This experiment consisted of two trials. During the first trial, subjects performed the task without rhythmic cuing, and researchers found that they all tended to move at a similar velocity. During the second trial, the subjects were divided into three groups. The first group performed the task as they had done previously. The second group performed the task while synchronizing the movement to an uneven rhythm while the third group synchronized to an even rhythm. EMG data indicated that for both the first trial and the group that performed the task with no rhythm in the second trial, biceps and triceps muscles contracted as reciprocals of each other. However, the two groups that performed this task to a rhythm displayed an overlap in the contraction of these antagonistic muscles. The biceps would contract even before the elbow was fully extended. Researchers suggest that this contraction was meant to decelerate the movement in order for the subjects to hit the target in synchrony with the beat. Finally, it is important to note that subjects in the group with the uneven rhythm displayed significantly more muscle variability than subjects in the even group.

Thaut, Schleiffers, and Davis (1991) replicated this study, replacing the uneven rhythm condition with a condition where the metronomic tempo was 30 percent less than the subject's internally pre-established tempo. Results indicated that

for the group where tempo was matched to preferred velocity, there was significantly less variability in the EMG of the triceps prior to contact with the target. In both groups with auditory rhythm, there was an increase in co-contraction. These two studies illustrate that auditory rhythm, particularly when match to preferred velocity, cues the entire flexion/extension movement by facilitating more efficient neuro-motor recruitment patterns.

When examining studies concerned with synchronization of gait to auditory stimuli, one finds that the results are relatively consistent with slight variations. Prassas and Thaut (1992) studied gait parameters of three females. The subjects were videotaped walking at their preferred cadence. Next, music was added at a tempo that matched the subjects' cadences. The researchers found minimal effects in gait parameters from the addition of the music in aspects such as stride length, range of motion in the hip and knee joints, center mass velocity, vertical displacement, and trunk angle.

Miller, Thaut, McIntosh, and Rice (1996) studied gait parameters and EMG activity in both healthy subjects and subjects with Parkinson's disease in non-musical and synchronization conditions. While the subjects with Parkinson's showed significant changes with the addition of Rhythmic Auditory Stimulation (RAS) (Thaut, 1999), the healthy controls did not. The authors proposed that RAS affects specific aspects of motor control rather than producing a "generic" gait. It is important to note, though, that although the healthy subjects did not display significant changes in gait parameters, they exhibited trends consistent with the changes of the subjects with Parkinson's. These trends included changes in the timing

variability and shape-symmetry of the tibialis anterior and vastus lateralis muscles as well as swing symmetry, velocity, and stride-length.

Thaut, McIntosh, Prassas, and Rice (1992) measured the effect of rhythmic cuing on gait parameters of healthy subjects by comparing a music and non-music condition at three different cadences. During the music condition, tempo was matched to cadence. Researchers found that rhythmic cuing facilitated significant changes ($p < 0.05$) in stride-symmetry and delayed onset and shorter duration of gastrocnemius EMG, providing evidence that rhythmic cuing facilitates more efficient neuro-motor recruitment patterns.

Implications for Physiological Responses during Exercise

It is now appropriate to discuss the effect of changes in neuromuscular recruitment on physiological responses during exercise. Studies have shown correlations among EMG activity, lactate levels, and salivary amylase (Chicharro, Pérez, Carvajal, Bandrés, & Lucía, 1999) and among EMG activity, lactate, and plasma catecholamine (Chwalbinska-Moneta et al., 1998). During exercise, blood lactate increases when the rate of production exceeds the rate of removal; an increase in blood lactate can influence muscle fatigue. As fitness level increases, lactate levels decrease at a given intensity.

It is worth noting that some researchers suggest that a relationship exists between locomotor and cardiovascular synchronization via connections between the cardiovascular centers in the brain and CPG circuits in the spinal-chord (Nomura,

Takei, & Yanagida, 2003). This concept will not be explored further in the present review of literature as the primary topic is auditory-motor synchronization.

The regulation of neuromuscular recruitment patterns has been shown to affect physiological responses and perceived exertion. Lay, Sparrow, Hughes, and O'Dwyer (2002) studied the effect of practice on such variables by having subjects participate in ten exercise sessions on rowing ergometers. Muscle activation patterns increased in coordination, demonstrating a change in neuromuscular recruitment. Results also indicated significant decreases in VO_2 and RPE as well as non-significant decreases in HR.

Sparrow, Hughes, Russell, and Le Rossignol (1999) studied the effects of practice and preferred rate during a rowing task. They found significant decreases in HR and RPE and non-significant decreases in VO_2 as a result of practice. When rowing at a preferred rate versus a non-preferred rate, subjects displayed significant decreases in all three variables.

A relationship between EMG activity and physiological responses is further solidified with evidence from a study where researchers altered neuromuscular recruitment patterns while keeping exercise intensity constant (Deschenes, Kraemer, McCoy, Volek, Turner, & Weinlein, 2003). Subjects participated in two cycling sessions lasting 30 minutes each. They peddled at 40 revolutions per minute (RPM) during one session and 80 RPM during the other; they received both visual and metronomic cues to maintain these cadences. Researchers adjusted the resistance against the cycle ergometer flywheel so that during both sessions, subjects exercised at 50-55 percent of their VO_{2max}.

Researchers measured EMG activity in the vastus medialis and vastus lateralis muscles and established that the 40 RPM condition elicited more pronounced muscle activation than the 80 RPM condition. Thus, the muscular recruitment patterns differed between conditions, but exercise intensity remained consistent.

The 40 RPM condition yielded significantly higher HR values ($p < 0.05$) at the conclusion of and post-exercise. Furthermore, in the 40 RPM condition, blood pressure and lactate values were elevated longer post-exercise, cortisol was elevated, and RPE was higher. To summarize, exercise intensity was kept constant, so the physiological and RPE changes between the two conditions were likely due to the alteration of neuromuscular patterns as well as the increase in force production by the muscles from the increased resistance during the 40 RPM condition. Thus, the 40 RPM condition was harder on the muscles even though the workload did not change across the two conditions.

According to the extant literature, synchronization with an external, auditory stimulus facilitates more efficient neuromuscular recruitment, thereby making the movement more efficient. The stimulus serves to cue the entire movement pattern as people synchronize to the duration between beats rather than each, individual beat. The reviewed literature also suggests a relationship between muscular recruitment patterns and physiological responses during exercise. Therefore, it is worth investigating the effect of synchronization to an external auditory stimulus on physiological responses and perceived exertion during exercise.

As previously discussed, the majority of studies concerned with the effect of music-listening during exercise have not addressed the mechanisms that enable music

to facilitate more efficient movement. Szmedra and Bacharach (1998) studied males participating in a repeated measures design where they ran on treadmills to up-beat music and in silence. The order of the treatment conditions was randomly assigned. Researchers measured variables including RPE, HR, and blood pressure every three minutes throughout the experiment and norepinephrine and plasma lactate pre and post-exercise. Results indicated that when running with music in the background, subjects displayed significantly lower HR, blood-pressure, and RPE than when running in silence. Post-exercise lactate levels were also lower after the music condition. The authors suggest that the music may have helped subjects to relax, producing the significant differences in physiological responses. However, given the research concerning auditory-motor synchronization, these results may have been due to the subjects running in synchrony with the music. One cannot make this statement with confidence, though, since the synchronization was never measured or manipulated. The difficulty in interpreting the results of this study is that one is not clear concerning the mechanisms that facilitated the significant differences.

Purpose

The purpose of the present investigation was to determine the effect of synchronization to an external, auditory stimulus on RPE as well as on physiological responses including volume of oxygen consumption, blood lactate, and HR when running on a motorized treadmill at 70 percent of maximum intensity.

Research questions. (1) Does a difference exist concerning the effect of synchronous, asynchronous, and no music on volume of oxygen consumption, blood lactate, heart rate, and rating of perceived exertion during treadmill running?
(2) Do physiological responses and perceived exertion change over time during an exercise session?
(3) Do interactions exist among treatment conditions and time during an exercise session concerning physiological responses and perceived exertion?

Null hypotheses. (1) No significant differences exist concerning the effect of synchronous, asynchronous, and no music on volume of oxygen consumption, blood lactate, heart rate, and rating of perceived exertion during treadmill running.
(2) No significant differences exist concerning changes in physiological responses and perceived exertion over time during an exercise session.
(3) No significant interactions exist among treatment conditions and time during an exercise session concerning physiological responses and perceived exertion.

CHAPTER III
METHOD

Participants

Thirteen subjects were recruited for this study. However, two individuals were not eligible to participate because they reported using sports supplements. Three individuals did not complete all of the trials due to fatigue, discomfort from the breathing apparatus, and scheduling conflicts. Therefore, eight participants were included in the data analysis, five females and three males. They ranged in age from 21-31 years. They were recruited through flyers distributed on the campus of Western Michigan University (see Appendix A) as well as via word of mouth. All participants were recreationally active, meaning they exercised or were physically active between 1.5 and 10 hours per week but were not involved in organized competitive sports. Musical background ranged from zero to 19 years of private instruction and zero to 18 years of ensemble participation. Table 1 shows means and standard deviations of subject descriptors as well as of preference ratings of the musical selection utilized in this study (see Appendix C).

Each participant completed a health screening questionnaire (see Appendix B) to determine his or her level of risk stratification as outlined in the guidelines established by the American College of Sports Medicine ([ACSM], 2000). Only participants with the ACSM Risk Stratification Level of Low Risk were eligible to participate in the study. All participants reported that they did not use any sports supplements or tobacco. In addition, they were asked to refrain from alcohol,

caffeine, and exercise 24 hours before each trial. With the exception of refraining from exercise 24 hours prior to each trial, participants were asked to maintain their normal exercise routines.

All trials took place in the Exercise Science Laboratory located in the Student Recreation Center on the campus of Western Michigan University.

Table 1: Means and Standard Deviations of Subject Descriptors

Subject Descriptor	Mean	SD
Age	25.6	3.3
BMI (kg/m^2)	21.8	1.9
Exercise (#h/w)	5.2	2.4
Resonant Frequency (#s/m)	161.9	11.0
VO_{2max} (mL/kg/min)	46.3	5.8
Mus Lessons (#yr)	6.0	7.8
Mus Ensemble (#yr)	6.5	6.7
Mus Preference Rating	3.0	0.9

Research Design

This experiment employed a repeated measures design as all participants completed all trials. The order of these trials was randomly assigned to each participant. For six participants, trial order was counter-balanced utilizing a Latin Square Design.

Procedure

Materials included a health screening form used to identify participants who may have had medical conditions that would have put them at risk while participating in this study (see Appendix B). Participants also completed a brief questionnaire containing background information including contact information, history of musical training, and a preference rating of the music that would be utilized in the experiment (see Appendix C). HR was measured with telemetry, (Polar Electro OY, Kempele, Finland), and RPE was measured using Borg's (6-20) Rating of Perceived Exertion scale (see Appendix D) (Borg, 1970).

VO_{2max} was measured with a ParvoMedics TrueOne 2400 Metabolic Measurement System, (Sandy, UT). A Microsoft Excel program was used to obtain a regression equation with VO_2 as a function of velocity to calculate a velocity that would produce an intensity of approximately 70 percent of VO_{2max} at zero percent grade.

Blood samples were obtained through finger sticks using automated lancets, and the blood was analyzed for lactate concentration using an automated analyzer (Analox GM7, Lunenburg, MA). Running cadence was assessed using a stop-watch feature of a Braille Note, (an adaptive note-taking device with a Windows operating system).

Participants ran on a Quinton motorized treadmill (Q65, Quinton Instrument Company, Brothell, WA) and listened to music through ear-phones (UM1, Westone Laboratories, Inc., Colorado Springs, CO) connected to an iPod Shuffle. The music was composed/arranged by the student researcher and her major advisor using the

software program Band-in-a-Box v.12, by PG Music. The music contained imbedded metronomic clicks and was in 4/4 time. Musical selections were identical for the asynchronous and synchronous conditions with the exception of tempo. The tempo of the asynchronous music equaled 70 percent of the tempo of the synchronous music. The tempo of the music during the synchronization condition was equal to each participant's running cadence at 70 percent of his or her $\dot{V}O_{2max}$.

The experiment consisted of an orientation session, an assessment trial, and three experimental trials. During the orientation session, the student researcher explained the research protocols to the participants and allowed them to ask any questions they had concerning the procedures. If they were still interested in participating, they read and signed the informed consent document (see Appendix E) that was approved by the Human Subjects Institutional Review Board. Next, they completed the health screening and background information questionnaires.

During the assessment trial, each participant's height and weight was first measured. The participant then ran on the motorized treadmill for approximately one minute to determine a comfortable velocity that induced running at a moderate intensity. Next, the participant was fitted with a HR monitor as well as with a nose clip and mouthpiece for the collection of expired respiratory gases using the metabolic measurement cart. After the participant was familiarized with the RPE scale, he or she walked on the treadmill for two minutes at 3 MPH, jogged/ran for two minutes at 5 MPH, and ran at the pre-determined velocity for two minutes at zero percent grade. Next, during each subsequent minute, the grade was increased by 2.5 percent. HR, RPE, and VO_2 were recorded at the end of each stage. The participant

continued to run until the point of volitional fatigue. The participant then walked for five minutes, which served as an active cool-down.

After a ten-minute rest period, the participant ran for one minute at a velocity correlated with 70 percent of his or her VO_{2max} at zero percent grade as estimated by the regression equation, and the student researcher calculated running cadence.

The three experimental trials consisted of no music, asynchronous music, and synchronous music. The order of trials was randomly assigned to each participant, and each trial lasted approximately 35 minutes. Four to 12 days separated each trial with two exceptions. For two subjects, the second and third experimental trials were separated by 17 and 29 days due to scheduling conflicts and illness.

Upon arrival to the laboratory for the experimental trials, each participant was weighed and instructed to sit for 10 minutes before a resting blood lactate sample was collected. Next, the participant was again fitted with a HR monitor as well as with a nose clip and mouthpiece, and he or she was again familiarized with the RPE scale. The participant walked on the treadmill for two minutes at 3 MPH, which served as a warm-up. Next, he or she ran for 20 minutes at a velocity correlated with 70 percent of VO_{2max}. Finally, the participant walked for three minutes, which served as a cool-down. During the two music conditions, music was only played during the 20-minute running period. Blood lactate, VO_2, HR, and RPE were recorded every five minutes during this 20-minute period. The participant's cadence at the midpoint of each five-minute period was also measured to identify any changes in cadence and to determine if these changes during each period affected the other dependent variables as recorded at the end of each period.

CHAPTER IV
DATA ANALASYS AND RESULTS

Data concerning volume of oxygen consumption, blood lactate, HR, RPE, and cadence was analyzed using a two-way ANOVA with repeated measures on both factors, where sample size $n = 8$. The factors consisted of treatment (three levels) and time (four levels). A fifth time level was utilized when analyzing blood lactate as baseline measures were taken for this variable. The level of statistical significance was established as $p \leq .05$. The SPSS statistical package was used for data analysis, and the Tukey HSD test was utilized for post-hoc comparisons.

Concerning cadence, the analysis yielded no significant main effects for treatment or for time, $p = .511$ and .137 respectively. The treatment by time interaction was also not significant, $p = .507$. Figure 1 shows the means and standard deviations of cadence values while Figure 2 shows these statistics as percentages above or below the resonant frequency calculated during the assessment trial.

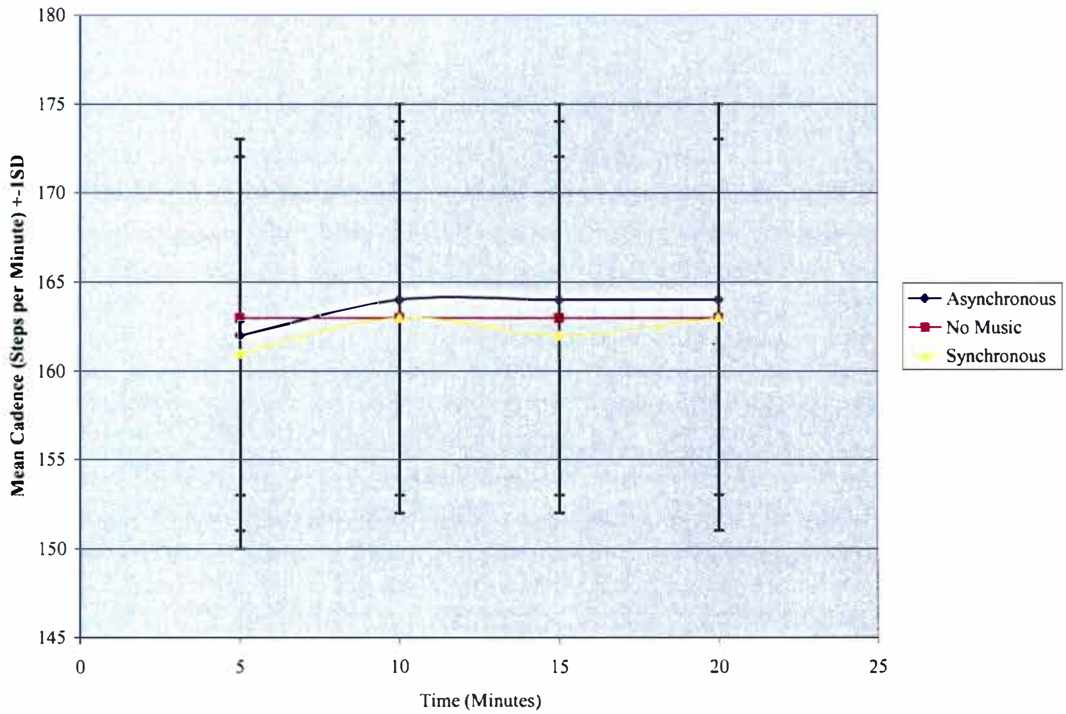

Figure 1: Effect of Music Condition and Time on Cadence

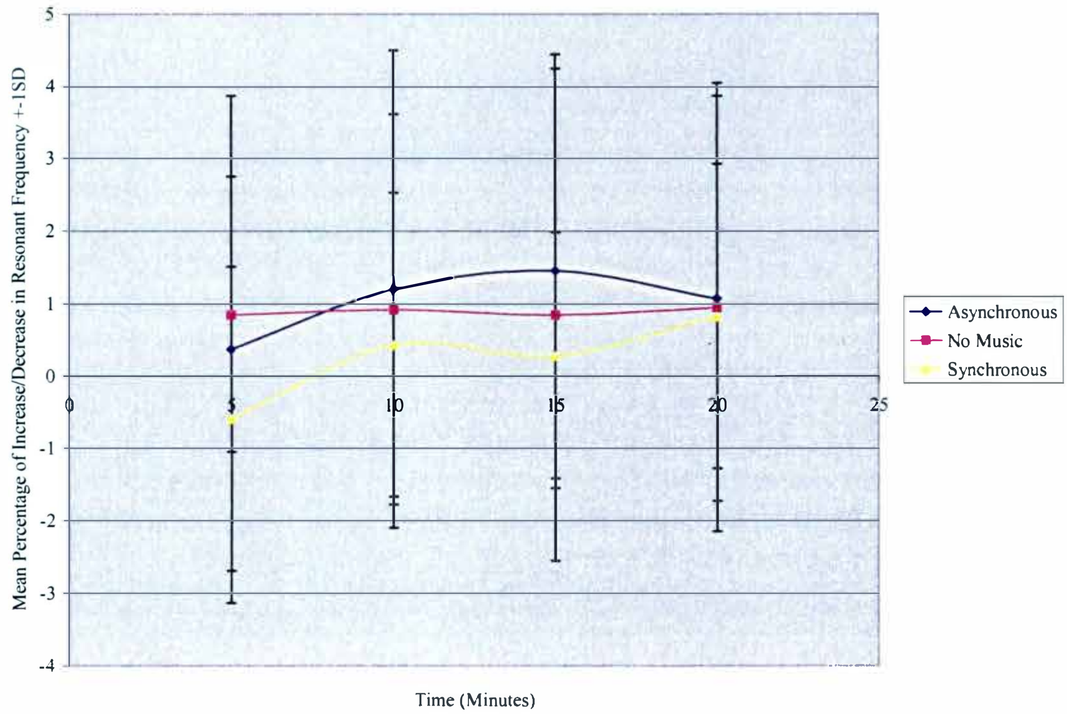

Figure 2: Percent Increase or Decrease of Resonant Frequency

The main effect of treatment on RPE was not significant, $p=.894$, nor was the treatment by time interaction, $p=.953$. The main effect of time on RPE was significant, where $p<.001$. Post-hoc comparisons revealed significant differences for all pairs of time points, $p<.05$. Means and standard deviations are shown in Figure 3.

Figure 4 shows means and standard deviations for HR over time and across conditions. No significant differences were found regarding a main effect for treatment or interaction effect. The main effect for time on HR was significant, $p<.001$. Post-hoc comparisons revealed significant differences, $p<.05$, between five and ten, five and 15, five and 20, and 10 and 20 minutes.

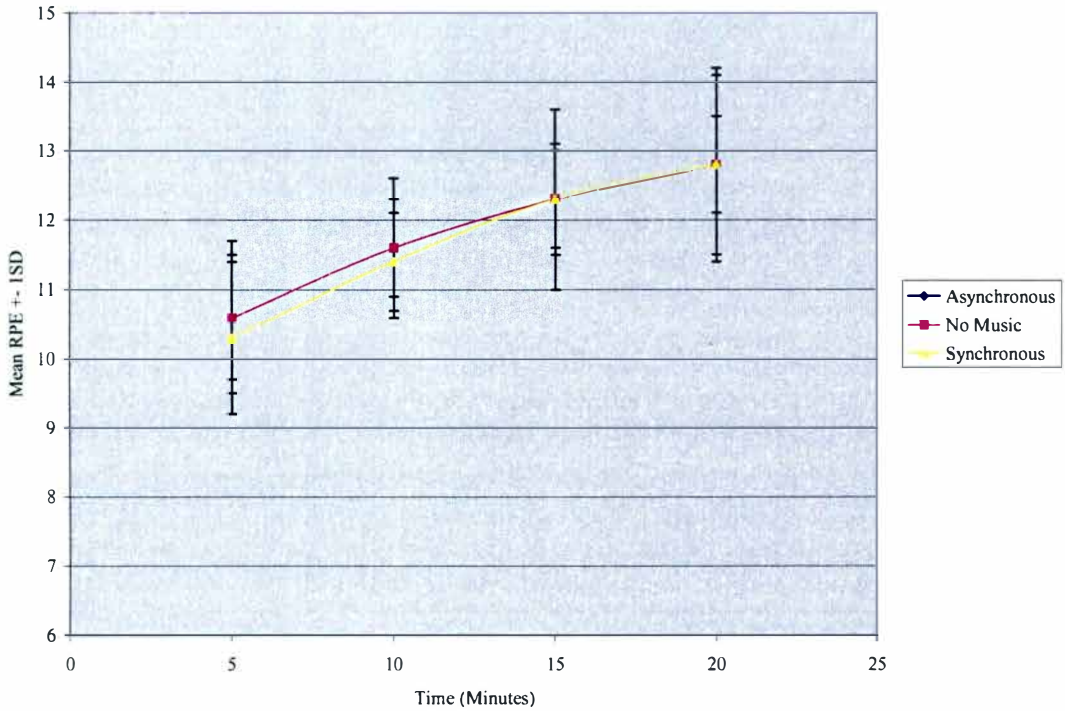

Figure 3: Effect of Music Condition and Time on RPE (Note: The asynchronous line is not visible as RPE values are identical to those in the no music condition).

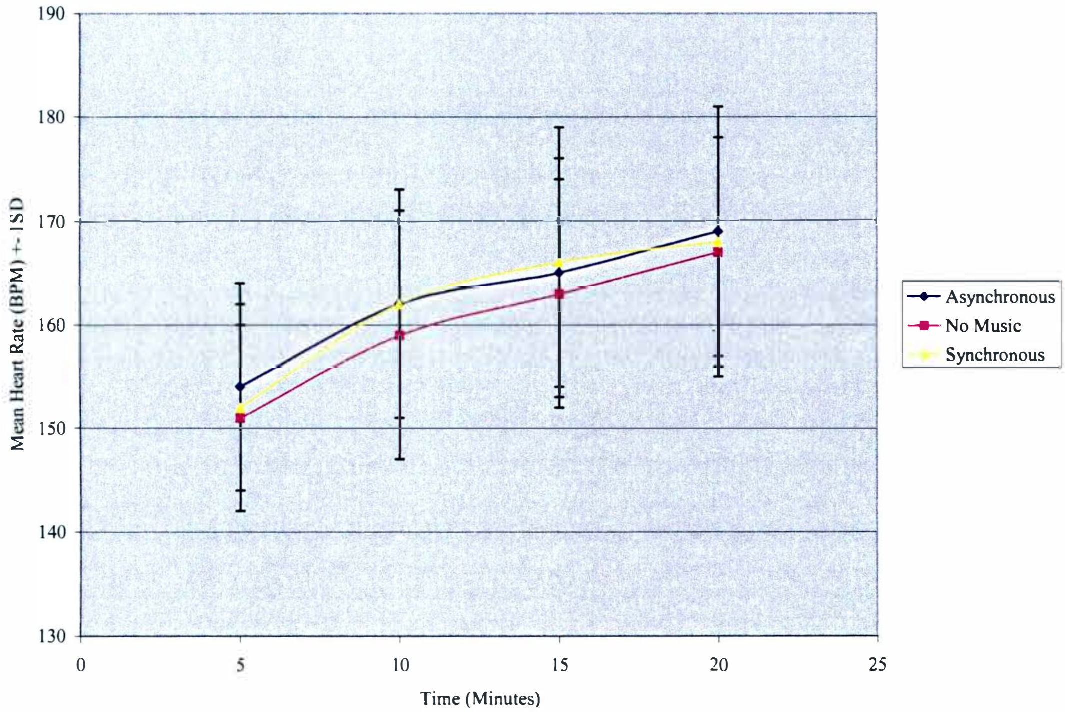

Figure 4: Effect of Music Condition and Time on Heart Rate

Means and standard deviations for VO_2 are shown in Figure 5. The treatment and interaction effects were not significant, p=.982 and .136 respectively. The main effect for time was significant, p=.011. Significant differences, p<.05, were found between five and 10 as well as between five and 20 minutes. Means and standard deviations of percent VO_{2max} are shown in Table 2 for each treatment condition.

Blood lactate means and standard deviations are shown in Figure 6. The treatment and interaction effects for blood lactate were not significant, p=.305 and .172 respectively. The main effect for time was significant, p<.001, with post-hoc comparisons revealing significant differences between each time point from baseline, p<.05. Differences in each pair of time points were not statistically significant.

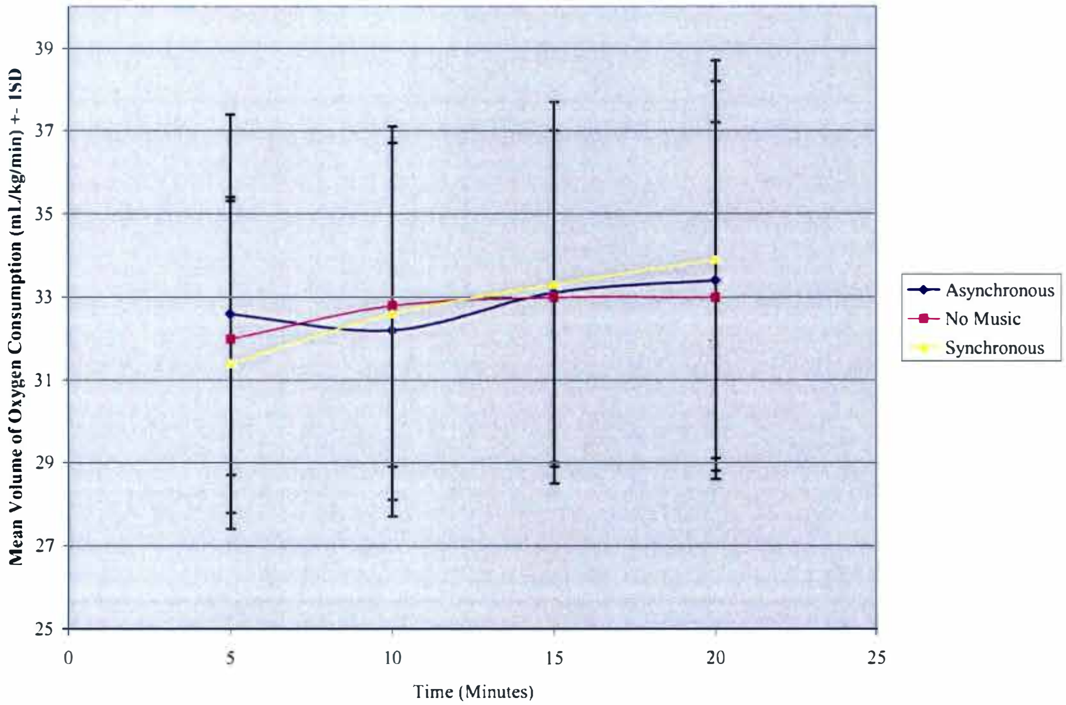

Figure 5: Effect of Music Condition and Time on VO_2

Table 2: Means and Standard Deviations of Percent VO_{2max}

Condition	Mean	SD
Asynchronous	72.6	8.5
No Music	71.6	6.9
Synchronous	72.3	7.0

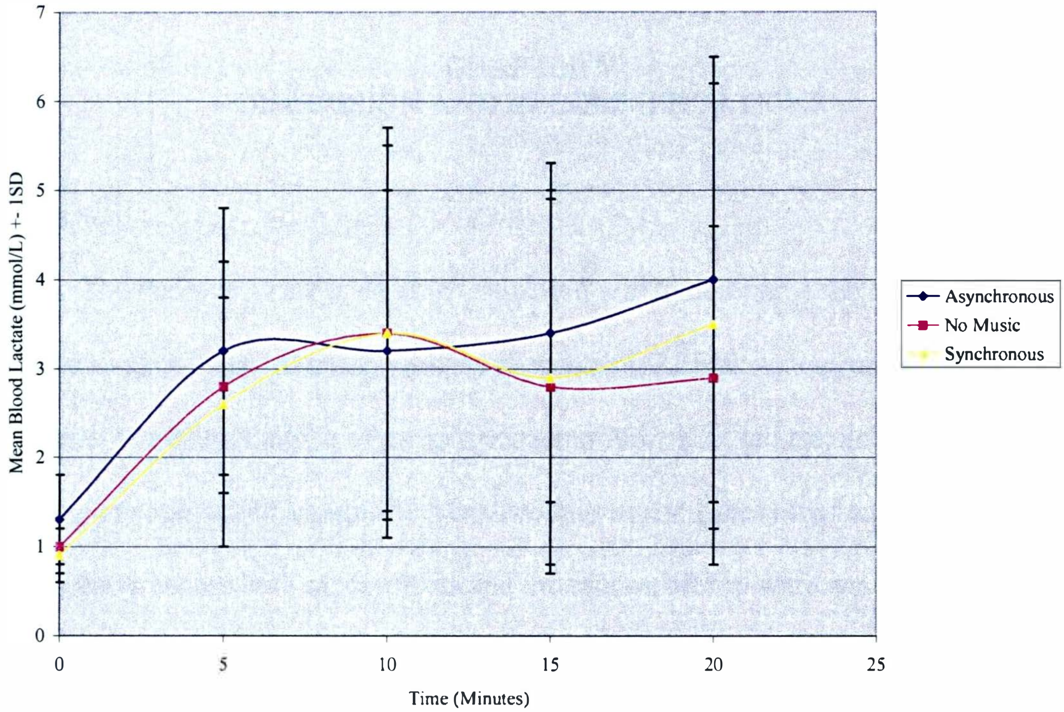

Figure 6: Effect of Music Condition and Time on Blood Lactate

CHAPTER V
DISCUSSION AND RECOMMENDATIONS

Discussion

The purpose of the present investigation was to determine the effect of motor synchronization to an external, auditory stimulus on RPE as well as on physiological responses including volume of oxygen consumption, blood lactate, and HR when running on a motorized treadmill. Music condition and time served as the two factors in this study, where both main effects and interaction effects were analyzed for significance.

According to the results of this study, the data failed to reject the null hypotheses concerning cadence. Although treatment condition and time had no significant effect on cadence, standard deviations were generally smaller during the synchronous condition at 10, 15, and 20 minutes (see Figure 2). Figure 2 is particularly meaningful as it displays the mean cadence percentages above or below the resonant frequency. This is important as the tempos of the synchronous and asynchronous music were calculated based on each subject's resonant frequency. Upon examination of the mean values and standard deviations in the synchronous condition, it is evident that the majority of subjects were not running in synchrony with the music. It is interesting to note, though, that the only negative percentage occurred during the synchronous condition, indicating a trend where subjects ran at a slightly slower mean cadence during the first five minutes of the synchronous condition compared to the other conditions. At 10, 15, and 20 minutes, the mean

percentage values were closer to zero during the synchronous versus the other conditions. This difference, although not statistically significant, indicates that on average, cadence values were closer to resonant frequency values when musical tempo was matched to resonant frequency.

Nilsson and Thorstensson (1987) observed that subjects were able to alter their stride frequency above and below their preferred frequency at various velocities. In the present study, at least ten minutes separated the VO_{2max} test from the resonant frequency assessment. It is possible that even with this rest period, the proximity of the two assessments may have affected some of the subjects' resonant frequency values. When examining the means in Figure 2, one can see that on average, subjects had higher cadence values during the three experimental trials compared to the resonant frequency values calculated during the assessment trial. It is possible that during the assessment trial, subjects would have had higher resonant frequency values if they hadn't completed the VO_{2max} test ten minutes prior to the resonant frequency assessment.

With regard to RPE, HR, VO_2, and blood lactate, the first and third null hypotheses are accepted, and the second is rejected based on the results of this study. These results contrast those from the study by Szmedra and Bacharach (1998), where background music produced significantly lower HR, RPE, and post-exercise plasma lactate values. A possible reason for this discrepancy is that the runners in the Szmedra and Bacharach study were described as being "well-trained," where the mean VO_{2max} equaled 63.4 mL/kg/min. In contrast, the subjects in the present investigation were recreationally active (see Table 1).

Hogberg (1952) reported that each runner has an optimal cadence and that for well-trained runners, the optimal cadence is the one preferred by the runners. The author also reported that an increase in stride length above the preferred one results in higher O_2 consumption compared to shortening the stride. It may be possible, then, that auditory-motor synchronization would affect trained and untrained runners differently. It should be noted, however, that other researchers have found untrained runners may benefit more in affective response during exercise from up-beat music compared to trained runners (Brownley, McMurray, & Hackney, 1995).

Another possible explanation of the differences found between results from the present investigation and the study by Szmedra and Bacharach is exercise intensity. In Szmedra and Bacharach's study, the velocity of the treadmill was increased until subjects achieved an intensity of 70 percent of VO_{2max}. This intensity was then maintained for 15 minutes.

However, in the present investigation, velocity and grade of the treadmill were kept constant during each trial. Changing the grade during a trial would not only affect neuro-motor recruitment (Simonsen, Dyhre-Poulsen, & Voigt, 1995), but it could also affect cadence. Swanson and Caldwell (2000) found that stride frequency was significantly higher during inclined versus level running on a motorized treadmill at a constant velocity. Even though the velocity to approximate 70 percent of VO_{2max} was calculated using a regression equation unique to each subject, the submaximal intensities still varied (see Table 2). This study employed a within-subjects design, so each subject ran at approximately the same intensity for all three trials. However,

physiological responses do vary across intensity levels, which may account for the difference between the results of this study and those from Szmedra and Bacharach.

In addition, in Szmedra and Bacharach's study, the second blood sample was collected after a three-minute active recovery period while the samples in the present study were collected during the exercise period. It was decided to collect the samples throughout the exercise period in order to measure treatment effects on physiological responses during exercise.

The findings from this study are in agreement with those from Roberts, Ritenhour, and Goss (2004). Physically active subjects adjusted speed and grade of a motorized treadmill to obtain an RPE of 13 and 17 while listening to liked, disliked, and no music. At an RPE of 13, music condition had no effect on selected grade, selected velocity, HR, or VO_2. This RPE represents a moderate intensity and is only slightly higher than the mean RPE values reported in the present investigation (see Figure 3). In both studies, music did not appear to have an effect on VO_2 and HR at a moderate exercise intensity.

The results of the present study also support those of Pujol et al. (2003). These authors found that at various stages of graded maximal exercise tests, preferred, non-preferred, and no music had no effect on RPE at given levels of blood lactate.

On the surface, the results of the present study appear to differ from the findings in Level III typically-occurring gait studies as discussed in Chapter II. Thaut et al. (1992) found that rhythmic cuing significantly improved stride symmetry and neuro-motor recruitment, and Miller et al. (1996) found trends in improved gait

kinematics and neuro-motor recruitment. As also noted in chapter II, though, Prassas and Thaut (1992) found minimal effects of rhythmic cuing on gait parameters.

In these three studies, subjects walked as compared to running in the present investigation. Neuro-motor recruitment is quite different between the two movement modalities (Capaday & Stein, 1987). In addition, the subjects in the three gait studies walked on the ground as compared to a motorized treadmill in the current study.

A motorized treadmill was utilized in this investigation in order to maintain a constant velocity for each participant. A constant velocity was imperative in this study in order to minimize unwanted effects on cadence values that did not result from treatment condition or time. The motorized treadmill may have interfered with the isolated effect of external auditory stimuli on the CPG as a motorized treadmill also provides afferent input to the CPG via kinesthetic feedback (Van de Crommert, Mulder, & Duysens, 1998). It is possible that this constant kinesthetic feedback from the treadmill could have also facilitated, perhaps even maximized, more efficient neuro-motor recruitment, thus masking any potential effect of auditory input. Furthermore, the auditory feedback from each heel strike could have provided auditory cuing, particularly during the no-music condition. Therefore, the subjects may have been receiving auditory cues during all three conditions instead of only receiving them during the two treatment conditions.

In addition, treadmill-walking has been shown to yield different gait parameters than walking on the ground at an equal velocity (Stolze et al., 1997). Therefore, the results of the present study can not be generalized to over-ground

running as kinesthetic afferent input and neuro-motor recruitment differ across the two running modalities.

Finally, Miller et al. (1996) note that rhythmic cuing could affect specific aspects of motor control rather than creating a generic or uniform gait. It is possible that the motor aspects are already optimized while running on a motorized treadmill at 70 percent of VO_{2max}. If this is the case, any possible effect of auditory cuing would be minimized.

Recommendations

The results of this research point to numerous exciting possibilities for areas of further study. It is this author's recommendation, should this study be replicated, to employ different participant recruitment strategies. Subjects were recruited via word-of-mouth as well as through brief announcements made to various classes. In addition, flyers were posted in the Student recreation Center. However, recruitment and data collection lasted for seven months as it was difficult to find people to participate. Two participants received extra credit through one of their classes, but these participants did not complete the study due to scheduling conflicts. Another participant did not complete the assessment trial due to discomfort from the breathing apparatus. Therefore, this author recommends specifically targeting prospective participants from Exercise Science or related programs as these students are familiar with the testing equipment. If feasible, a monetary incentive may also be more effective in encouraging completion of the study compared to providing extra credit or providing explanations to each participant concerning his or her data.

As mentioned earlier, researchers of future studies may want to assess resonant frequency on a different day than the VO_{2max} test to avoid any effect of fatigue on resonant frequency values. Another important aspect to consider is that in the present investigation, cadence was measured by counting the number of steps during a given period of time. Since people synchronize to the duration between beats instead of to the beat itself, it was assumed for the purposes of this study that if cadence equaled musical tempo, synchronization was taking place. This is not necessarily accurate, though. A participant could have altered gait components such as stride length or stance/swing phase for a few seconds during the period when steps were counted. These alterations could have affected cadence values even though the person may have been running in, or out of, synchrony with the auditory stimulus during the majority of the trial. This author recommends using foot switches in future investigations so that contact time and synchronization can be accurately recorded and measured.

Another possible modification for future studies is the collection of EMG data. This is suggested because even if cadence values remain relatively constant over time and across the three treatment conditions, neuro-motor recruitment could still vary. This would enable researchers to more directly study the effects of different neuro-recruitment patterns, as altered by auditory stimuli, on physiological responses and RPE.

In the present investigation, participants were not instructed to attempt to synchronize their steps with the beat of the music. Also, they were not informed as to the order of their trials until they had completed the entire study. It may be useful to

examine the effect of verbal instruction prior to the trials, where subjects are told to match their steps to the tempo of the music.

Furthermore, it may be beneficial to study not only synchronous versus asynchronous music, but also to investigate the effect of cadence modification at a given velocity. This could be achieved by replacing the asynchronous condition (where tempo = 70 percent of resonant frequency) with music where tempo = 95 or 105 percent of resonant frequency. Since trained runners typically run at their optimal cadence as noted in the previous section, the effects of synchronous versus asynchronous music as well as preferred versus modified cadence should be investigated for both trained and untrained runners.

In the study by Szmedra and Bacharach, the participants reported having no experience listening to music through head-phones while running on a motorized treadmill. This history of music-listening during exercise was not collected from participants in the present investigation. This information may be useful in future studies.

In order to keep exercise intensity and treadmill grade as constant as possible across participants, the velocity of the treadmill was altered to approximate 70 percent of VO_{2max} at zero percent grade for each participant. Maintaining a grade of zero percent could have resulted in uncomfortable running velocities for the participants as exercise intensity was manipulated only through changing the velocity of the treadmill. In addition, intensities varied greatly across participants (see Table 2). Therefore, another recommendation is to allow subjects to choose their own speed and grade to produce a moderate level of perceived exertion, calculate resonant

frequency, and use the preferred speed and grade for the experimental trials. VO_2 would still be measured during the experimental trials, but a VO_{2max} test would not be necessary. This modification may have more practical applications as participants would have more input concerning their preferred velocity and grade and is particularly worth considering given the variability of exercise intensities in the present study.

It may also be worthwhile to study auditory-motor synchronization using other exercise equipment, for example, a cycle ergometer. With this device, one could alter the workload to maintain a given intensity level across RPMs (Deschenes et al., 2000). Where Deschenes et al. cued RPMs in both conditions with auditory and visual stimuli, it may be worth investigating the two cuing modalities separately as studies have shown a preference for auditory versus visual cuing (Repp & Penel, 2004).

With an ever-increasing emphasis on the promotion of wellness in the United States, it is this author's recommendation that music therapists utilize their knowledge and expertise to further study the uses and mechanisms of music during exercise. If enough evidence were to exist concerning the impact of auditory-motor synchronization on physiological responses during exercise, it would then be appropriate to explore clinical applications of such responses. Blood lactate influences muscle fatigue, which could affect the length of time clients are able to engage in therapeutic music interventions. Improved physiological responses during exercise may also contribute to greater compliance during therapy.

Music therapists' training includes, but is not limited to, the impact of music on psychological, physiological, and sensorimotor responses.

Therefore, it is only fitting that these professionals assume active roles in researching and implementing uses of music during exercise, where music is not only motivational, enjoyable, and diversional, but is also facilitative.

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Appendix A

Subject Recruitment Flyer

Please Volunteer:

For a research study to examine the effect of music on efficiency during exercise.

Time requirements include:

One orientation visit and four 35- minute exercise trials.

Where:

The exercise science lab in the Student recreation Center at WMU.

To participate you must:

* Be between the ages of 18-35
* Exercise between 1.5 and 10 hours per week.
* not be taking vitamins or supplements (excluding a daily multi-vitamin)

To learn more:

Contact Tracy Kiel
Tracy.kiel@wmich.edu
342-0702

Appendix B

Health Screening Form

Physical Readiness Questionnaire

Yes	No		
☐	☐	1.	Has your doctor ever said that you have a heart condition <u>and</u> that you should only do physical activity recommended by a doctor?
☐	☐	2.	Do you feel pain in your chest when you do physical activity?
☐	☐	3.	In the past month, have you had chest pain when you were not doing physical activity?
☐	☐	4.	Do you lose your balance because of dizziness or do you ever lose consciousness?
☐	☐	5.	Do you have a bone or joint problem that could be made worse by a change in your physical activity?
☐	☐	6.	Is your doctor currently prescribing drugs (for example water pills) for your blood pressure or heart condition?
☐	☐	7.	Do you know of any other reason you should not do physical activity?

If you answered YES to one or more of these questions, vigorous exercise or exercise testing should be postponed. Medical clearance from your physician is necessary.

American College of Sports Medicine, 2000, Par-Q & You

Appendix C

Subject Questionnaire

Subject information

Code Number:

Phone number:

E-mail:

Gender:

Age:

Average Number of hours you exercise per week:

Number of years that you received private music lessons:

Dates (years):

Number of years you participated in a musical ensemble:

Dates (years):

Please rate the following musical selection:

One = greatly dislike
Five = greatly like

_____

Appendix D

RPE Scale

BORG SCALE OF PERCEIVED EXERTION

6
7 Very, Very Light
8
9 Very Light
10
11 Fairly Light
12
13 Somewhat Hard
14
15 Hard
16
17 Very Hard
18
19 Very, Very Hard
20

Appendix E

Letter of Informed Consent

Western Michigan University
Department of: Music

Principal Investigator: Edward Roth, MM NMT, MT-BC
Co-Investigator: Christopher C. Cheatham, Ph.D.
Student Investigator: Tracy Kiel

The Effect of Synchronization on Physiological Responses and Perceived Exertion during Treadmill Running

You have been invited to participate in a research project entitled "The Effect of Synchronization on Physiological Responses and Perceived Exertion during Treadmill Running." This study will fulfill the thesis requirement for a Masters Degree in music therapy for Tracy Kiel. This consent document will explain the purpose of this research project and will explain all of the time commitments, the procedures used in the study, and the risks and benefits of participation.

Study Purpose
The purpose of the present study is to examine the effect of synchronization to music on oxygen consumption (efficiency), plasma lactate (the lactic acid that causes soreness), heart rate, and perceived exertion (how hard you think you're working) while running on a treadmill.

Qualifications to Participate in this Research
To be able to participate in this research project, you must meet the following criteria:

- You must be between the ages of 18 and 35 years old.
- You must be recreationally active. This means that you exercise between 1.5 and 10 hours per week and that you are not involved in any competitive sports.
- You must fill out a health history questionnaire and only if the results from this questionnaire place you in a category of "Low Risk" for exercise will you be allowed to participate.
- You must not be currently taking any supplements such as sports supplements, vitamins, or minerals.

Duration of the Study
In addition to this orientation visit, you will be asked to come to the Exercise Physiology Laboratory of Western Michigan University located on the first floor of the Student Recreation Center four times. These visits will consist of an assessment trial and three experimental trials.

The "Orientation" visit will take approximately 20 minutes, and the assessment trial will last approximately 40 minutes. The three experimental trials will last approximately 35 minutes each.
Your participation in this study should last no more than six weeks.

Study Procedures

In addition to this orientation visit, you will be asked to attend four exercise sessions with Tracy Kiel in the Exercise Physiology Laboratory located in the Student Recreational Center on the campus of Western Michigan University. You will not have to change your exercise program or diet during the study. However, you will be asked not to exercise for the 24 hours before you come in for the assessment and Experimental Trials. We will also ask that you not drink any alcohol or take any caffeine the day before and the day of your visits to the laboratory. Also, for the assessment and the experimental trials, we ask that you come to the laboratory wearing a t-shirt, shorts, and running/gym shoes. Details concerning these trials can be found on the attached instruction sheet.

The student investigator will call you 48 hours prior to your appointments to remind you about the time and location of the study.

Orientation Visit

When you arrive for the "Orientation" visit, the student investigator will go over this consent form with you and explain the study and all of its procedures, risks, and benefits to you. You will be encouraged to ask any questions that you may have. If you decide to participate, one of the investigators will ask you to sign this consent form.

You will also complete a health history questionnaire. The investigators will use this information to classify your "risk level" for exercise based on guidelines established by the American College of Sports Medicine. You can participate in this study only if your "risk level" is "Low-Risk". This risk-level procedure will be explained to you. Finally, you will complete a background questionnaire.

Possible Risks of Your Participation in This Study

Risks and inconveniences associated with intense exercise include muscular fatigue and possibly muscle soreness on the following day. The exercise will be stressful but is generally easily tolerated by individuals and is not dangerous for healthy individuals. The student investigator performing the VO_{2max} test was trained by the co-investigator who has much experience in performing exercise tests, and the student investigator is familiar with emergency procedures.

A possible inconvenience is paying for parking if you do not currently have a WMU parking sticker.

The risks associated with the finger stick blood samples include soreness, bruising, and infection. These risks are minimized by observing proper sterile techniques. Also, the student investigator collecting the blood samples is properly trained by the co-investigator who has much experience in taking blood samples.

As in all research, there may be unforeseen risks to the participant. If an accidental injury occurs, appropriate emergency measures will be taken. The student investigator is certified in CPR and will be present throughout the trials. There will be no compensation or additional treatment made available to you except as otherwise stated in this consent form. You will NOT be compensated for participating in this study.

Benefits of Your Participation in this Study
There may be no direct benefit to you besides learning about your fitness level. The investigators will explain all of the results to you. You will also benefit by learning about research and some of the laboratory procedures used in collecting research data.

Conditions of Participation in the Study
In addition to meeting all qualifications to participate as listed above, we also ask that you follow all of the study guidelines, such as not exercising, not drinking alcohol, and not taking any caffeine for the day before and the day of your visits to the laboratory for the assessment and experimental Trials.
Because the data collected could be affected if you do not follow these guidelines, we ask that you tell us if you did not follow any of the guidelines. You will not suffer any penalties from the investigators if you do not follow the guidelines, but it is important for us to know. In this case, we can reschedule one of your appointments or you can choose not to participate in the study any longer.

Confidentiality of Your Results
In order to maintain confidentiality, the study will be focused on group data and an identification number (rather than the participant's name) will be used to record data. Following the study, the primary investigator and the research committee will have access to the original data. The original data will be retained in a locked cabinet for a minimum of three years after the completion of the study in the School of Music at Western Michigan University.
If the results of the study are published in a journal or presented at a conference, no names will ever be used.

Withdrawal from the Study
You can choose to stop participating in the study at anytime for any reason. You will not suffer any prejudice or penalty by your decision to stop your participation. You will experience NO consequences either academically or personally if you choose to withdraw from this study.
The study investigators can also decide to stop your participation in the study without your consent.

Should you have any questions prior to or during the study, you can contact the student investigator, Tracy Kiel at 269-342-0702, or the primary investigator, Edward Roth at 269-387-4679. You may also contact the Chair, Human Subjects Institutional

Review Board at 269-387-8293 or the Vice President for Research at 269-387-8298 if questions arise during the course of the study.

This consent document has been approved for use for one year by the Human Subjects Institutional Review Board (HSIRB) as indicated by the stamped date and signature of the board chair in the upper right corner. Do not participate in this study if the stamped date is older than one year.

"I have read this informed consent. The risks and benefits have been explained to me. I agree to take part in this study."

____

Please Print Your Name

____ __________________

Participant's Signature Date

Permission obtained by: ________________________ __________________

Signature of Investigator Date

Appendix F

Instructional Handout

Instructions for the Four Trials

Assessment trial

During this trial we will calculate your height and weight. We will also calculate your maximal oxygen consumption (VO_{2max}). When you arrive at the laboratory, you will step on to a motorized treadmill, we will "hook you up" to the Metabolic Measurement Cart so that we can measure how much oxygen your body uses during exercise and how much carbon dioxide your body produces. To do this, you will breathe through a clean, sanitized mouthpiece (similar to a snorkel mouthpiece) and you will wear a pair of nose clips so that you can only breathe through your mouth. The air you blow out during exercise goes into the Metabolic Measurement Cart and the amount of oxygen and carbon dioxide is measured. We will then begin the exercise test. We will increase the speed of the treadmill until volitional fatigue. Volitional fatigue is the point during exercise when you feel like you can exercise no longer. In other words, the exercise is just too hard to continue. This feeling might occur due to leg fatigue, overall fatigue, **rapid breathing,** or other factors relating to maximal exercise. You will typically be on the treadmill for approximately 8 to 15 minutes. When you are finished with the exercise test, we will take the mouthpiece and nose clips off, and you will jog/walk for a few minutes at a very low level for a cool-down period.

> After a brief rest period, you will run at a speed coinciding with 70 percent of your maximal oxygen consumption. You will run at this speed for approximately one minute while the student researcher calculates your cadence (number of steps per minute.)
>
> You will be running at this same speed during the three experimental trials; this is to ensure that everyone is exercising at the same intensity.

Experimental Trials

When you arrive at the laboratory, we will strap a heart rate monitor around your chest. We will also "hook you up" to the Metabolic Measurement Cart again to measure your oxygen consumption. We will also explain how to use the Borg Ratings of Perceived Exertion Scale. This is a scale with numbers and words describing how hard the exercise is. To use the scale, you simply point to a number.

During each trial, you will run on a motorized treadmill for 20 minutes at 70 percent of your VO_{2max} (see above). This period will be preceded by a warm-up and followed by a cool-down. During the 20-minute running period, we will monitor your heart rate and oxygen consumption continuously and record the values every five minutes. We will also ask you how you feel using the Borg scale every five minutes. In addition, we will take small blood samples from your finger at five minute intervals.

Before we do this, we will clean your finger with an alcohol pad, let it dry, and then prick your finger with a small sterile needle. We will then fill a very small glass tube with your blood. The amount of blood we take each time is only a few drops. After we take the blood we will hold a small piece of gauze on your finger to stop the bleeding. We will measure how much lactic acid is in the blood samples we take from you. Nothing else will be measured in your blood.

All three trials will be identical with the exception of the music. The order of the trials will be randomly assigned. During one trial, you will run with no music. During a second trial, the tempo of the music will match your steps per minute while during the third trial, the music will not match your steps. You will listen to the music through head-phones and may adjust the volume to fit your preference. With the exception of tempo, the musical selections will be identical for both music conditions.

Appendix G

Protocol Clearance from the Human Subjects Institutional Review Board

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: July 14, 2006

To: Edward Roth, Principal Investigator
Chris Cheatham, Co-Principal Investigator
Tracy Kiel, Student Investigator for thesis
Jolene Berger, Student Investigator
Eric Appiah, Student Investigator

From: Mary Lagerwey, Ph.D., Chair

Re: HSIRB Project Number: 06-06-03

This letter will serve as confirmation that your research project entitled "The Effect of Synchronization on Physiological Responses and Perceived Exertion During Treadmill Running" has been **approved** under the **full** category of review by the Human Subjects Institutional Review Board. The conditions and duration of this approval are specified in the Policies of Western Michigan University. You may now begin to implement the research as described in the application.

Please note that you may **only** conduct this research exactly in the form it was approved. You must seek specific board approval for any changes in this project. You must also seek reapproval if the project extends beyond the termination date noted below. In addition if there are any unanticipated adverse reactions or unanticipated events associated with the conduct of this research, you should immediately suspend the project and contact the Chair of the HSIRB for consultation.

The Board wishes you success in the pursuit of your research goals.

Approval Termination: June 21, 2007

Walwood Hall, Kalamazoo, MI 49008-5456

Appendix H

Approved HSIRB Protocol

The Effect of Synchronization on Physiological Responses and Perceived Exertion during Treadmill Running

Principal Investigator/Faculty Advisor: Edward Roth, MM NMT, MT-BC
Co-Investigator: Christopher C. Cheatham, Ph.D.
Student Investigator: Tracy Kiel

Abstract

The purpose of the proposed investigation is to examine the effect of synchronization on physiological responses and ratings of perceived exertion on treadmill running. Eight recreationally active subjects will participate in one assessment trial and three experimental trials. During the assessment trial, researchers will calculate each subject's VO_{2max} as well as his or her running cadence at 70 percent of VO_{2max}.

The three experimental trials will consist of no music, synchronization (where the tempo of the music equals the subject's cadence, and background music (where the tempo equals 70 percent of cadence. The order of conditions will be randomly assigned to each subject. Subjects will run for 20 minutes at 70 percent of VO_{2max}, and heart rate, plasma lactate concentration, oxygen consumption, and ratings of perceived exertion will be recorded every five minutes. Data will be analyzed utilizing a split plot design.

Project Description

Purpose

The purpose of this study is to examine the effect of synchronization to music on oxygen consumption, plasma lactate concentration, heart rate, and ratings of perceived exertion during treadmill running.

Background

Research has shown that when people synchronize their movement to a rhythmic pulse, this movement becomes more efficient (Safranek, Koshland, & Raymond, 1982). In this study, female subjects were asked to flex and extend their elbows in order to hit various targets with hand-held pointers. This experiment consisted of two trials. During the first trial, subjects performed the task without music, and researchers found that they all tended to move at very similar speeds. During the second trial, the subjects were divided into three groups. The first group performed the task exactly like they did before. The second group performed the task while synchronizing to an uneven rhythm while the third group synchronized to an even rhythm.

EMG data indicated that for both the first trial and the group that performed the task with no rhythm in the second trial, biceps and triceps muscles contracted as reciprocals of each other. However, the two groups that performed this task to a rhythm displayed an overlap in the contraction of these antagonistic muscles. The biceps would contract even before the elbow was fully extended. Researchers suggest that this contraction was meant to decelerate the movement in order for the subjects to hit the target in synchrony with the beat. Finally, it is important to note that subjects in the group with the uneven rhythm displayed significantly more muscle variability than subjects in the even group. This study indicates that synchronization induces more efficient motor recruitment, thus, making the movement itself more efficient.

Since this is the case, one would predict that synchronization to music during exercise would have a significant effect on other variables including oxygen consumption, plasma lactate, heart-rate, and perceived exertion. Unfortunately, while many studies have been conducted to analyze these dependent variables, few have manipulated and controlled for the synchronization factor. In a literature review conducted by Karageorghis and Terry (1997), one learns that the evidence for the use of music during exercise to lower heart rate and blood pressure varies from study to study. This is also true when examining perceived exertion. However, although the evidence is inconsistent, this may be due in part to the various research designs employed.

In one study, Annesi (2001) measured perceived exertion and other variables including distraction, oxygen consumption, and length of exercise in four different treatment conditions. One group of adults exercised to music, another exercised while watching television, a third exercised to the combination of music and television, and the fourth served as a control. Results indicated that the combination group made significant improvements in oxygen consumption compared to the other groups. However, no differences in perceived exertion were found. Again, it is important to note that the subjects who listen to music were not instructed to synchronize with the beat in this experiment.
In a final study, 10 males participated in a repeated measures design where they ran on treadmills to music and in silence (Szmedra & Bacharach, 1998). The order of the treatment conditions was randomly assigned. Researchers measured variables including perceived exertion, norepinephrine, plasma lactate, heart rate, and blood pressure every three minutes throughout the experiment. Results indicated that when running with music in the background, subjects displayed significantly lower levels of plasma lactate, lower heart rates, lower blood-pressure, and lower levels of perceived exertion than when running in silence.

These results may have been due to the subjects' running in and out of synchrony with the music. However, one can not make this statement with absolute confidence since the synchronization was never measured or manipulated. The difficulty in interpreting the results of this study is that one is not clear concerning the mechanisms that facilitated the significant differences.

From the given background, the purpose of this study is to compare the effects of three conditions on oxygen consumption, plasma lactate, heart rate, and perceived exertion during treadmill running. This study will serve as Tracy Kiel's thesis.

Research Procedures

Nine participants, at least four males and four females, will complete this study. However, up to 15 subjects may be recruited in order to account for subjects' dropping out or failing to meet or follow the criteria for this study. If participants do not show up to scheduled sessions/trials, the student investigator will contact them and ask them if they would still like to participate in the study, reminding them that they will suffer no penalty or prejudice if they decide to terminate their participation. If they still would like to participate, the trials will be rescheduled. However, if a participant cancels more than twice without prior notice, he or she will be excluded from the study.

All prospective participants must meet the inclusion requirements and then will be asked to meet with the student investigator in the Exercise Physiology Laboratory in the Student Recreation Center on the campus of Western Michigan University. Participants will meet with the student investigator for an orientation visit. Next, the participants will visit the laboratory on four separate occasions. These visits will consist of an assessment trial and three experimental trials. For each subject, the research will be conducted over a five-six week time frame.

We will request that participants refrain from drinking any alcohol or take any caffeine the day before and the day of the visits to the laboratory for the assessment and experimental trials. Caffeine can increase heart rate and increase nervous system activity. Caffeine and alcohol can cause a person to become dehydrated which may also affect the responses to exercise. Therefore, to obtain accurate/representative responses to the exercise, we ask that the participants refrain from these compounds.

At the beginning of each trial, the student investigator will ask participants if they followed these guidelines. If not, the session will be rescheduled. If a session must be rescheduled more than twice for this reason, the participant will be excluded from the study.

Orientation Visit

The first meeting will serve as an orientation visit at which time each participant will be familiarized with the study procedures, informed consent will be obtained, and health history and background questionnaires will be completed (appendices B & C).

Each participant will read the informed consent form and the research protocols will be explained by the student investigator. Each participant will then be

given the opportunity to ask any questions he or she might have concerning the research study. Once the student investigator has explained the procedure to the participant and has answered all questions, the participant will give informed consent if he or she wishes to participate. After informed consent is obtained, the participant will complete the health history and background questionnaires. If the participant meets the inclusion criteria, he or she will be allowed to participate. If participants do not meet the criteria, they will be excluded from the study (see the exclusion script under subject selection). The last question on the background questionnaire involves the participants' listening to a 30-second clip of the music that will be used during this experiment. Participants will be asked to rate how much they like the music on a five-point scale, where one = strongly dislike and five = strongly like.

Assessment Trial

During this trial, researchers will measure participants' height and weight, maximal oxygen consumption (VO_{2max}), and running cadence at a velocity correlated with 70 percent of their VO_{2max}.

Upon arrival to the laboratory, Researchers will measure participants' height and weight. Next, each participant will be fitted with a nose clip and a mouthpiece for the collection of expired respiratory gases using the metabolic measurement cart. The metabolic measurement cart measures ventilation and the oxygen and carbon dioxide concentrations of the expired respiratory gases to determine oxygen consumption (VO_2) and carbon dioxide production (VCO_2). The mouthpieces and nose piece will be disinfected with Cidex solution after each trial. Each participant will run on a Quinton motorized treadmill while the researchers gradually increase the velocity. The participant will continue to run until the point of volitional fatigue. Volitional fatigue is the point during exercise when the participant feels like he or she can exercise no longer. Although there is no specific criterion for this concept, it is analogous to the exercise being of a sufficient intensity that the participant feels like he or she has reached his or her maximal potential. In other words, the exercise is just too hard to continue. This feeling might occur due to leg fatigue, overall fatigue, hyperventilation, or other factors relating to maximal exercise. The following will be stated to each participant immediately before the start of this trial.

"The purpose of this test is to determine your maximal exercise intensity. Because of that, we need you to give us your best effort. The exercise test continues until you can't run any longer. This is a good indicator that you have reached your maximum and your body won't be able to exercise any harder."

Once the VO_{2max} test is terminated, each participant will continue to jog/walk at a very low intensity for approximately five minutes as an active cool-down. After a five-minute rest period, the participant will run for one minute at a velocity correlated with 70 percent of his or her maximal oxygen consumption while the student researcher calculates the participant's running cadence using a stop-watch feature on a Braille Note, (an adaptive Braille note taking device with a Windows operating system). Finally, the participant will walk for one minute, which will serve as a second cool-down.

Experimental Trials

Subjects will participate in three experimental trials, where the order of these trials will be randomly assigned. The trials consist of running to no music, background music, and in synchrony to music. During all conditions, subjects will run at 70 percent of the velocity correlated with their maximal oxygen consumption. During the two musical conditions, subjects will listen to recorded music through head-phones. They will adjust the volume to a comfortable listening level. The music was composed by Edward Roth using the software program Garage Band. The music during the synchronization condition will have a tempo (beats per minute) equal to each participant's running cadence, and the tempo of the music in the background condition will equal 70 percent of the participant's cadence. The music will contain imbedded metronomic clicks. With the exception of the difference in tempo, the pieces of music will be identical.

Upon arrival to the laboratory, each participant will again be fitted with a nose clip and a mouthpiece for the collection of expired respiratory gases using the metabolic measurement cart. Participants will also be fitted with a Polar heart rate monitor which has a strap that goes around the chest. Next, each participant will be instructed on how to use the Borg Ratings of Perceived Exertion (RPE) chart (Appendix D). This procedure requires that the participant point to a number on a chart representing the level of fatigue that he or she feels. Once instrumentation of the participant is complete, the exercise test will begin.

Participants will begin with five minutes of walking which will serve as a warm-up. Next, they will run for 20 minutes on a motorized treadmill at 70 percent of the velocity correlated with their VO_{2max} (calculated in the assessment trial). Finally, they will walk for approximately three minutes which will serve as a cool-down.

Oxygen consumption, heart rate, and perceived exertion will be measured every five minutes during the 20-minute running period. Blood samples will also be taken every five minutes during this period through finger sticks. During the two music conditions, music will only be played during this period, not during the warm-up or cool-down. The student investigator will also measure cadence during each five-minute period.

Blood Sampling Procedures

As previously mentioned, finger stick blood samples will be obtained during the experimental trials. These samples can easily be obtained from the participants as the procedure only lasts a few seconds, and participants simply rest their hands on the rail of the treadmill. Therefore, the procedure will not interfere with balance or other factors relating to safety or exercise performance. Prior to each blood sample, the participant's finger will be cleaned with an alcohol pad and allowed to dry. Gauze will be applied to the finger to keep it dry and free of impurities. A trained student investigator will then "prick" the participant's finger with a sterile, disposable finger stick lancet. This disposable, single-use lancet is automated so that the depth of penetration will be standardized. The fingertip will be punctured on the side of the finger to minimize discomfort. With gentle pressure on the finger, the student investigator will collect a very small blood sample (~30uL, which translates into a few drops) from the finger using a capillary tube. A piece of gauze will then be placed over the small puncture site. If the person continues to bleed, gauze and a tight fitting band-aid will be placed over the puncture site. After the blood collection, the lancet and gauze will be disposed of in a biohazard bag or sharps container. A different site on different fingers will be used as the collection site for the multiple samples collected during the exercise test protocol. Over the entire exercise test protocol, less than 2 mL of blood (less than one-fifth of one tablespoon) will be obtained. Blood sampling and products questionnaire is attached. After a blood sample is obtained, the blood will be analyzed for plasma lactate concentration using an automated analyzer (Analox GM7, Lunenburg, MA). The capillary tube with the remaining blood will be disposed of in a biohazard, sharps container immediately following centrifuge testing (Appendix E).

The risks associated with blood sampling will be minimized by using universal precautions. The area of blood sampling (finger) will be cleaned prior to blood sampling using an alcohol swab. All supplies utilized for the blood collection will be new, sterile and only used once. **All investigators who may come in contact with blood will wear** lab coats and a clean pair of latex gloves throughout the testing. All blood sampling supplies will be properly disposed of in biohazard bags and a sharps container after use. If complications arise during the blood collection, the participant will be referred to Sindecuse health center for further evaluation.

Role of Student Investigators

The co-investigator will train Tracy Kiel, Jolene Berger, and Steven Ball concerning VO_{2max} testing and blood draws/plasma lactate analysis. Tracy will be responsible for subject-recruitment as well as for all responsibilities during the orientation session. Jolene and Steven will be conducting the blood draws as well as reading heart rate, o2, and plasma lactate data. Tracy and either Jolene or Steven will be present for all four trials.

Research Design

This research will employ a repeated measures design as each participant will complete the three experimental trials. Due to the use of a repeated measures design, testing of a large number of participants is not necessary and statistical power can be achieved with only eight participants.

Location of Data Collection

All testing and data collection during the four trials will be performed in the Exercise Science Laboratory located on the first floor of Western Michigan University's Student Recreation Center. The data will be documented and saved to a file for retrieval. Individuals other than the principal and co-principal investigators will not have access to this information. All material will be stored in a locked cabinet in the principal investigator's office when not in use.

Duration of the Study

The initial orientation visit will last approximately 20 minutes, and the assessment trial will last approximately 40 minutes. The three experimental trials will last approximately 35 minutes each. The spacing between trials for each subject will range from four to 10 days. Completion of the study for each participant may take up to six weeks. The requested length of approval for the entire study is one year although data collection should take considerably less time than the requested approval period.

Dissemination of Results

Once the study is completed, a manuscript will be submitted to an appropriate exercise physiology journal for publication and the results will be utilized for Tracy Kiel's master's thesis.

METHODS OF ANALYSIS

Data concerning oxygen consumption, plasma lactate, heart rate, and RPE will be analyzed using a split plot design with factors being treatment and time. Gender, age, height, weight, musical preference, and years of musical training will be analyzed utilizing analysis of co-variates. The level of statistical significance will be established as $P < 0.05$. The SAS statistical package will be used for data analysis.

BENEFITS OF RESEARCH

There may be no direct benefits to the participants beyond an increase in knowledge about their plasma lactate levels, heart rate, and perceived exertion as well as knowledge concerning their maximal oxygen consumptions. Procedures for plasma lactate and VO_{2max} testing will be thoroughly explained to each participant so that he or she will become more educated concerning these parameters. The participants will also gain exposure to the procedures of scientific research.

The benefits to the investigators as well as the scientific community include an increase in knowledge with regards to the effect of synchronization on oxygen consumption, plasma lactate, heart rate, and perceived exertion while running at a given intensity.

SUBJECT SELECTION

Nine recreationally active participants, at least four males and four females, will be recruited for this study (appendix A). Recreationally active participants means any person that exercises or is physically active for between 1.5 and 10 hours a week and that is not involved in organized competitive sports.

Each participant will also complete a health history questionnaire to determine his or her level of risk stratification as outlined in the American College of Sports Medicine's (ACSM) Guidelines for Exercise Testing and Prescription (appendix B). Only participants with the ACSM Risk Stratification Level of Low Risk will be eligible to participate in the study. ACSM Guidelines have established that it is not necessary for participants who are classified at the level of Low Risk to have a physician's exam prior to maximal exercise testing (ACSM, 2000). Each individual not meeting the inclusion criteria will be read the exclusion script below:

> "I regret to inform you that based on your answers to the inclusion and exclusion questionnaire you do not meet the inclusion criteria for this study and will not be permitted to participate. Although you are not permitted to participate in this study at this time you will not be penalized in any nature because of your exclusion from this study. If you have further questions concerning your level of risk while exercising, please speak to your personal physician or visit Sindecuse Health Center. Thank you for your time and consideration in participating in this process."

The exact procedures to recruit participants will be to distribute flyers to friends as well as to students at the Student Recreation Center on the campus of Western Michigan University. When distributing flyers, it will be made clear that

participation is completely voluntary; no social consequences will result if friends/acquaintances choose not to participate. It will be made clear to friends of the student investigator If a prospective participant calls inquiring about the study, he or she will be told the general purpose of the study and the requirements for the participants as listed in the consent form. Participants must be between the ages of 18 and 35 years. Any male over the age of 45 years and any female over the age of 55 years is automatically classified as "moderate-risk" according to the ACSM Guidelines for Exercise Testing and Prescription. Because we will only test persons classified as "low-risk" we have chosen the upper age range of 35 years to allow for an even greater safety margin (ACSM, 2000).

The participants must meet all inclusion requirements in order to participate in this study. If a participant does not meet the criteria, the student investigator will recruit another participant to take his or her place in order to collect data from eight participants.

Once the participants have met the inclusion requirements, they will be asked not to alter their workout regimen. In addition, we will request that participants refrain from drinking any alcohol or take any caffeine the day before and the day of the visits to the laboratory for the experimental trials. Caffeine can increase heart rate and increase nervous system activity. Caffeine and alcohol can cause a person to become dehydrated which may also affect the responses to exercise. Therefore, to obtain accurate/representative responses to the exercise, we ask that the participants refrain from these compounds the day before and the day of the experimental trials.

RISKS TO SUBJECTS

Intense, maximal exercise can cause fatigue, weakness, dizziness, and/or disorientation. Risks associated with blood sampling can include infection, soreness, and possible hematoma. By following proper testing procedures, these risks will be minimized. The procedures to minimize these risks are outlined in the "Protection for Subjects" section of this document. Also, the abstentions from caffeine for the 24 hours prior to each experimental trial may produce some symptoms of caffeine withdraw such as a mild headache. Additional risks include mild discomfort and/or fatigue. There is also a risk of musculoskeletal injury (muscle pulls/strains) due to the fact that the participants are running/jogging. Finally, more serious health complications could occur due to unforeseen circumstances.

Inconveniences of participation include the amount of time participants will commit to this study, as they will participate in an orientation session, an assessment trial, and three experimental trials. In addition, participants will have to pay for parking if they do not have a permit to park on WMU's campus.

PROTECTION FOR SUBJECTS

The student investigator will make certain that participants are aware of and understand all of the above risks, which are also outlined in the consent document, before the participants give their informed consent to participate in the study. She will also inform them of the parking expenses before they come for the orientation session.

The risks associated with intense, maximal exercise will be minimized by the inclusion of participants who only meet the level of ACSM Risk Stratification of Low Risk. The risk of a major cardiac event during exercise testing in this participant population (Low Risk) is less than 0.1 incidences per 10,000 tests (ACSM, 2000). In addition, heart rate will be monitored continuously throughout the exercise testing in order to ensure that each participant is having a normal response to the exercise testing. Lastly, a student investigator is trained in CPR techniques and emergency procedures. A spotter will be standing next to the treadmill throughout the entire trials in case the participant reports feeling dizzy or disoriented.

The risks associated with blood sampling will be minimized by using universal precautions. The area of blood sampling (finger) will be cleaned prior to blood sampling using an alcohol swab. All supplies utilized for the blood collection will be new, sterile and only used once. All investigators will wear lab coats and a clean pair of latex gloves throughout the testing. All blood sampling supplies will be properly disposed of in biohazard bags and a sharps container after use. If complications arise during the blood collection, the participant will be referred to Sindecuse health center for further evaluation.

It will be explained to each participant that he or she is allowed to terminate testing at anytime for any reason during the study. It will be explained that the participant will suffer no penalty or prejudice from any investigator or from Western Michigan University if he or she chooses to terminate their participation in the study.

The co-investigator is experienced in administering maximal exercise tests as well as blood collection and will train the student investigators on the proper testing procedures prior to any interaction with any participant. During testing, there will be no other individuals in the immediate testing area except for those involved in data collections.

Finally, in the unlikely event of an emergency, campus police (7-5555) will be immediately called which will initiate the process for the arrival of emergency personnel. During safety training provided by the University, it was stated to call campus police instead of immediately dialing 911. If necessary, CPR will be administered by a certified student investigator who will be present at all testing sessions. If further medical care is needed, the participant will be referred to the Sindecuse Health Center. All participants are encouraged to be open about their concerns to the investigators.

CONFIDENTIALITY OF DATA

All participants will have their privacy protected. At the start of the study, each participant will be assigned a case number for data recording purposes. The principal and student investigator will have a list of participant names, contact information and case numbers that will be used for contact with the participants during the course of the study. The data and results from this study will be stored and locked in a file cabinet in the principal investigator's office in the Dalton Center at Western Michigan University with only the principal investigator having access to the data. Data will be kept on file for a minimum of three years at which time it may be destroyed. No names or pictures of the participants will be used in any subsequent publication of the research data.

INSTRUMENTATION

The health history questionnaire and the background questionnaire to be used are included (Appendices B & C). The Borg RPE scale to be used is also included (Appendix D). More details regarding the blood sampling procedure are attached (Appendix E).

INFORMED CONSENT PROCESS

When a prospective participant first contacts the student investigator and expresses interest in participating in the study, the student investigator will briefly go over the purpose of the study and a summary of the major research protocols (i.e. VO_{2max} testing, finger stick blood draws). If the prospective participant is still interested, the student investigator will make an appointment with the individual and explain that at that time all of the research protocols, risks, benefits, etc. will be explained and all questions will be answered.

As previously discussed, each participant will read the informed consent form and the research protocols will be explained by the student investigator. Each participant will then be given the opportunity to ask any questions he or she might have concerning the research study. Once all questions have been answered, those who still want to participate will be invited to sign the consent document. A copy of the informed consent form signed by the participant and the investigators will be provided to each participant. Since informed consent will take place during the orientation session, it will be obtained individually.

Appendix I

HSIRB Blood Collection Questionnaire

Collection of Blood or Blood Products Questionnaire

COLLECTION OF THE BLOOD PRODUCT

1. Blood collection procedures will take place in the exercise science laboratory on the campus of Western Michigan University. The co-investigator will train the student investigators in conducting the finger sticks for blood collection and disposal.
2. A routine finger stick with a sterile disposable finger stick lancet will be used to collect the blood sample. The lancet is an automated device to keep the level of needle penetration consistent. Three drops of blood, approximately ~30uL, will be drawn into a capillary tube to test the lactate level in and automated analyzer. The sample will be collected and disposed of by OSHA trained personnel within the HPER department and Graduate Athletic Training program.
3. Basic alcohol prep will be used to treat the collection site to remove sweat and impurities. Gauze will then be applied to maintain dryness before the finger stick.
4. Lab coats, gloves, and any other personal protective equipment deemed necessary will be used when handling samples. OSHA guidelines and Universal Precautions will be implemented when collecting and disposing of the blood.
5. Medical history forms will be filled out by each participant and reviewed by the investigators. Any participant with a self-reported history of blood disorders will be excluded from the study.
6. The student investigator collecting the blood has not been vaccinated for Hepatitis B.
7. Marvin Darling, Sindecuse Medical Laboratory Director will be made aware of any accidental contact with blood samples. Complications arising from the finger sticks will be referred to Sindecuse Health Center for medical attention.
8. Samples will be tested within 5 minutes of blood collection and then disposed of immediately.
9. The only way that a blood sample would be stored is if there is a mechanical problem with the automated lactate analyzer and in this case the blood samples would be stored in a laboratory refrigerator for up to 2 days. The blood samples do not require labeling as they will only be stored for a short time with limited accessibility.

TREATMENT OF THE MATERIAL USED TO DRAW THE BLOOD SAMPLE

1. Instruments used to collect the blood sample will be disposed of in their respective biohazard waste containers. Finger stick lancets will be disposed of in a Sharps container. Capillary tubes and gauze will be disposed of in biohazardous containers

2. Instruments used to analyze the blood samples are not disposable. The instruments have their own decontamination system built in to flush antiseptic fluids through the instrument.
3. Any materials that may have come in contact with the blood sample that are disposable will be disposed of in biohazardous containers. Non-disposable items will be disinfected with Cidex disinfecting agent while following Universal Precautions. Bloodborne Pathogens Training as well as OSHA guidelines already established at Western Michigan University within the HPER department will be followed.

STORAGE AND DISPOSITION OF THE BLOOD SAMPLE:

1. The only way that a blood sample would be stored is if there is a mechanical problem with the automated lactate analyzer and in this case the blood samples would be stored in a laboratory refrigerator for up to 2 days.
2. Bloodborne Pathogen Training procedures already established at Western Michigan University within the HPER department will be followed.
3. Blood samples will be disposed of in biohazardous waste containers.

Appendix J

Pilot Data

Table J1. Subject A's heart rate across time increments and treatment conditions

Condition	0 min.	5 min.	10 min.	15 min.	20 min.
No music	83	164	173	171	175
Fast	92	175	175	173	175
Slow	83	162	166	168	164

Table J2. Subject A's ratings of perceived exertion across time increments and treatment conditions

Condition	0 min.	5 min.	10 min.	15 min.	20 min.
No music	1	4	5	6	6
Fast	2	4	5	5	5
Slow	1	5	5	6	6

Table J3. Subject B's heart rate across time increments and treatment conditions

Condition	0 min.	5 min.	10 min.	15 min.	20 min.
No music	87	162	168	171	175
Fast	93	159	168	169	171
Slow	112	180	181	184	191

Table J4. Subject B's ratings of perceived exertion across time increments and treatment conditions

Condition	0 min.	5 min.	10 min.	15 min.	20 min.
No music	1	3	4	4	4
Fast	1	4	4	4	4
Slow	2	4	4	4	4