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## Use of Music to Improve Running Performance

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Use of Music to Improve Running Performance

by

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A thesis submitted in partial fulfillment  
of the requirements for the degree of  
Master of Science in Applied Behavior Analysis  
Department of Child and Family Studies  
College of Behavioral and Community Sciences  
University of South Florida

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## **DEDICATION**

This thesis is dedicated to my parents, Robert and Christine Buttice, and grandparents, William and Mary Norton. You have always believed in me and encouraged me throughout my entire academic career. I would not be the person I am today without you. Thank you so much for everything.

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## **ABSTRACT**

Running is an exercise that requires minimal equipment and gear therefore, running is easily accessible for many people. Research has shown performance benefits when music is used while running such as increased cadence (steps per minute), increased speed, and decrease in perceived exertion. Since music is easily accessible during a run (e.g., smartphone or smartwatch), one can utilize the technology in these smart devices to track specific aspects of their run.

Accelerometers, GPS, heart rate sensors, gyroscopes, and barometers can be utilized to track speed, distance, physical exertion, steps, and cadence. Software developers can take advantage of these features in smart devices to create applications that combine performance features with music that could potentially increase running performance. This literature review describes the use of Applied Behavior Analysis in sports and running, reviews studies that used music to increase exercise and running performance, and discusses studies that combined music and technology to increase running performance. Considerations for future research using ABA, music, technology, and running are also discussed.

## **CHAPTER ONE:**

### **INTRODUCTION**

Exercise has been identified by the Surgeon General as an important way to decrease one's risk of developing many chronic diseases (U.S. Department of Health and Human Services [HHS], 2010). One of the many suggestions for preventing these chronic diseases is to increase physical activity by engaging in a minimum of "150 minutes of moderate-intensity physical activity" each week (HHS, 2010). Some of the benefits of exercise are decreasing risk of disease, strengthening bones and muscles, and increasing mental health (HHS, 2010). Although exercise is not a guaranteed way of preventing disease or increasing mental health, it is a component of healthy living that can have many short-term and long-term benefits.

A large portion of individuals living in the United States exercise regularly. A little over 50 percent of adult Americans met the "Physical Activity Guidelines" for aerobic exercise (Centers for Disease Control and Prevention [CDC], 2017). This large number of people means that research in exercise is very important to fully understand what can help people exercise more, what can motivate people to start exercising and keep exercising, and how to improve exercise performance. Applied behavior analysis (ABA) is a field that can benefit a person using behavioral techniques to improve exercise adherence and performance. ABA has been increasingly used to improve many aspects of exercise and sports performance. A literature review by Schenk and Miltenberger (2019) found a total of 101 studies that used a variety of behavior interventions to improve performance across numerous sports and athletes. The

abundance of ABA research on sports shows the importance and benefits of ABA on sports and physical activities.

People have numerous options to increase their physical activity. People can increase their physical activity by lifting weights (Sewal et al., 1988), walking (Karageorghis et al., 2009; Moens et al., 2014), running (Balvis et al., 2016; Bonnette et al., 2012; Bood et al., 2013; Jun et al., 2015; Lee & Kimmerly, 2016; Matesic & Cromartie, 2008; Mohammadzadeh et al., 2008; Ramji et al., 2016; Simpson & Karageorghis, 2006; Thakare et al., 2017; Van Dyck & Leman 2016; Wack et al., 2014; Ward & Dunaway, 1995; Wysocki et al., 1979), swimming (Karageorghis et al., 2013; Schonwetter et al., 2014), cycling (Mythili & Sudha, 2017; Nakamura et al., 2010; Waterhouse et al., 2010), dancing (Quinn et al., 2017), and other sports (Schenk & Miltenberger 2019). Combinations of different exercises can also be completed. However, doing certain physical activities can require resources and money. Memberships to access gym equipment or pools, purchasing weights or gym equipment, and buying bikes can deter many from doing physical activities that require these types of equipment. Running typically only requires the cost of running shoes which tend to cost less than other exercise equipment. The lower cost of running means more people can have access to this exercise. Given that running is more intense than walking, it means running fits the moderate-intensity exercise recommended by the HHS (2010). Given the low cost and easy access, it is not surprising that running is a very popular exercise. In the United States, approximately 56 million people ran in 2017 (Lock, 2018). This review will first discuss the broad use of ABA related to sports and health. Next, ABA interventions for running will be discussed. Then, studies and literature reviews showing increases in running performance using music will be described, leading to the combination of

music and technology to increase running performance. Future research considerations based on research findings and suggestions for future research will also be discussed in this review.

## **CHAPTER TWO:**

### **BROAD APPLICATION OF APPLIED BEHAVIOR ANALYSIS**

ABA, in addition to being used for exercise and running, is a broad field of study and has a wide range of applications. Just to name a few, ABA has been effective in improving skill acquisition for individuals with various disabilities (Cariveau et al., 2016; Cook et al., 2017; Rapp et al., 2019); improving specific components of sports performance (Kelly & Miltenberger, 2016; Maryam et al., 2009; Quinn et al., 2017; Quintero et al., 2020; Schenk & Miltenberger, 2019; Tai & Miltenberger, 2017); decreasing challenging behaviors (Beavers, et al., 2013; Rooker et al., 2018; Sullivan et al., 2020) and increasing employment safety behaviors (Ditzian et al., 2015; Gravina et al., 2018; Lebbon, et al., 2011).

Because ABA is widespread in its applications, research combining easily-accessible technology, such as a smartphones or smartwatches, and ABA can also be beneficial for increasing exercise safety and performance (Balvis et al., 2016; Jun et al., 2015; Moens et al., 2014). In the United States, approximately just over 80% of people own a smartphone (Pew Research Center, 2019). Smartphones have accelerometers which can be used to track movement such as exercise (Höchsmann et al., 2018) which can be combined with GPS data to track location (Adamakis, 2017). Researchers can take advantage of this technology and applications used to collect exercise data to implement and evaluate vast amounts of exercise research (Silva et al., 2020). Because running is popular and easily accessible, research should focus on combining technology, running, and ABA to evaluate treatments that can potentially increase running safety and running performance.

## **CHAPTER THREE:**

### **APPLIED BEHAVIOR ANALYSIS IN SPORTS AND HEALTH**

Applied behavior analysis (ABA) has been used in many aspects of sports and health, especially to increase performance or enhance specific skills. The following studies show procedures of ABA used with sports and exercise. Wysocki et al. (1979) used a behavioral contract to increase exercise, in the form of aerobic points, in college students. The researchers had participants try different exercises before choosing a contract that would determine how many aerobic points the participant needed to obtain each week. Participants gave up several items of value to researchers and earned an item back each time the contract was met during the treatment phase. Aerobic points were recorded during a baseline period to determine baseline levels of exercise. In the treatment phase, the participant would set a contract that would determine the number of exercise points that they were to accumulate. Participants would earn back up to two of their items per week; failure to achieve the points in their contracts would result in the participant not earning the items back that week and they would be donated instead. Participants earned more aerobic points during treatment phases in this ABAB reversal design indicating that behavioral contracting was effective in increasing exercise.

A more recent study by Juwono (2019) also used a behavior contract, goal setting, self-monitoring, and feedback to increase physical activity in three out of four participants using a multiple baseline with a changing criterion design. Participants were provided with a Fitbit to wear and used the Fitbit app to track their running progress during the study. In baseline, participants were told to do their normal amount of physical activity while wearing the Fitbit. In

the experimental conditions, participants would meet each week with the researcher and determine a goal for the week, and make a monetary deposit ranging from \$10-\$30 that would be earned back if their goal was met, or donated if the goal was not met; feedback on the previous week was also discussed during each meeting. Goals were to be increased each week of experimental phases if attained, or remained the same if not attained. The dependent variable in this study was moderate to vigorous physical activity, defined as a heartrate over 135 or higher during exercise. Overall, three out of the four participants successfully met their goals each week, increasing their exercise. Zarate et al. (2019) used goal setting and feedback to increase exercise. Four participants ranging in age from 21 to 24 years old wore a Fitbit Flex to measure intense steps. Intense steps were described as having 400 or more steps in a 5 min time period as labeled by the Fitbit results screen. Goals were determined by having each participant wear the Fitbit throughout baseline and calculating a goal that would either equal 1 mi or 10% higher than the weekly mean distance in baseline. During the experimental phase, participants would have their goal increased by 10% if the previous week's goal was met. Feedback was given each week to participants using a text message giving the previous week's data and a new goal for the next week. The majority of participants increased their exercise level with these ABA procedures.

Many more examples of ABA in sports are listed in a literature review conducted by Schenk and Miltenberger (2019) which found 23 different ABA interventions used in research for 21 different sports. This review categorized ABA procedures used in sports research into four basic categories: consequence procedures; antecedent procedures; feedback procedures; and skills training procedures. Consequence procedures consisted of positive and negative reinforcement, auditory feedback, token economy, and forward or backward chaining. Quinn et al. (2017) used the consequence procedure called auditory feedback to increase dance skills for

several dancers. A clicker was used to signal that a specific component of a performance was correct as they were happening without saying anything. Antecedent procedures consisted of goal setting, instruction, video modeling, expert modeling, and physical prompting. Maryam et al. (2009) used two antecedent procedures to increase performance of discus and hammer throwing. Video-modeling and verbal instruction were used in a pretest-posttest design where some participants only received verbal instruction while other participants received video-modeling. Both groups saw an increase in performance, however, video-modeling had slightly better improvement over verbal instruction. Feedback procedures consisted of verbal feedback, video feedback, public posting, self-monitoring, and graphical feedback.

Another example of ABA procedures in sports was the use of video feedback to increase horseback riding skills (Kelly & Miltenberger, 2016). Video feedback in this study involved the participant being video recorded while performing a horseback riding routine. After the participant finished the routine, the participant would immediately watch their recorded performance while receiving verbal feedback by the instructor. Skills training procedures consisted of behavioral rehearsal, self-talk, self-imagery, relaxation training, simulated practice, habit reversal, acceptance and commitment therapy, discrimination training, and behavioral skills training (BST). Skills training, specifically BST, was used by Tai and Miltenberger (2017) to increase safe tackling skills in youth football players which can help decrease instances of concussion which can be caused by unsafe tackling. BST uses instruction, modeling, rehearsal, and feedback to teach one or more skills (Gatheridge et al., 2004). The children in Tai and Miltenberger's (2017) study, ages 10 and 11, all demonstrated increases in safe tackling skills after BST was implemented. To summarize, a variety of ABA procedures have been

implemented across multiple sports to successfully increase skills, improve safety, and improve performance.

## **CHAPTER FOUR:**

### **APPLIED BEHAVIOR ANALYSIS IN RUNNING**

Similar to other sports, ABA has also been used to enhance different aspects of running. Interestingly, although the study by Wysocki et al. (1979) gave participants a choice in exercises that could earn aerobic points, participants engaged in running most often. The authors listed this as a possible limitation of their study as “84%” of aerobic points were earned through running. The two main reasons listed by the authors were that running was simple, especially for participants with limited exercise experience, and also because running gave participants the most aerobic points compared to any other exercises (i.e., running was one of the most efficient ways to earn aerobic points as running a 9 min mile would award 4 points whereas cycling the same amount of time would only earn 1 point and swimming would earn 3.5 points). Not mentioned, however, was how Matching Law could have impacted participants’ choices. Matching Law, described by Herrnstein (1961), could have potentially predicted running being the most popular choice in the Wysocki et al. (1979) study because Matching Law would predict that when reinforcement is higher for one activity over another, participants will engage in the most reinforced activity more often. Another study using ABA for running was by Shapiro and Shapiro (1985) where behavioral coaching was used to increase running speed for track sprinters. Sprinters had each component of a skill analyzed and scored by their coach. Feedback was provided and modeling of correct behaviors was also implemented to improve track skills such as starting at starting blocks. Wack et al. (2014) used goal setting and feedback to increase running distance of participants. Participants set goals that increased each week as long as their

previous goals were met. Feedback was provided by showing graphed results and a verbal explanation of performance. Runs were recorded using a Nike+ SportKit which uses a sensor to track walking or running movement. Data collected from this device indicated the time and duration of each run. Results were compared to baseline results where participants did not set goals. All participants increased their running performance with goal setting in place. Zarate et al. (2019) mentioned that some participants chose running as a way to increase exercise using goal setting and feedback. In addition to specific behavioral interventions to increase exercise performance, the use of music has been evaluated for improving exercise performance.

## **CHAPTER FIVE:**

### **USE OF MUSIC TO IMPROVE PERFORMANCE IN SPORTS AND HEALTH**

Researchers have found that listening to music while exercising can potentially: increase a person's affect (Brownley et al., 1995); increase grip strength (Karageorghis et al., 1996); lower perceived exertion (Karageorghis & Terry, 1997; Mythili & Sudha, 2017; Terry et al., 2012; Waterhouse et al., 2010); increase dissociation from indoor exercise with the addition of a motivational video (Barwood et al., 2009); increase arousal (Bishop, 2010; Koç & Curtseit, 2009); and increase overall exercise performance (Karageorghis et al., 2012; Karageorghis & Priest, 2012a, 2012b; Karageorghis et al., 2013; Nakamura et al., 2010; Waterhouse et al., 2010). Karageorghis et al. (1996) had participants listen to stimulative music, white noise, and sedative music. Afterwards, a dynamometer was used to measure grip strength of 50 participants in a repeated measure group design. Measurements were taken one time a week for three weeks in each condition. The stimulative music condition produced the highest grip strength compared to the white noise condition, and the sedative music condition produced the lowest grip strength of all conditions. Waterhouse et al. (2010) conducted a study evaluating the effects of music tempo on cycling performance. Twelve male participants rode an indoor exercise bike while listening to a track of pre-selected music of varying tempos. Tempos ranged from normal, 10% faster, and 10% slower than normal. Participants chose the intensity of their workout and were told they needed to cycle for 30 min without over-exertion. Results indicated participants performed better in the faster music conditions. Also, participants reported they enjoyed faster music over the slower music, had lower perceived exertion, and participants cycling cadence was higher for

faster music, indicating faster pedaling. Distance traveled was also higher in the faster music condition. Similarly, another cycling study was conducted to evaluate the effects of music on aerobic exercise (Mythili & Sudha, 2017). A total of twenty participants, male and female, exercised on an exercise bike in a no-music and fast-music condition. Participants performed better in the fast music condition by traveling further. Rating of perceived exertion was also rated lower in the music condition. An additional study also evaluated the effects of music on cycling performance (Nakamura et al., 2010). This study compared preferred music, nonpreferred music, and no music for 15 male participants. The participants were able to choose 10 preferred and 10 nonpreferred music selections. Two trials were conducted to gather baseline exhaustion times which was characterized as the participant no longer being able to maintain a speed of 27km/hr for 3 s. Participants listened to preferred music, nonpreferred music, and no music while cycling at 27km/hr until exhaustion. Results indicated that participants performed better in the preferred music conditions compared to nonpreferred music condition (i.e., participants continued cycling at 27km/hr longer in the preferred music conditions), and performed the worst in the no music conditions.

Music's effects on swimming has also been evaluated by Karageorghis et al. (2013). In this study, 26 participants listened to music using an mp3 player that could be used in water. A pre-test phase was conducted in this study and had participants listen to similar music as in the experimental phase. The researchers noted that the pre-test phases were to evaluate possible learning effects. In the experimental phase of the study, participants each participated in a motivational music trial, an oudeterous music trial, and a no music trial where each participant would swim 200m in an Olympic-sized swimming pool. Oudeterous music does not motivate and is neutral. Results indicated that on average, swimmers' times were faster in the music trials

compared to the non-music trials. Differences between the two music conditions were not significant; the mean time in the motivational music condition was slightly better than the outdeterous condition. Overall, the effects of music on exercise appear to help increase a person's enjoyment of exercise and increase aspects of their performance.

## **CHAPTER SIX:**

### **USE OF MUSIC TO IMPROVE PERFORMANCE IN RUNNING**

Studies incorporating music have demonstrated increases in running performance similar to the studies that evaluated non-running exercises. These improvements include ability to run longer (Bood et al., 2013; Thakare et al., 2017), increase in overall running performance (Bonnette et al., 2012; Simpson & Karageorghis, 2006; Van Dyck & Leman 2016), increase time to exhaustion (Mohammadzadeh et al., 2008), and faster running speed (Bonnette et al., 2012; Lee & Kimmerly, 2016; Ward & Dunaway 1995). Ward and Dunaway (1995) increased running speed by using music. Baseline consisted of music throughout the run, whereas treatment b consisted of music contingent on running faster as measured by laps run in a specific amount of time. Treatment c consisted of contingent music on running slower, or fewer laps in a specific amount of time. This ABCB single-subject reversal design with a changing criterion component showed that contingent music can affect a person's running speed. Participants would consistently adjust their running speed based on the contingency of the music (i.e., as criterion was increased, running speed also increased to meet criterion). The reversal phases showed a clear decrease in running speed when the contingency was lowered; an indication of experimental control. Bonnette et al. (2012) found that groups of participants performed better with music compared to no music. Participants were told to run on a pre-determined, marked, course that was 1.5 mi. in length. The first run consisted of all participants running without music. The second run, five days later, required runners to listen to music using self-selected music on their personal music players (e.g., iPod or MP3). The mean running time for runners

was faster during the music condition and slower for the no-music condition, indicating that music increased running performance of the runners. A potential limitation to this study, mentioned by the authors, was that runners ran as a group and did not run individually which could have caused a competition between runners potentially affecting results. A change in weather conditions could have also contributed to these results. In a different study, Bood et al. (2013) evaluated synchronizing music to a runner's cadence while participants ran until exhaustion on a treadmill in three different conditions. There was a control condition with no music, a condition with motivational music paired with the runner's cadence, and a metronome condition paired with the runner's cadence. Participants time to exhaustion was higher in both the metronome and music conditions compared to the no sound condition. On a similar note, Thakare et al. (2017) found that listening to music increased the duration of a person's run compared to a no music condition. A total of fifty participants, male and female, were told to run until they felt tired on a treadmill. Participants ran without music on the first trial and came back one day later to run the second trial while listening to self-selected music out loud on their phones. All of these studies demonstrate the beneficial impact music can have on improving running performance.

Another important factor related to running performance, evaluated in some studies, is rate of perceived exertion. Multiple studies include rating of perceived exertion measures and show that this rating typically is lower in music conditions compared to non-music conditions (Lee & Kimmerly, 2016; Matesic & Cromartie, 2002; Miller et al., 2010; Mohammadzadeh et al., 2008). Generally, a lower perceived exertion score is better because an exercise would feel easier and that less effort was needed to perform a particular exercise compared to a high perceived exertion score. In ABA, an establishing operation (EO) makes a reinforcer stronger

(Miltenberger, 2016). If a run is perceived as easier or more fun using music, these could be EO's that make running more reinforcing. Miller et al. (2010) demonstrated that participants' enjoyment of their exercise, a treadmill run, was higher when their perceived exertion score was lower, which they hypothesized. Overall, these studies showed how potential physical and psychological effects of music on running could result in beneficial outcomes for runners. The use of technology to evaluate running performance is another important research topic, as music can be combined with technology to increase running performance.

## **CHAPTER SEVEN:**

### **USE OF TECHNOLOGY IN RUNNING**

Technology has been used reliably as a way to improve running performance. A literature review by Peart et al. (2019) mentioned some technology that has been used in running research which includes smartphones and applications that use these sensors (e.g., GPS, accelerometers, heart rate sensors). Barometers, magnetometers, and gyroscopes are used together by smartphones to get more accurate movement tracking (Henriksen, et al., 2018). Specialized movement sensors such as Fitbit, and Nike+ have also been used to measure exercise in research (Juwono, 2019; Wack et al., 2014; Zarate et al., 2019). Henriksen et al. (2018) also mentioned researchers studied smartwatches and exercise watches that can include heartrate sensors (e.g., Apple Watch & Fitbit). One study that specifically combined technology and running was conducted by Wack et al. (2014). Researchers in this study used Nike+ SportKit to track runners without the need to physically observe a person's run in order to increase the distance run using goalsetting and feedback. All runners increased their running distance using goal setting. Also mentioned was how this technology could be used to autonomously collect data. Research by Van Dyck et al. (2015) demonstrated that runners matched their running cadence to music tempo using two iPods and D-Jogger. This was achieved by having runners listen to music with slight shifts in tempo, unnoticed by the runner, while calculating their cadence. It was found that runners were matching the tempo of the music to their steps. Jun et al. (2015) created Runner's Jukebox, a smartphone application, which utilized an algorithm they created to track a runner's cadence, choose music, and modify the tempo of the music to match the cadence of the runner.

Data from smartphone sensors were used to accurately calculate cadence which could be used to match music tempo to cadence. This study was a demonstration showing that their app could accurately change music tempo based on a person's cadence. Balvis et al. (2016) used two types of audio feedback to help runners maintain a specific cadence with the use of algorithms they created and a smartphone. The running app they created provided either vocal feedback or beat feedback. Vocal feedback would tell the participant how to maintain the target cadence. The beat feedback would provide a beat if the participant's cadence was too fast or too slow. Participants were more successful keeping the target cadence with the beat feedback and preferred this over vocal feedback. This was achieved even though feedback was not constant during the exercise. Because technology is abundantly used in running research, it is also important to evaluate music combined with technology and running to improve performance.

## **CHAPTER EIGHT:**

### **COMBINING MUSIC AND TECHNOLOGY TO IMPROVE PERFORMANCE IN RUNNING**

With the abundance of easily accessible technology such as smartphones, smart watches and exercise watches, applications have been developed to track and measure running performance using music. Several studies have used their own applications to pair music rhythm to a runner's cadence (Jun et al., 2015; Moens et al., 2014). For example, Moens et al. (2014) used a custom-made application for Android devices called the D-Jogger to match music tempo to a person's steps. The D-jogger application used multiple sensors placed on the body that would track a person's walking speed. The application automatically paired walking cadence to music that was playing using algorithms created by the researchers. Participants were able to walk or run any speed they desired on a treadmill during this study. Four experiments were conducted in this study. In experiment 1, D-Jogger was set to change music tempo or song based on a person's cadence. The tempo matched the cadence of participants, but would not match the participants' footfalls. The software would eventually match the person's footfalls automatically. Participants ended up making many small changes to their cadence to match the music. Experiment 2 measured the mean cadence of the participant's previous five steps before the music changed then kept the tempo constant. A new song would start somewhere between footfalls. Participants would usually match their cadence to the music. In experiment 3, D-Jogger matched the runner's cadence but introduced two possible scenarios. Either the music exactly matched the footfall, or the music was exactly in between footfalls when a different song started;

participants would make small changes to match the tempo if the tempo was in between footfalls. In experiment 4, the D-Jogger actively matched the footfalls of the participant; it was noted that participants matched their cadence to the beat of the music more often and did not have to change their cadence to match the tempo as often. Although this study was not specific to running, the methodology could certainly be utilized for running and other exercise. A study by Jun et al. (2015) paired music with smartphone sensors in an app that could match music to a runner's cadence, however, improvement in running speed was not evaluated in this study. Research combining music, technology, and running in a mobile app, is limited which indicates a potential direction for future research.

## **CHAPTER NINE:**

### **CONSIDERATIONS FOR FUTURE RESEARCH**

With the large amount of research in exercise and running it is important to consider these findings when expanding the research base for improving performance. Research has demonstrated the importance of runner experience, cadence, and music synchronization to cadence to improve running performance.

#### **Runner's Experience**

Experience of a runner needs to be considered when gathering participants. Brownley et al. (1995) found that non-experienced runners benefitted more from music on a run versus experienced runners. These findings have also been supported by a study evaluating trained versus untrained runners on a self-paced, 20 min run (Matesic & Cromartie, 2008). Researchers in this study had participants run for 20 min at their own pace while having their lap pace measured. The untrained group benefited more from music than the trained group by having lower lap times and lower perceived exertion scores than experienced runners. It is important to realize the possible effects that a person's exercise experience has on the effectiveness of music. Therefore, future studies might consider using runners that have minimal running experience or determine if other variations in music could benefit more experienced runners.

#### **Runner's Cadence**

The next important aspect of running is the implication that music can have on running cadence, or steps per minute. Research has demonstrated that runners tend to match their cadence to the tempo of the music or beat they are listening to (Bood et al., 2013). Bood and colleagues

compared music and no music conditions to a metronome condition. The authors matched the beats-per-minute (BPM) of the music to each participant's normal running cadence. Music and metronome conditions produced similar increases in performance, therefore, cadence is an important concept when designing a running study to improve performance. Van Dyck et al. (2015) also demonstrated that runners matched their running cadence to music tempo. This was achieved by having runners listen to music with slight shifts in tempo, unnoticed by the runner, while calculating their cadence. It was found that runners were matching tempo of the music to their steps. Ramji et al. (2016) also evaluated running cadence in relation to music. Additionally, stride length and distance traveled was assessed. Results indicated no difference in cadence, but differences were found in stride length, specifically, distance traveled. Future research should combine music with running, especially music with different or variable tempos found in some smartphone apps, and evaluate running performance.

### **Synchronization of Music Tempo with Cadence**

Research has also indicated the importance of synchronous music. Ramji et al. (2016) found synchronous music was more effective for improved running performance by increasing stride length. Asynchronous music did not have the same results in running performance. Synchronous music was explained as music that is associated with running pace and asynchronous music was music tempo that was significantly slower than a participant's natural running pace. Simpson and Karageorghis (2006) also demonstrated the importance of synchronous music over no music. However, this study examined performance on a relatively short and intense 400m sprint which may not have been long enough to find strong effects of music when compared to a longer running distance. More research is needed on the effects of synchronous music versus asynchronous music.

## **Music Rating Scale**

Karageorghis et al. (1999) created the Brunel Music Rating Inventory (BMRI) as a way to choose music that best suits an individual and their perceived motivation by specific music. The BMRI was later revised to the BMRI-2 to better predict a person's perceived motivation by music (Karageorghis et al., 2006). The BMRI-3 was developed a few years later (Karageorghis, 2008). Although the BMRI scales are generally used by researchers when having participants select music, Lane et al. (2011) demonstrated that participants could successfully use this rating scale to select music. This could potentially be used to select songs in running-related research, or compare music selected from this rating scale to music selected by applications or the runners themselves. Research could also compare exercise performance with music selected by the participant compared to music selected using the BMRI-2. This could potentially determine if the BMRI-2 could be helpful in behavioral research.

## **CHAPTER TEN:**

### **CONCLUSION**

Given the extensive research related to music and its effects on exercise and running, one area of focus for new research might be the use of applications to improve running performance such as speed or distance run. Application developers are taking advantage of technology and its availability, such as a smartphones and smartwatches, to create applications to use for runners or people interested in starting running, some of which are mentioned on a list of applications by Runner's World (2019). Such applications track data such as running pace, cadence, time, distance run, average pace, heartrate, elevation changes, and path of run. Data from each run can easily be accessed within the application to monitor running performance.

There are multiple applications that pair music, running, GPS, and other smartphone sensors such as the barometer, accelerometers, gyroscope, and even heart rate sensors such as in a smartwatch to give large amounts of feedback to a runner. Examples of such apps include Human, Couch to 5K, Strava, Runcoach, Runtastic, and "Zombies, Run!" (Runner's World, 2019). An example of an application that uses mostly all available movement and location sensors combined with music is RockMyRun. This is one example of an application that can match the beat of the music to a runner's cadence or heartbeat (RockMyRun, n.d.). This specific application also gives the option to run to preselected music meant to prepare a runner for a 5K or marathon. The tempo in these preselected options is intended to match a runner's cadence to possibly motivate a runner to speed up their cadence to the beat of the music that is playing. Future studies should consider evaluating different aspects of such an application, for instance

using the pre-selected music in the 5K section to potentially increase running performance, or, using the feature that matches music tempo to cadence to see if this increases running performance.

With the plethora of running apps being advertised to runners, it is important to evaluate these applications to ensure that their claims are truly backed by research. Although studies have developed their own applications used in their research, no known studies have evaluated the use of publicly available applications to increase running performance using music. Data from these applications can easily be tracked and could be particularly helpful for ABA research combined with behavioral procedures such as goal-setting, public posting, positive reinforcement, and more. Additionally, applications that also include the addition of music could result in socially valid improvements in running without the need for additional behavioral procedures. If these applications that incorporate music are found to improve performance, they could be easily used by runners in a variety of running settings. Future research should evaluate music applications for running and potentially other types of exercise to determine the necessary conditions for increased performance and to assess the social acceptability of the available applications. Results of this research might suggest new features that could be added to further enhance applications to continue to improve athletic performance.

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