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Assessing a Punching Bag Feedback Performance Device

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Physical exercise has been integrated into treatment efforts in reversing the number of overweight and obese individuals. Furthermore, exercise extends mortality, enhances general quality of life, and it is a protective health factor for preventing the progression some mental health disorders. Electronic athletic training equipment easily allows monitoring of real-time physical activity, and enables tracking of progress made toward individualized performance goals. There are limitations to only using visual feedback (e.g., visual depictions of heart rate, speed, distance traveled, or calories burned etc.) to track and improve exercise and athletic performance, especially for some sports, such as boxing. This issue could be addressed by incorporating real-time audio along with visual feedback on crucial dimensions of a boxing workout. The study proposed herein is designed to evaluate if the audio/ visual feedback package using a multiple baseline design across subjects results in better workouts and improved athletic performance, when compared to a standard punching bag workout.

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by

Neil Deochand

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CONFLICT OF INTEREST

The student investigator (Neil Deochand) and the faculty mentor for this project (Dr. Wayne Fuqua) are disclosing a conflict of interest on this research project. Both investigators currently hold rights to a patent on the device being evaluated in this research project. However, we have attempted to resolve this conflict by, (1) disclosing this conflict of interest at the outset of the research, 2) declaring our patent holding status to the participants during the informed consent process, 3) offering the resources and information necessary for replication to other researchers, 4) completing the appropriate research ethics training, 5) relying on objective, machine–defined measures of performance that are more accurate and reliable than measures that rely on human observers and recorders; and 6) adhering to the governing ethical principles of the American Psychological Association (APA) and the Behavior Analysis Certification Board (BACB) as we conducted all aspects of the research reported herein.

INTRODUCTION

In the United States (US), obesity has reached epidemic proportions. In 2010, roughly 35% of adult men and women had a Body Mass Index (BMI) of 30 or above (Flegal, Carroll, Kit, Ogden, 2012) a widely recognized criterion for obesity in adults (WHO, 2011). Furthermore, obesity is a risk factor for a number of serious health problems including: cardiovascular disease, diabetes, and a wide range of musculoskeletal disorders. Although, in the US obesity prevalence has remained relatively stable from 2003-2012, there is no indication of a reduction (Ogden, Carroll, Kit, & Flegal, 2014), and the global obesity epidemic has continued to escalate (Gortmaker et al., 2011). Unfortunately, low and middle income countries, face both a rapid rise in non-communicable illnesses and a heavy burden of infectious diseases (WHO, 2011). Additionally, the availability of cheaper dietary options in these countries results in overweight/ obese individuals with inadequate nutrition (WHO, 2011).

However, even with the first world's additional resources, managing health conditions resulting from inactivity and poor diet through tertiary care cause serious financial strain. For example, the United Kingdom, like the US, suffers similar economic strains from health care expenditure for medical procedures to either, prolong, or improve the quality of life for individuals that are obese or overweight (Wang, McPherson, Marsh, Gortmaker, & Brown, 2011). It has been estimated that over a quarter of the growth in health-care expenditure in the US between 1987-2001 could be attributed to managing health-issues directly related to a patient's status as obese or overweight, with projected expenses expected to double every decade (Wang et al., 2011).

The low cost and availability of high calorie processed food coincides with the rising overweight and obesity rates (WHO, 2011). Additionally, division of labor has resulted in reduction of physical activity in the work place, and an increase in sedentary behavior (Green, Sigurdsson, & Wilder, 2016), at least for industrialized countries. Diet and physical activity are the most effective non-invasive strategies to manage weight gain and improve health status. This suggests the best health outcomes would result from simultaneously, (1) increasing calorie expenditure via physical activity, and (2) reducing the number of calories consumed and avoiding processed food via dietary management, although encouraging these outcomes at the policy level is challenging (Gortmaker et al., 2011).

Physical exercise has additional benefits, beyond preventing weight gain, including preventing the development or progression of some mental health issues, such as anxiety and depression (Strohle, 2009). Even minor ailments like head-aches have been combatted effectively by increasing physical activity (Fitterling, Martin, Gramling, Cole, & Milan, 1988). Furthermore, physical activity has been shown to have cognitive enhancing effects (Gomez-Pinilla & Hillman, 2013). Thus, the fundamental premise of the present study is that developing procedures or products to motivate people to exercise more often, with greater duration or intensity, could have multiple benefits in the prevention of chronic diseases, and the improvement of physical health and mental well-being.

The study proposed herein is designed to evaluate a method for increasing the two dimensions of physical activity tied to the calorific expenditure of energy, the duration and intensity of exercise. Behavioral interventions focused on increasing physical activity can result in weight loss (Van Camp, & Hayes, 2012), and exercise is an observable dependent variable for exercise promotion interventions (Martin, 2015). Furthermore, regularly scheduled physical activity can reduce many of the health risks associated with being overweight, as well as improve overall quality of life (U.S. Department of Health and Human Services, 2010).

Literature Review

The exercise promotion literature employs both group and single subject designs. Group designs are typically randomized controlled trials where group aggregate scores are compared. Group studies have revealed the generalized finding that restricted dieting and exercise therapy offer the most therapeutic effects for obese individuals (Ueno, et al., 1997).

Before selecting an intervention it is important to ascertain the functional variables to target. For example, if skill deficits prevent performing the physical activity, then training the prerequisite skills of the exercise behavior could enhance performance, otherwise developing strategies to motivate the individual to maintain their physical activity routines could be the relevant component of an intervention (De Luca & Holborn, 1992; Booth, Roberts, & Laye, 2012). Many of the studies evaluate package treatments, making it challenging to ascertain what element(s) of the treatment produced the most meaningful impact on exercise and physical activity for the participant (Martin, Thompson, & Regehr, 2004). Despite this challenge, when investigating a new treatment package, it can be time-efficient to combine a range of hypothesized controlling variables in an effort to develop a successful intervention, and later conduct a component analysis.

Research on interventions to promote the amount and magnitude of exercise overlap substantially with research designed to enhance athletic performance. In the former, the focus is on increasing the caloric expenditure from exercise, typically by improving adherence to exercise regimens and increasing the intensity and duration of physical activity/exercise. For example, De Luca & Holborn (1992) were able to demonstrate cycling behavior increased (speed measured in revolutions per minute) proportionally to raising the variable ratio requirement for speed goals, leading to delivery of conditioned reinforcers (points exchangeable for backup reinforcers) to both obese and non-obese 11-year old boys.

Sports psychology research involving athletes frequently targets the appropriate form, team skills, pass completion, free-throw accuracy, or another dimensions related to the succeeding in competition, such as speed or force of the activity (Brobst & Ward, 2002). Other commonly used physiological metrics employed in research are; blood lactate levels, Sp02 (estimate of blood oxygen saturation), heart rate, and VO2 max, which relates to the maximum oxygen uptake during strenuous physical activity. Blood lactate levels are often employed when measuring muscle exhaustion (Brupbacher, Harder, Faude, Zahner, & Donath, 2014), whereas the other measures might be used for more aerobic activities. Usually, the exercise requirement, weight or distance, is kept constant in the scheduled exercise, but the individual could complete the activity faster, last longer before exhaustion, or demonstrate physiological gains.

In the athletic performance domain, the focus is on developing interventions that improve the quality of athletic performance, defined either structurally (by the topography or performance of the behavior) or functionally (by the performance- relevant outcome of the behavior). In many instances, these literatures have converging findings when they are delivered to improve performance for a combination of athletic skills, as well as promoting the duration and intensity of exercise. Efforts to develop behavioral interventions to increase physical activity and enhance athletic performance utilize many of the same strategies, and when successful can be instrumental in body weight management and fitness.

Interventions have varied in their focus on how to achieve increases in athletic performance. Some of the common interventions include: skills training, goal setting (public posting [Brobst, & Ward, 2002], self-set [Ward, & Carnes, 2002], behavioral contracting [Aragona, Cassady, & Drabman, 1975; Wysocki, Hall, Iwata, & Riordan, 1979]), feedback, video modeling and feedback (Boyer, Miltenberger, Batsche, & Fogel, 2009), mental training comprising of self-talk and imagery, self-monitoring (McKenzie, & Rushall, 1974), and coaching (Allison, & Ayllon, 1980; Komaki, & Barnett, 1977; Koop, & Martin, 1983). Many of these interventions require the investment of time by a trainer to monitor athletic performance, provide instructions and provide differential consequences for improvements in athletic performance. While generally effective, trainer mediated interventions are time consuming, expensive, and they require direct access to a trainer. Thus there is a need to develop and evaluate equipment that automatically senses physical performance, which can be programmed to deliver differential consequences in an effort to sustain or improve athletic performance. This may minimize the resources required for an exercise intervention, and increase access to interventions that maintain long-term exercise behavior.

Current exercise research focuses extensively on scheduled exercise, which is defined as a scheduled structured activity for the sake of meeting a specified workout goal e.g. preferred heart rate zone, time spent active, distance travelled, and force or speed goals. Daily activity differs from scheduled exercise, where the terminal reinforcer might be completing an errand, or measuring the number of steps achieved throughout the day, excluding any scheduled activities. Generally, the intensity of exertion levels in structured scheduled physical activity exceeds that of daily activity, albeit for a shorter period of time. However, some researchers have recommended increasing daily activity rather than scheduled exercise, because of its poor adherence in the literature (VanWormer, 2004). Alternatively, Green et al. (2016) focused their efforts on minimizing an incompatible behavior, sedentary behavior, to increase movement in the workplace with feedback and prompting. This approach has merit in that it increases the time window to increase physical activity. Furthermore, high non-adherence and drop-out rates are commonplace in scheduled aerobic exercise programs (Fitterling et al, 1988). Unfortunately, this approach does not address the issue of exercise adherence for scheduled activity.

In the short-term, early physical activity is associated with aversive stimuli resulting from the stress induced upon the body through exercise, but even a slight habituation to these effects, could allow individuals to contact natural reinforcers occasioned by long-term exercise. Anecdotally, participants have commented that interventions like the contingency contract, enabled them to combat the short-term aversive consequences related starting an exercise regimen (Wysocki et al., 1979). Studies often increase goals gradually to minimize exposure to aversive physiological arousal resulting from over-exertion. For example, De Luca & Holborn (1992) started at a 15% increase from baseline levels before raising criteria, in order to maintain adherence in a trials to criterion design. Therefore, using individualized goals and embedding reinforcers at least in the short-term could minimize drop-out rates. Investigating other supplemental reinforcers that could be inserted into a workout routine, like music, could mitigate the initially unpleasant aversive stimuli associated with starting a workout routine.

Music and Exergaming

Because the study reported herein uses exercise contingent changes in music (e.g., tempo and volume), it is important to provide a brief overview of the research on the relationship between music and exercise. Music often accompanies exercise regimens, and it can have ergogenic (performance enhancing) effects upon exercise behavior, especially when the pace of the music is synchronized with the activity (Terry, Karageorghis, Saha, & D'Auria, 2012). For example, faster music tempos (i.e., beats per minute) increased the rate of submaximal cycling performance even when participants were unaware of the changes (Waterhouse, Hudson, & Edwards, 2010). Furthermore, adding music to an exercise session increases the time-to-exhaustion (99% of VO2 Peak) by roughly 19%, reduces the perceived exertion, and reduces blood lactate levels when compared to no-music conditions (Terry et al., 2012). Therefore, music can result in performance, motivational, and physiological benefits.

Music is most powerful as a motivational variable for exercise when it is played at 120 beats per minute (bpm) and above (Terry et al., 2012), however, this could depend on the activity in question (running or walking), or stage of activity i.e. warm-up vs. physical conditioning. For example, in the study by Karageorghis, et al., (2013) the selection of the music tempo of 130 bpm was based on the biomechanics of swimming compared to land based activities. The Brunel Music Rating Inventory-2 has been used to identify motivational music compared to neutral music, however, both motivational and neutral music had performance gains, 2.1% vs. 1.8% compared to no music controls, in 200-m freestyle swimming time trials (Karageorghis, et al., 2013). In athletic training even marginal performance gains could be a worthy investment, especially when ranking in competition could be decided by a millisecond margin. Current tools still require adaptation to capture what constitutes a motivational sound track. Furthermore, what is considered motivational might be dependent upon the user, therefore, offering the user the choice to select their music preference is an important practical consideration (Terry et al., 2012). Certainly, the beat of the music can confer substantial performance gains, if tailored to the activity in question.

Karageorghis et al. (2011) examined preference for four bands of music speed; slow (95–100 bpm), medium (115–120 bpm), fast (135–140 bpm), and very fast (155–160 bpm), in relation to cycling exercise intensity (operationally defined by set percentages of maximum heart rate). Physiological arousal and preferred music tempo have a clear positive relationship, but there are non-linear inflection points as the maximum heart rate increases, where preference shifts to faster music speeds (Karageorghis et al., 2011). This suggests participants' would prefer using a playlist that increases in beats per minute in concordance with the workout.

Interestingly, lyrics vs no lyrics in the music have only demonstrated minimal effects upon cycling exercise behavior, but further research is required in this domain (Sanchez, Moss, Twist, & Karageorghis, 2014). Minimal performance or physiological differences have also been reported when assigning randomized beats per minute (140 bpm, 120 bpm, 110 bpm, and no music) to trained cyclists with at least three years riding experience (Dyer & McKune, 2013). For some exercises like cross-fit, music can actually be distracting and hinder performance (Brupbacher, et al., 2014).

There is a body of research suggesting that there could be interactive benefits form combining both video and music into an exercise intervention. For example, there has been an impetus to "gamify" exercise (exergaming) or find various means to entertain exercisers, rather than fight the battle of reducing screen time or video gaming (Bosch, Poloni, Thornton, & Lynskey, 2012; Graf, Pratt, Hester, & Short, 2009; Siegel, Haddock, Dubois, A& Wilkin, 2009). These interventions have been successful at demonstrating games involving physical activity can be used be as an alternative to traditional cardiovascular training.

The music literature suggests synchronizing music to the activity in question, allowing participants to choose their music genre, and using a playlist that increases in beats per minute as the exercise intensifies. However, there is no research examining the effects of altering music as a consequence to a physical activity. Furthermore, few studies have examined the boxing as the physical activity of interest. Therefore, this research offers novel applications of music contingently delivered to participants, and its respective effect upon boxing performance, as measured in force in frequency of punches.

Boxing

There are fundamental differences between some physical activities. It may not be possible for individuals suffering from knee or joint issues, which are often co-morbidly occurring in individuals that are overweight or obese, to engage in excessive walking or jogging. Furthermore, these activities are only associated with aerobic or cardiovascular fitness, and not anaerobic muscle development. Therefore offering additional exercise options is imperative to catering to the specific activity needs of individuals that either do not prefer that type of exercise, or are unable to perform that exercise due to health concerns. One such promising physical activity is boxing, as it confers both aerobic and anaerobic benefits to the exerciser. Most often, boxing sessions utilize a 100 lb. heavy bag (a suspended large cylindrical bag) to practice powerful punches. Even without the resistance of a heavy bag, 30 minutes of Wii Boxing is an appropriate activity to receive cardiovascular gains (Bosch et al., 2012). It has been noted that boxing elevates the heart rate and energy expenditure, and compares favorably to other exercise modalities (Bosch et al., 2012; Kravitz, Greeene, Burkett, & Wongsathikun, 2003). Furthermore, it is an activity that has not received much attention from sport psychology and behavioral journals (Martin et al., 2004), and it has a number of response dimensions that can be measured, including the magnitude (force) or punches, the frequency or rate of punches. Thus, boxing was selected as the modality of exercise for the research reported herein.

Contribution

There are several innovative features of the research described herein. First, it extends the line of investigation regarding the interactivity of music and exercise behavior, using boxing, an under-researched exercise behavior, as the activity of interest. Boxing could be an attractive alternative exercise form for those people who are trying to get in shape and lose weight, but have not succeeded with traditional exercise programs, although it should be noted other physical activities are more conducive to weight loss. In addition to cardiovascular training it offers combined strength and endurance training

(Kravitz et al., 2003). Furthermore, it could also be a suitable alternative to exercise forms that require strenuous leg movement, which can limit the prescribed activities a participant can engage in based on health status.

Conjugate Schedules

Conjugate reinforcement operates by altering some dimension of a reinforcer, often, rate, duration, or intensity proportionally to a specified response. This provides the individual continuous feedback regarding their performance. Reverse conjugate schedules using negative punishment are generally utilized to lower a response, but they have shown more response variability (MacAleese, Ghezzi, & Rapp, 2015). Lindsley (1957) was the first to label conjugate schedules in a study analyzing adult sleep cycles. Since then, it has been applied in assessing the attending behavior for social reinforcers (Lindsley, 1963), assessing attending and feedback in dyadic supervision (Nathan, 1965), assessing preference for auditory stimuli (Mira, 1970), among many other applications (for an extensive review see MacAleese et al., 2015)

Conjugate schedules often do not need instruction to function (Mira, 1970), furthermore, they are fundamental to human experience, because they are ubiquitous in the natural environment. This type of reinforcer preparation functions with children as young as four months old, and notably when compared to continuous reinforcement caused less emotional behavior (Voltaire, Gerwitz, & Pelaez). Behavior usually has a measurable and proportional impact on the environment, and for this reason is has been dubbed the most "fundamental schedule" (Kelso & Fuchs, 2016). If feeling the wind rush past you and seeing the countryside are reinforcing stimuli when cycling, then wind and visual stimuli will continuously fluctuate with movement, and likely it will be directly proportional to the speed with which you pedal the bicycle.

Our device functions by simulating joint conjugate reinforcement (positive and negative), by requiring participants to meet a speed and force goal for their punches every 5-seconds in order to gain access to their preferred music. Otherwise, there are programmed consequences to the participant's music if punch force and/ or the punching speed is lower than the average goal. For example, punching below the average goal would require subsequently harder than average punches to raise the volume, and punching below the average speed goal would require faster punches for the music to play the music at its regular tempo. This adjusting requirement is based on an updating 5-second average performance goal set in relation to the participants' baseline performance. Therefore, changes in the music (e.g., the volume or tempo of music) are a consequence to the behaviors of interest (frequency and force of punches). Although, conjugate schedules have not been extensively studied, they have been shown to maintain high and steady rates of responding, because reinforcer redundancy is minimized by such preparations (MacAleese et al., 2015).

The punching bag feedback system can be conceptualized as conjugate schedules when considering that frequency and force are both stimulus dimensions of each response, which in turn impact the speed and volume of music respectively (for further details see Unique Device Features). Although, it should be noted that there is dichotomous feedback embedded in the feedback system, in the form of discrete changes on a screen, where the goal box (for frequency and force) is colored green when the individual is at or above their goal, and red when they are below their goal (see Figure 1).

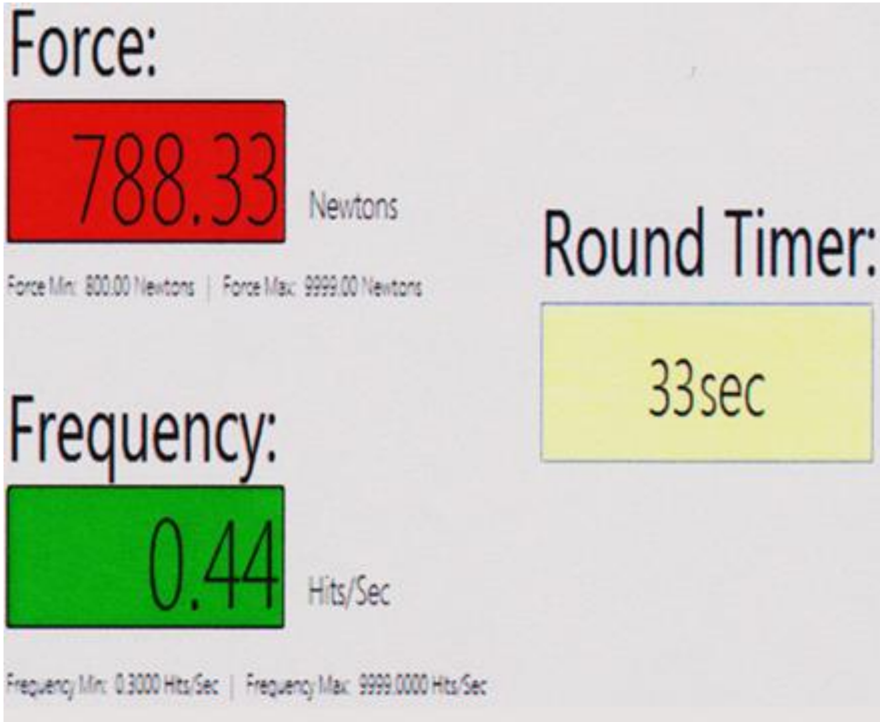

Figure 1. Visual alterations based on force and frequency goals.

Auditory versus Visual Feedback

Technology can be utilized to quantify, enhance and motivate athletic performance. Traditionally it has involved the visual display of basic data feedback such as heart rate, distance traveled, or calories burned, so users may visually track their exercise progress. The primary benefit of this feedback modality is that you get a permanent product depicting a readout over time, but it requires direct visual access for moment to moment feedback. For many sports, such as boxing, monitoring a video output while training on a punching or heavy bag may not be practical. In fact, visual feedback alone could result in inadvertent injury, or redirect attention from the physical activity. To solve this problem, an alternative feedback system has been developed at WMU providing real-time feedback on performance using auditory feedback in addition to visual feedback.

Unique Device Features

The device that is described in this experiment can automate goals for the user, or be set manually. Every 5-seconds the participant had to maintain performance at, or above, that goal for their music to play appropriately, otherwise performing below a speed goal would play the music at a speed where the music was not discernable, or punching too softly would reduce the volume of the music. Additionally, the screen display would highlight their frequency or force goal as “red” designating that they were below their performance benchmark.

The prototype punching bag that is the focus of this research, used automated sensors that can detect and quantify the frequency and intensity of punches, then programmatically alter the music based on these data. The speed music adjusts with the speed of the exercise (e.g. punches per minute) so that it co-varies, where responding (i.e. hitting the punching bag) at a frequency lower than the benchmark goal for frequency of punches, results in an increase in the tempo compared to its original tempo. The force of the punch (e.g. Newtons) would alter the volume (dB) of the music, so that a harder punch would make the music more audible, and a softer punch than the goal would reduce the volume of the music.

Specifically, if the participant fell below their frequency goal, music starts at 1.3x the play-speed for the first second, then in each subsequent second the participant is behind, the music plays 1.4x, 1.6x, 1.8x and so on, until the music play speed is 3.0x faster (10 seconds of responding below goal). The play speed would remain at 3.0x play-speed until the person is above, or at, the specified goal. Similarly, when the participant fell below their force goal, music volume plays at 50% (- 6 to 8 dB) for the first second, then 40% (- 8 to 10 dB), then 30% (- 10 to 12) dB, then 20% (- 12 to 16 dB), and then to 10% (- 16 to 20 dB) of its original play volume (5 seconds responding below goal). This contingency would remain at 3x music play speed and 10% play volume until the person is above, or at, the specified force goal.

Furthermore the specified ranges prior to a change in feedback would be user specific and based on their baseline (previous) performance, rather than set by pre-classified fitness levels e.g. expert or novice. Equally important, the benchmarks for frequency and intensity can be adjusted over time as a person's performance improves or, in other cases declines.

The goal of this research is to evaluate the effectiveness of an automated audio/visual-feedback system on a structured punching bag workout routine. Immediate feedback on athletic performance can be helpful to allow users to determine whether their athletic performance is improving and/or being maintained at a desired level. The applied benefits of exercise interventions are more easily disseminated when the costs their delivery are minimized, they are easily accessible, and when participant's report high customer satisfaction. Not only does this bode well for adherence to fitness program, but it could be predictive of long term maintenance. This research could confer significant insight into health promotion, for reducing obesity and increasing access to long-term health benefits conferred from exercise, if the proposed technological solution has ergogenic effects.

METHOD

Pilot Study

The study was divided into a pilot test, and an experimental phase. During the pilot test, volunteers were recruited by email to assess the audio-feedback element that would be used in the experimental phase. No performance data were recorded for the pilot test, beyond verbal feedback from the participants, which was used to calibrate the research apparatus for the second stage of the study. The goal of this phase was to calibrate the device so it was positioned effectively for workouts, and to identify the audio characteristics and contingencies that they were reported as reinforcing and aversive, to arrange effective programmed audio contingencies for the experimental phase

Six participants volunteered for one workout session comprising of 4 three-minute rounds with 3 one-minute breaks for a total of 15 minutes. There was no compensation for the pilot study. In general, participants reported that the goals set by the experimenter should be set programmatically and gradually, otherwise music changes could become de-motivating. Furthermore, without a focal point or target, users were unsure as to where to hit the bag, especially if it were to twist to the side. Additionally, participants reported that when the bag moved laterally as a result of a punch, that it disrupted subsequent punches because the target was not stationary. Lastly, it was reported that wireless head-sets impaired punching performance, because impact with the bag sometimes dislodged the wireless ear-piece through which music was programmed.

In response to feedback from the pilot test phase a number of modifications were made: a) the bag was anchored to 60 lbs. to reduce movement of the bag in response to punches; b) a wrap with an outline of a boxing opponent was added to the punching bag to provide a visual target for punches, c) a Jabra Speak510 was used to deliver the audio, and d) a marker was added to the floor for appropriate foot placement. The aim of the study was to focus solely on punching (force and frequency), while minimizing the need to engage in "foot work". The bag was anchored in such a way to minimize spin and the side to side motion of the bag. More precisely, two ropes were added on either side of the bag, and one rope behind the bag to stop the bag from swinging too far away from the participant.

Recruitment, Informed Consent, and Screening

Recruitment

Potential participants were recruited by three primary methods: the posting of flyers, going to classrooms to advertise the research opportunity, and sending recruitment emails to an administrative contact (see Appendix A). The administrative contact is usually the individual responsible for emailing students in their mailing list with departmental updates. The researcher had permission to post flyers containing details about the study on campus and in a local gym (with the owner's permission). Classroom recruitment occurred in health psychology class (PSY 4630), in an arts and sciences seminar (AS 3900), and an undergraduate research group.

All recruitment materials highlighted the inclusionary and exclusionary criteria for the study, and detailed the time commitments, risks, and compensation for study participants. To assist in recruitment and retention there was an incentive in the form of a $25 amazon gift card (or upwards to $50 in Amazon gift cards), which could be earned based on their participation. Initially, nine participants (6 female, 3 male) were recruited, but a male participant dropped out after three sessions due to scheduling conflicts.

Informed Consent

To participate in experimental phase of the study, participants that expressed an interest in the exercise research met with the researcher, where additional details regarding the study were provided. Before signing the informed consent form, participants had the opportunity to ask questions regarding the informed consent process (Appendix B), and the date that the study was approved by the HSIRB (Appendix C) as well as the contact information for the HSIRB. They were informed verbally that they would be asked to fill out some questionnaires regarding demographic and health characteristics (e.g. gender, physical activity levels, CVD risk level, emergency contact information etc.). The potential participants were informed that: a) the study focused on the force and frequency of punches to a punching bag device that would automatically record data; b) of their right to stop participating at any time, for any reason, without suffering any prejudice or penalty by their decision to stop, and c) of the opportunity to earn $25 (upwards to $50 if invited to complete two sets of 12 sessions) Amazon e-gift card in compensation for every 12 sessions completed, and for not having more than one unexcused no-show or two reschedules (more than 24 hour notice) to an appointment for every 12 sessions over a 7 week period.

Screening Criteria

The justification for the age range lower limit of 18 was to recruit participants who were legally eligible to consent to participating in the study. The upper age limit (45 for a male, or 55 for a female) was selected due to the fact that ACSM classifies older participants as having a higher risk factor for cardiovascular disease. In order to ensure that music was reinforcing for the participant, we recruited those that preferred to listen to music while exercising. This enabled participants to select preferred music playlists for the purpose of engaging in physical activity. To prevent oversampling of one sex, we capped recruitment to not exceed 66% for one sex.

Inclusion Criteria:

1) Female 18-55 years old or male 18-45 years old.
2) Prefer to exercise with music.
3) Report an interested in increasing their physical activity.
4) Males and females will be eligible to participate, but no more than 66% of a particular sex will be recruited in the study to prevent oversampling of one sex.

Exclusion criteria:

1) Individuals with any hearing or vision impairments.
2) Report extensive experience working out on a heavy bag.
3) Report as athletic and regular aerobic activity (3 or more times a week) or strenuous strength training.
4) High risk for Cardio-Vascular Disease (see additional details on exclusionary criteria in Appendix D: Screening Tool).

Extensive training history with a heavy punching bag was an exclusionary criteria, because performance increases for those with this experience could be attributed to getting in tune with their previous work-out routine. Our recruitment efforts were directed toward individuals who reported an interest in exercising more regularly, and did not identify as athletic with a rigorous workout regimen. For example, in the Physical

Activity Screening Tool (PAST in Appendix D) engaging in aerobic activity 3 or more times a week, very vigorous anaerobic activity, and self-reporting as athletic would exclude participation. Considering the intervention involved auditory and visual components, individuals with hearing or visual impairments were also excluded from participating in the research. Lastly, it was imperative to screen individuals based on their health risks for engaging in physical activity. One convenient method is to utilize validated pre-activity health screening tools such as the American College of Sports Medicine (ACSM) to assess participant risk of engaging in physical activity. Any individuals that had contraindicated high risk factors that would prohibit physical activity with moderate physical activity involving a punching bag were excluded. If the screening tool indicated an elevated risk, the individual could still consult a medical professional to override concerns highlighted by the ACSM.

The PAST (Appendix D) was created combining the ACSM and our inclusion/ exclusion criteria as part of the screening process. If the results of the PAST indicated that participant did not meet the participation criteria, the investigators explained the reasons why the participant was ineligible to participate in the research. No participants were excluded, however, two interested female participants who wanted to participate in the study were asked to wait until more male participants were recruited to prevent oversampling.

Human Participant Protection

As detailed in the approved HSIRB protocol, the experimenter took steps to minimize risk to participants. These efforts included the following practices: Participants were asked to schedule a minimum of two punching workout sessions per week, but were not allowed to participate in more than three sessions per week in an effort to prevent physical exhaustion and injuries related to over-exercising.

A health screening tool was used to identify participants who would experience only minimum risks from engaging in physical activity (see Appendix E). To maintain privacy a private room was used to work-out, and participants' were assigned four digit numbers to maintain confidentiality. The investigator also ensured water was available at all times, had a scripted emergency protocol if the participant experienced major physical discomfort, and was trained in Cardiopulmonary resuscitation (CPR) and how to use an Automated External Defibrillator (AED). A weekly activity assessment (see Appendix F) allowed the investigator to gauge any changes in the health status of the individual to reevaluate the safety of continued participation. Furthermore, before participating in the boxing activity participants learned from exercise videos how to stretch before exercising, the appropriate stance for boxing, and the correct way to jab (e.g. wrapping thumb outside clenched fist) the heavy bag to prevent accidental injuries. The investigator remained present to monitor safety, and to offer tips on appropriate punching if the participant diverted from the strategies conferred from the punching safety video. The investigator recommended participants with longer nails to consider cutting them to prevent the force of the punch from causing discomfort from pressure exerted from clenched fists. All participants had their own hand-wrap to prevent cross-contamination from using the same equipment. The investigator wiped down the room, and weighing scales after use with a cleaning towel and disinfectant spray.

Participants

Participants (N=8) were WMU undergraduate (n=3) or graduate students (n=3), and working professionals (n=2). Younger adults aged between18-33 years old (Mage = 24.9 years) were recruited. A majority were female (6 Female/ 2 Male), and as a result of the third male withdrawing from the study, this led to inadvertently violating the preferred cap to avoid oversampling one gender. None were smokers or had contraindicated health factors precluding moderate physical activity involving a boxing workout. Drop-out (n=1) and no-shows in the study were relatively low. For example, there were only two no-shows, and five reschedules out of 119 scheduled sessions. Participant 3 did not return to complete the post evaluation, but completed the consumer acceptability section.

DESIGN

The multiple baseline design (MBD) across subjects was selected instead of a randomized or matched group-control design which were disqualified due to practical considerations (Johnston & Pennnypacker, 2010; Huitema, 2011). In our case matching features of a control group with an experimental intervention group (e.g. athleticism, arm-span, weight, height etc.) would require a longer duration for the effective recruitment of participants, or delay the onset of the treatment until the matched participants were identified. Other notable limitations of a majority of group designs are that they are costly to employ, require a large number of participants, and non-responders are not offered a tailored and more effective treatment. In sports psychology journals the use of single subject designs has risen in popularity after positive reviews of the behavior-analytic approach to investigating sport psychology (Martin et al., 2004). One potential rationale for this upsurge in popularity of single-subject designs is that these designs allow the subject to serve as their own control, and selection differences between the experimental or control group features are not a threat to interpreting the results.

Study

A MBD was used to compare the effects of performance contingent music (hereafter referred to as the experimental phase, phase B, or by its more descriptive label, "performance contingent music") with a condition in which ambient music was provided in a non-contingent manner (hereafter referred to as baseline, phase A, or by its more descriptive label, "non-contingent music"). Three of the participants were assigned to a short baseline (three sessions of non-contingent music), and the other five received an extended baseline (seven sessions of non-contingent music).

Regardless whether the participant received a long or short baseline, the A and B phase in together consisted of 12 sessions, where each session was comprised of four 3-minute rounds. Six of the eight participants received one A and B phase. The researcher invited three completers to return for the second round, however, only two opted to return (receiving two phases of non-contingent music and two phases of contingent music in the following order – A-B-A-B). For participants invited to return, after returning to baseline they would receive the intervention at a different stage from their first round i.e. if they received a short baseline, they received the extended baseline, and vice versa. The results from these two participants allowed us to assess if the effects of the experimental phase were enduring, or reverted back to baseline performance levels.

Staggering the delivery of the experimental phase allowed for highly sensitive conclusions to be drawn regarding the effectiveness of the intervention, while minimizing threats to the internal validity based on practice effects, reactivity from repeated exposure to assessment and participant history (Johnston & Pennnypacker, 2010). Furthermore, each individual could receive a tailored performance goal based of their respective baseline performance, and adjusting this goal accordingly could maximize the likelihood all participants respond positively to the intervention.

Individual goals were set for both force and speed, and gradually increased as in a trials to criterion design. Goals for speed were usually set lower than that of force, as participants verbally reported preferred lower speeds goals. Tailoring the performance goals for each individual required an examination of both self-reported fatigue post exercise, sick/ lower performance days, and the trajectory of the data path after charting the preceding session information.

Length of the Study

Completers of the study for the A-B phase were expected to complete 10-12 sessions lasting 45-60 minutes over a 4-7 week period, or approximately 2 months. Completers of the A-B-A-B phase, participants were expected to complete 22-24 sessions (45-60 minutes) over a 10-12 week period. Participants were allowed to reschedule two sessions, or have one-no show, and still receive compensation. The minimum number of completers needed for a comprehensive evaluation of the punching bag device was considered to be 6 participants. For seven of the eight participants (one completed the study in four weeks) the Christmas Break disrupted the continuity between sessions, by up to two weeks.

Music Selection

Each participant provided information regarding preferred music, including specific artists and song titles. This information was then used to select four songs that the participants would be provided across all conditions, baseline and experimental phases. In order to control for the individual differences in the speed of the music and make comparisons where appropriate, the average beats per minute of the music roughly averaged out to 120-125 bpm (see Table 1). Additionally, based on the ergonomics of a safe punching bag workout, an individual should exercise at a gradually increasing pace to prevent injury, therefore the music bpm started off slower and accelerated (100 to 110-125 to 125-135 to >136). Based on research by Karageorghis et al. (2011) this crescendo in bpm was more likely to be preferred by the participants, because preference shifts to faster music speeds with increased physiological arousal. Table 1 below lists the genre of music, and beats per minute of the four songs in the order that the participant experienced them in all baseline and experimental phases.

Table 1

Beats per minute and genre of participants' four selected songs

		Song bpm				
Participant	Music Genre	*1st*	*2nd*	*3rd*	*4th*	*Mean*
1 (F)	Pop Rock	100	117	120	148	121.25
2 (F)	Rap	104	116	120	140	120
3 (F)	Country/ Pop	104	125	130	140	124.75
4 (F)	Electronic Dance Music	109	126	128	138	125.25
5 (M)	Electronic Dance Music	109	126	128	138	125.25
6 (M)	Dubstep	104	125	128	140	124.25
7 (F)	Rap	104	116	120	140	120
8 (F)	Alternative Rock	105	120	125	136	121.5

Dependent Variable

The primary dependent measures recorded by the heavy bag device are: relative force of punches, and total number punches recorded every 5 seconds for every four rounds (36 intervals per each round, or a 144 intervals per session) during the workout routine. These measures relate directly to intensity and continuity of physical boxing activity, and they were recorded automatically by the punching bag accelerometer sensors. Participants specifically focused on jabs (straight fully extended shoulder level punch), and the investigator was present monitoring the type of punches to ensure they were the same topography.

Dependent Variable Integrity

A punch is defined as a clenched fist making contact with the bag over 623 N. The investigator ensured that the bag was not excessively spinning (inflates force), and that the participant did not run toward the bag (and remained in a certain perimeter minimizing foot movement). The data will be presented as round averages, but include standard error as a measure of variance. Other pertinent variables that were recorded were weight and body fat percentile before the first session and last session. In the final work-out session, the participant completed a social validity questionnaire post assessment (see Appendix G). The tool assessed whether the participant preferred visual, audio feedback, or a combination of both. Another important consideration was whether the participant reported increases in general daily activity, or indicated that they engaged in additional structured exercise.

Independent Variable

In baseline, non-contingent music (preferred songs from Table1) played without displaying any visual feedback from the monitor. After collecting baseline data, the force performance benchmark for the first experimental phase session was set at roughly 70-120% of the mean force performance, and the speed goal was set at 30-80% of the mean performance from baseline speed. Each session the performance goal was usually increased based on participant performance, resulting in the final session having a substantially higher goal than the first experimental session (see Table 2). The performance goal for speed was usually set lower than that of force, because participants verbally reported maintaining higher speeds as the most challenging element of the workout. Tailoring the performance goals for each individual required an examination of both self-reported fatigue post exercise, sick/ lower performance days, and the trajectory of the data path after charting the preceding session information.

During the experimental phase, the feedback package comprised of a round timer, color changes for frequency and force readouts (red when below the goal, and green for at, or above the preferred range), audio-feedback adjusting programmatically based on average 5 second bin data (force changes the volume, and frequency changes the speed).

Table 2

Summary of first and last goals for force and speed per participant. * signifies extrapolated speed data from the last baseline session for the first of the two A-B phases.

Participant	First Force Goal % of B/L	First Speed Goal % of B/L	Last Force Goal % of B/L	Last Speed Goal % of B/L
1	97.7	51.8	183.1	137.1
2	73.8	70.3	118.1	87.9
3	88.1	31.9	128.1	79.8
4	99.3	84.5	178.7	169.1
5	89.4	60.8	102.8	91.2
6	76.7	57.8	87.2	86.6
7	70	80	143.8	180*
8	110.1	83.2	206.5	249.7*

Setting and Device

The device (see Figure 2) consisted of a wrap placed around a 100 lb. punching bag, which had two accelerometers, one placed at the top, and the other placed at the bottom of the device. The relative position of these accelerometers as the bag swung after an impact, could be used to evaluate the force of the punch in relative Newtons (N), and the rate at which it oscillated helped in determining the number of punches. The N is a unit of force measure, where one N is the force needed to give one Kilogram mass the acceleration of 1 meter per second squared (ms^{-2}). Our minimum force threshold was calculated by the lower limit of 1.4g from the accelerometer, multiplied by the weight in kilograms (45.4 kg) of the bag and the acceleration due to gravity (9.8 ms^{-2}) (45.4 * 1.4 * 9.8 = 623 N). There force of punches had to be above the 623 N to be recorded as a punch (for both force and frequency), otherwise no data would be recorded for that 5-second interval. Two images depict the bag and its electronic components. The device was professionally mounted allowing participants to safely exercise in private side-room of the Behavioral Medicine Laboratory.

After the malfunction, the micro-controller was moved to a new location where movement from punching the bag minimized the impact to the electronic components.

Figure 2. Image A (on left) depicts the original placement of the microcontroller before the malfunction, whereas image B (on right) depicts its location on a separate beam.

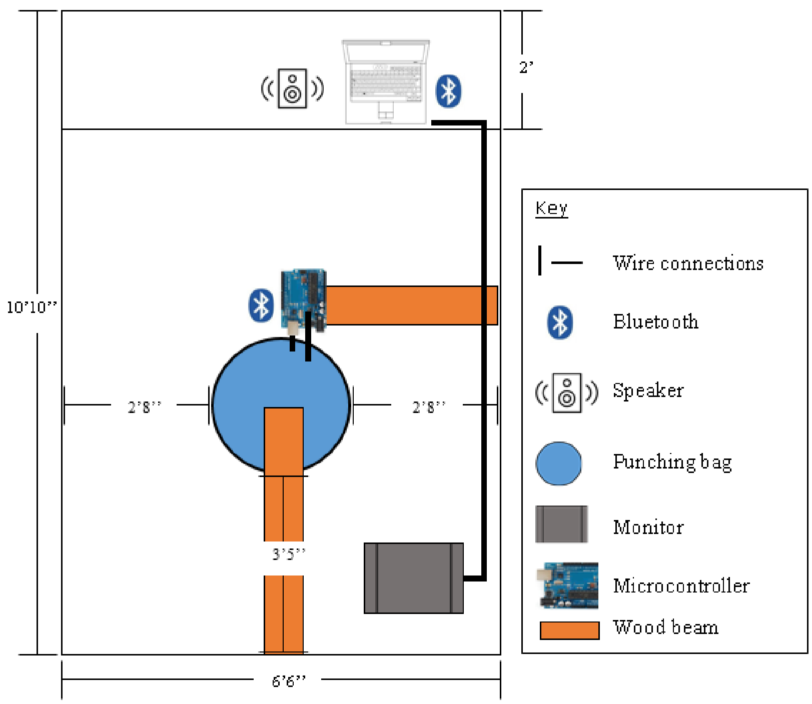

Figure 3. Technical drawing of the layout of the exercise room.

The researcher's computer could be linked to a wall mounted screen visible on the participant's left (see technical layout Figure 3) to depict workout information in the form of numbers for force and frequency and color changes (green = at or above performance goal, and red below goal). The average decibel reading directly at the speaker (max 87dB) averaged 80 dB, but at the location of the participant it was 62 dB (measured using Decible meter[Sound,Noise] app for Android IOS). Generally, the investigator sat behind the participant out of view, however, if the punches resulted in spinning the bag the researcher moved behind the bag to prevent inadvertent disconnection from the microcontroller.

RESULTS

Data Validity and Selection

The focus of this research was detection of changes in the frequency and force of punching bag strikes over the phases of this study. The investigator was present during all sessions to monitor the health and safety of the participant, and to ensure the movement of the participant, the type of punch, and the location of strikes remained consistent. Due to the sensitivity of the device, a punch was defined as any forceful impact with the punching bag that was over 623 N relative force (non-calibrated to real-world force but internally consistent). It was not possible to calibrate the accelerometers with the application of a standard external force, but comparisons made between two recorded force measures could provide the actual N force increase. Although, we cannot guarantee that a read out of 700 N (for example) was an exact measure of the force of a punch, we can guarantee that an increase from 700 to 1000 N was a 300 N increase, because the accelerometers were sensitive to changes in the frequency and intensity of punches

Data exclusion

Unfortunately, during the first round of exercise there was a hardware malfunction, which required a replacement of the top accelerometer, and moving of the microcontroller to prevent unnecessary physical stress (see Figure 2). Datum for the first session for four participants were excluded in the results, because the malfunction could have impaired the accuracy of the data collection. It was not possible to determine if the malfunction was ongoing during testing, and it was only after it stopped recording data altogether that the researcher was aware that it required repair. Therefore, the decision was made to include data only after the repair (raw data available upon request), because of potential accuracy issues regarding the first sessions prior to the malfunction.

Generally, the device functioned as intended, but errors did arise, for example, during the P8's ninth session multiple error dialogue message boxes appeared, and subsequently an inflated first round resulted. In this instance the first round was replaced by a round after the session was over with the same one-minute break separating experimental rounds. The outlier was still charted because the researcher could not track the source of the issue. At other times, the device required resetting to be able to synch to the microcontroller to the computer, and ensure that it was collecting real-time data. Additionally, participant 8 (P8) reported physical discomfort in session six (round 24) and opted to discontinue after two of the four rounds were collected. These two rounds were excluded and not graphed, because they would not reflect an overall 12 minute workout. Therefore, the subsequent session seven replaced the incomplete session. A total of119 sessions were collected for the eight participants.

Individual Data

Data were graphed individually and presented in dyadic pairs, with both force and speed data, in Figures 4, 5, 6, and 7. Although the delivery of the phases were staggered, of the eight participants, five received the extended baseline, three participants received the short baseline, and two of those three were in the A-B-A-B condition. After pairing the two individuals that received A-B-A-B condition, there remained only one short baseline condition to compare to an extended baseline. Unfortunately, it was not possible to predict who would complete the follow-up to return to baseline and experimental phases, but we did counterbalance exposure to each phase i.e. if the participant received a short baseline, they were assigned an extended baseline in the return.

Each participant will be abbreviated, where the term P1 refers to participant one, P2 refers to participant two, and so on and so forth. Each data point reflect a 3 minute round derived from an average of 5-second interval data, and each four data points constituted a session occurring on one day. A break in a series reflects a hiatus from the study greater than two weeks as a result of the Christmas break. P3 and P5 returned from their break after session 10, while P2, P4, P6, and P7 returned after session 11, and P8 returned after session 12. Only P1 was unaffected by the break because she completed the study before the holiday period. White filled circles indicate that the participant reported as feeling unwell, and the error-bars represent standard error for the 5-second interval data.

Data will be discussed in terms of level changes, shifts in slope, changes in the peak responding between conditions (maximum effect), and Percentage of Non-Overlapping Data (PND). In Figure 4, P1 had a stable trend for force and a decreasing trend for speed, and only experienced gains in performance after the experimental phase was implemented, despite being prescribed to the extended baseline condition. For example, her maximum force (3110) in the experimental phase was 2.6 x more when compared to her maximum baseline force (1196 N), and 65% of data points were above maximum effect in baseline (PND). These increases in force may not reflect an increase in the intensity of exercise unless speed was stable or on an increasing trend. Fortunately, introducing the experimental phase reversed the decreasing trend in baseline for speed of punches. There was a slight increase in maximum speed, as it was 1.12 x greater in the experimental phase, although there were much greater gains in overall average speeds in the experimental phase (1.9 x greater than baseline). However, 15% PND for speed reveal only slight treatment effects along this response dimension.

P2 instead had a much more stable baseline and maintained a steady but gradual upward trend in performance in the experimental phase, with no clear level changes. Her max force in the experimental phase (3636 N) was approximately 1.5 x greater than her maximal force in baseline (2474 N). Maximal and average speeds (both 1.03 x greater in B phase) were relatively similar across conditions, but PND for force (35%) was larger than PND for speed (10%).

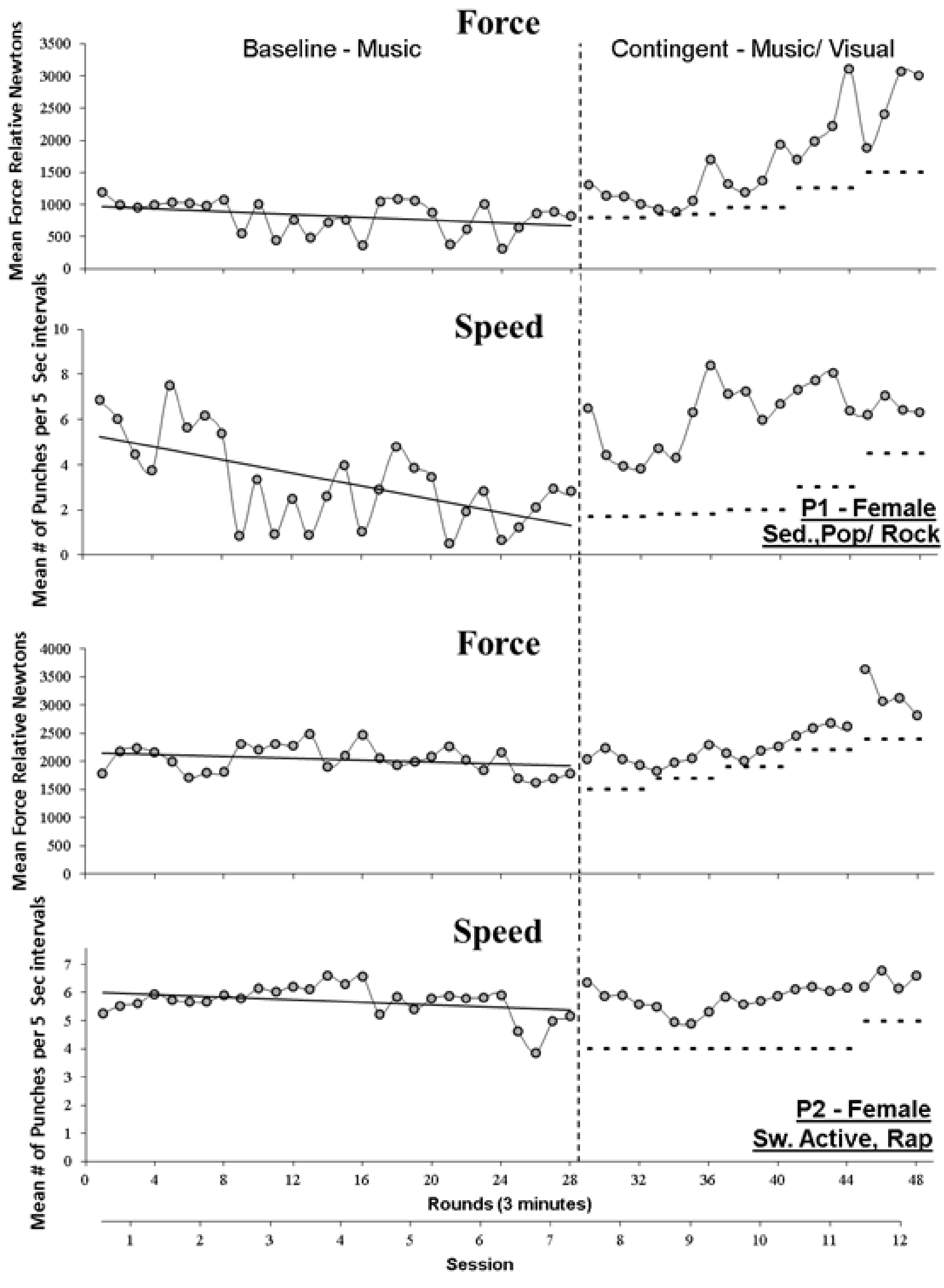

Figure 4. AB data for participant one and two. Each data point depicts the average force and speed of 5-second data for 3-minute rounds, where four rounds comprises a session. Dashed markers signify the specified force or speed goal, where falling below would

augment the music and visual display. Gender, activity levels (Sed. = sedentary, Sw. active = somewhat active), and music preference are identified in the subject label.

Figure 5 depicts what was a decreasing trend for P3's force and speed data prior to the intervention. P3 received a shorter baseline, and made larger gains during the experimental phase for maintaining her punching speed above baseline levels, although there were no clear level changes. For instance, her maximum force in the experimental phase (1902 N) was 1.2 x more when compared to her maximum baseline force (1580 N). Maximal and average speeds in both conditions were 1.4 x greater in the experimental phase. P3 seemed to respond more effectively to the treatment for the speed component of the experimental phase, as indicated by the PND for speed being 91%, which highlights more extensive treatment effects when compared to force (28% PND).

Unfortunately, during sessions seven and eight P3 expressed an interest in participating in the punching bag session despite reporting to be unwell. This coincided with a drop-off in performance for force, but not speed. After returning from a break between academic semesters, her performance was below the data path trajectory, which could have been described as a slight upward trend when discounting the sick days. Unfortunately, her performance was below the benchmark for the 11^{th} session, and she was exposed to the aversive music contingency for more than 50% of the session, which could accounted for her dip in performance during session 11. She did not continue participation in the study to complete session 12.

After exposure to the intervention, P4's force and speed jumped to equivalent peak baseline force and speed levels, before reaching peaks 1.7-1.8 x her baseline speed and force peaks respectively. After returning from the break there was a clear jump-up effect in performance for her force data, but her speed had an upward shift before the Christmas break. PND for force was 80% and 85% for speed, indicating clear intervention effects. The overall average difference in force was 1.7 x greater in the experimental phase for P3, but speed was 2.2 x greater. Both P3 and P4 had primary treatment effect gains for speed.

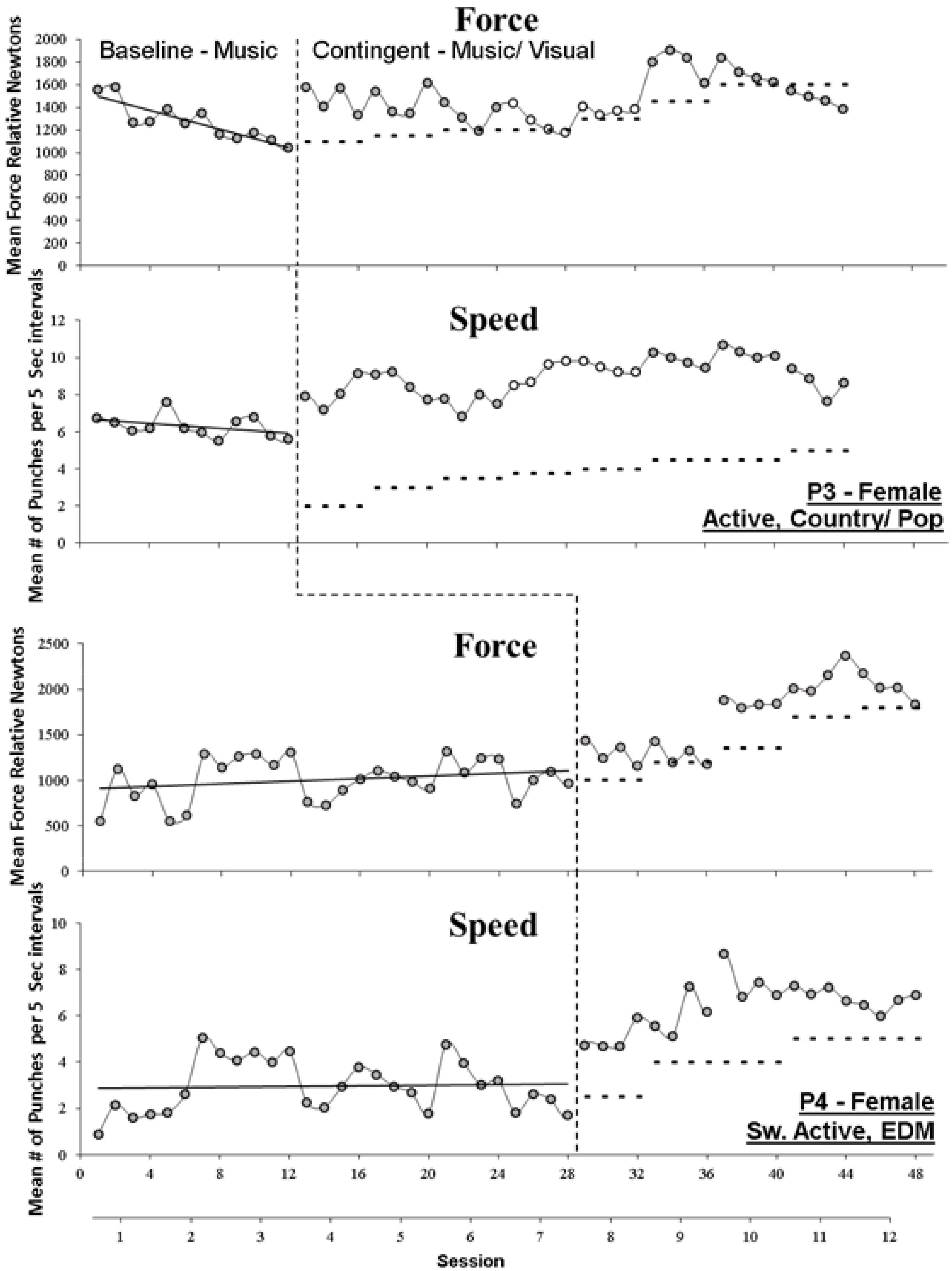

Figure 5. AB data for participant three and four. Each data point depicts the average force and speed of 5-second data for 3-minute rounds, where four rounds comprises a session. Dashed markers signify the specified force or speed goals. Open white markers are days that the participant indicated that they were not feeling well, but still opted to

participate. Gender, activity levels (Sw. active = somewhat active), and music preference are identified in the subject label.

In figure 6, both P5 and P6, who received the extended baseline had smaller gains compared to the rest of the group. Furthermore, P5's data path in baseline was already on an increasing trend, therefore the initial increase in force data in the eighth session cannot solely be accounted for by the introduction of the experimental phase. For this reason, it is not as prescient to discuss this individuals gains in relation to the exposure to the experimental phase. For P6, force performance appeared to fluctuate less with the exposure to the experimental phase, so it is possible the intervention had some stimulus control on impacting the variability in the force of the punches. However, baseline had the highest maximum force reading (4039 N) and in the experimental phase there was a decrement in peak levels of force responding. In relation to average response increases for both force and frequency, there was only a 6-7% gain in the average force and frequency with the exposure to the experimental phase. Furthermore, P6 demonstrated a very slight increase in the upward trend of both force and frequency data when exposed contingent music/ visual condition. Both participants had data path envelopes in baseline that overlapped much of the data path for the experimental phase. These participants reported that they were physically active. Therefore, it is possible that those participants who reported as physically active were quicker in reaching maximal performance, leading to ceiling effect, which could have made it more challenging for the intervention to demonstrate any further gains.

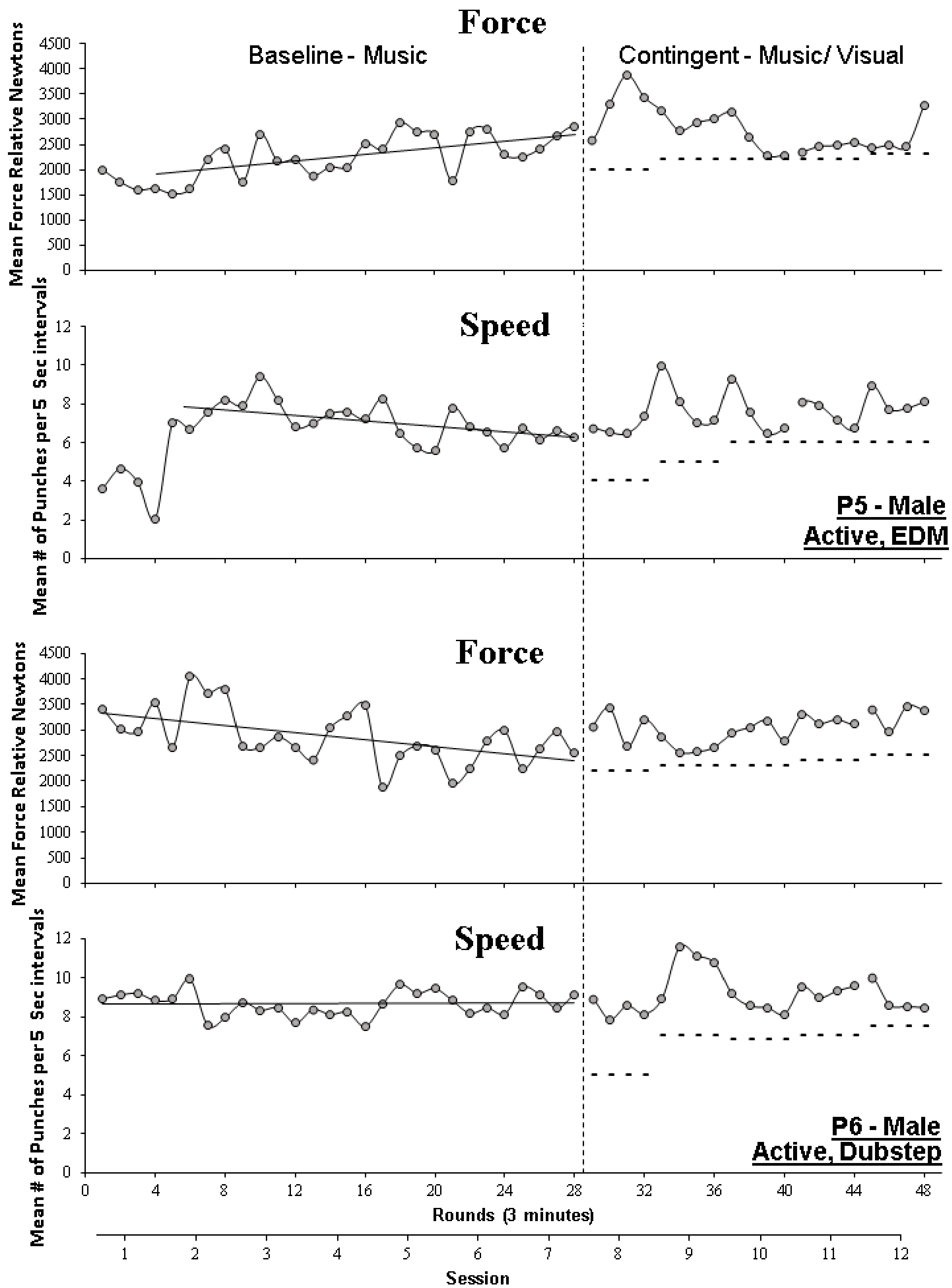

Figure 6. AB data for participant five and six. Each data point depicts the average force and speed of 5-second data for 3-minute rounds, where four rounds comprises a session. Dashed markers signify the specified force or speed goals. Gender, activity levels, and music preference are identified in the subject label.

In Figure 7, P7 demonstrated very large performance gains reflecting large level changes and moderate slope increases, which did not transfer when returned to baseline. Peak effects in P7's baseline (1958 N) were approximately 1.7 x less than those in the first experimental phase (3324 N). Similarly, speed was more than doubled with the onset of the first experimental phase (4 to 8.8 punches per 5-seconds). PND for the first A-B phase was 94% for force and 100% for speed, thus reflecting impressive gains from the experimental phase, and these continued into the second A-B phase, where in the second experimental phase 100% of data points were non-overlapping for both response dimensions. This indicates that the individual was relying on the feedback from the device to maintain their level of activity. They were able again to increase their performance when returned to the experimental phase for the second time, even though they did not reach the same peaks in performance, presumably because the second intervention had shorter exposure.

There were clear level changes for force and frequency in P8's first A-B phase. Peak force levels close to 2.3 x greater in the experimental phase (2081 N) when compared to baseline (911 N). Similarly, peak speed was 2.7 x greater in the experimental phase (10.1 punches/ 5-seconds) when compared to baseline (3.7 punches/ 5-seconds). PND in the experimental phase for force was 100% and 94% for speed. Curiously, P8 continued to perform at similar levels after returning to baseline, indicating that there was some transference of performance gains between conditions. Accessing the kinesthetic feedback of what qualified a forceful punch, and learning to pace their punches to the rhythm of their non-contingent music may have allowed them to continue to perform at similar levels. However, after returning to baseline, there was a stable performance with no apparent upward improvement in performance, but on returning back to the intervention, this appeared to prompt the individual to increase their performance at least for force (PND 60%). Perhaps, the intervention functioned more of a prompt to continue to improve their performance, while internalizing the levels of performance already gained, resulting in little change when the intervention was removed. Many of the participants established performance gains in either force or frequency of punches during the experimental phase, with some experiencing gains in both. However, the data from P7 and P8 demonstrated clearer experimental control, because their behavior was examined again with a return to baseline. In general, participants that received the maximal gains, self-reported their physical activity as either, sedentary, or somewhat active.

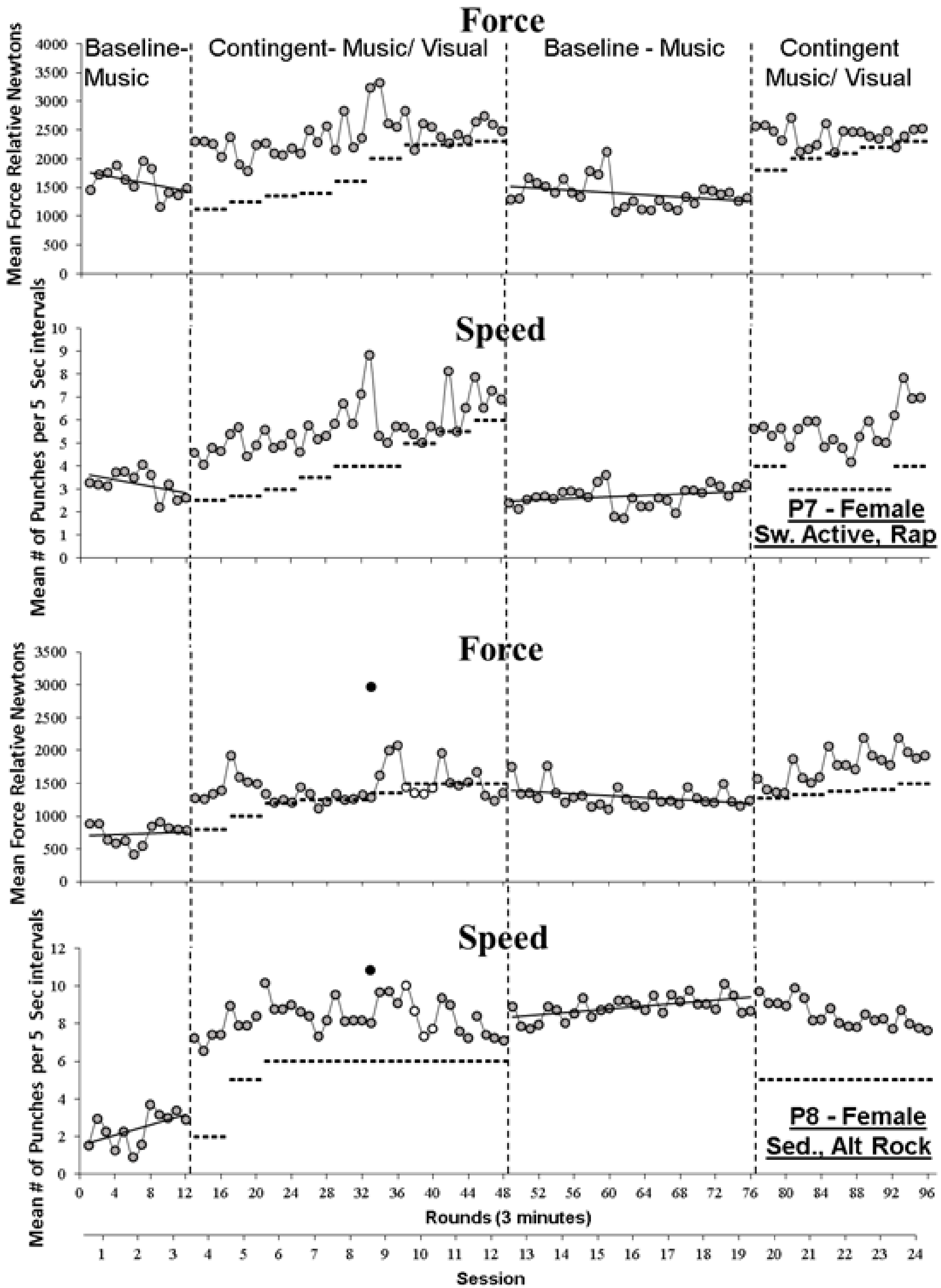

Figure 7. ABAB data for participant seven and eight. Each data point depicts the average force and speed of 5-second data for 3-minute rounds, where four rounds comprises a session. Error-bars represent standard error. Dashed markers signify the specified force or speed goals. Open white markers are days that the participant indicated that they were not feeling well, but still wanted to participate. The dark filled data point represents an outlier

round. Gender, activity levels (Sed. = sedentary, Sw. active = somewhat active), and music preference are identified in the subject label.

For P1, P3, P4, P7, and P8 there were step-up performance gains implicating a motivational component to the intervention, in that participants had the ability to perform at such levels, but required a specific set of contingencies (the response contingent audio condition) to motivate this level of performance.

Generally, when performance goals were set, they were based on trajectory of their data path, verbal feedback from the participants regarding the difficulty of the exercise (as well as reported sick days), and subsequent goals were adjusted in a similar manner. In some cases, the elevation in performance goal could have hindered performance with increased exposure to aversive sound consequences for performing below the goal, as could be the case for the last session for P3, where performance fell below the dashed goal makers.

Group Data

Group level analysis reveals significant aggregate gains for participants, although these gains were not distributed equally to each participant according the individual analysis. Figure 8 depicts the overall differences in average force and frequency of punches during baseline and experimental phases. In the baseline phase participants were punching at around 1592.3 relative N, but during the contingent music/ visual condition participants were punching an additional 400 N (2060.9 relative N). However, this may not reflect an increase in actual exertion unless speed increased, or remained unaltered.

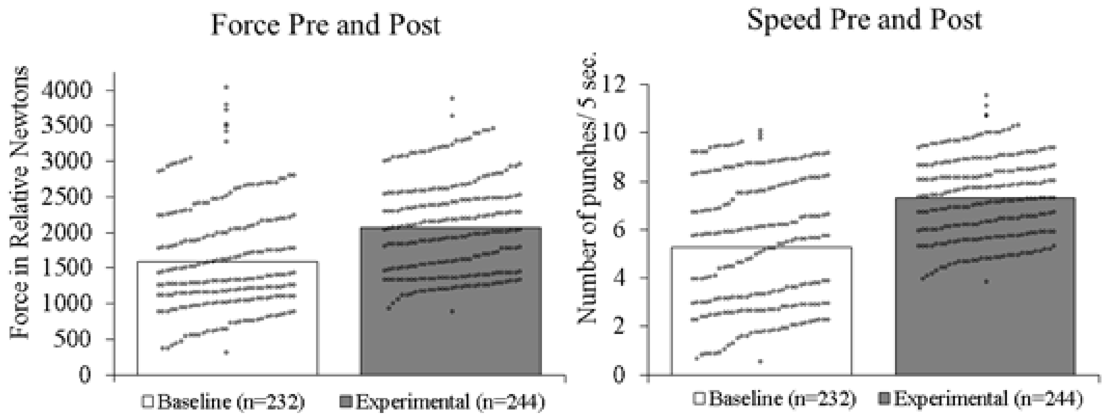

Figure 8. Depicts the average force and speed sessions in the baseline and experimental phases. Dotted markers are denote 3-minute round data.

Interestingly, the results specify that the number of punches increased from 5.3 punches per each 5-second interval (roughly a punch per second) to 7.3 punches for a typical recording bin, accounting for two punches extra punches every 5-seconds. This constitutes an increase of .4 punches per second. There were large differences in force readings between baseline (M = 1592.3, SD= 866.7) and the experimental phase (M =2060.9, SD= 826.3) conditions. Similarly, there were large differences in speed between baseline (M = 5.3, SD= 3.1) and the experimental phase (M =7.3, SD= 2.5) with no overlap from standard error. Despite overlap between the data points reflecting individual round data when comparing baseline and experimental phases, the largest difference upon visual inspection is between the lowest force and speed readings between the conditions. This indicates that the individuals were less likely to perform at their lowest levels in the baseline when in the experimental phase. However, this change in performance could be attribute to pausing less often or working out more intensely.

After examining the number of 5-second intervals, in baseline there appeared to be a larger number of pauses, which is operationally defined as punches lower than 623 N or not punching for 5-seconds or more. This complicates the analysis as to whether pausing was the result of not punching the bag, or punching the bag lower than the minimum force threshold. Considering, the researcher never witnessed pauses longer than 5-seconds, except perhaps in the final seconds of the 4th round, this data likely represents punches below 623 N that were not captured by the device in the 5-second interval. Punching force correlates with body weight, however, technique in the punch strike can allow relatively light individuals to punch at extreme forces in relation to their weight (pound for pound). For example, P1 weighed 137 lbs. and was able to punch at an average force above 3000 N for two rounds. If peak punching force ranges from 1666 N to 6860 N (Waliko, 2004), then it is entirely possible for average force of punches to be within the range of 623 N to 1666 N even at 100 lbs. which is a weight amount that all participants' exceeded.

Figure 9 depicts a conservative comparison of total pausing for baseline and experimental phases, because there were more experimental observation 5-second interval bins, increasing the opportunity for total pauses to be recorded. Furthermore, pausing may be underscored because only those intervals scored as 0 were summated, and even though some intervals recorded data for other 5 second intervals, some portion of that interval may have contained pausing resulting from an absence of punches or punches below 627 N. Although, pausing was minimal, comprising 6.12% of session data in baseline, after the experimental session it was reduced to 0.28%. This is a major gain from implementing the intervention, as this constitutes roughly 22 times less pausing, or fewer instances where punches were below 623 N. Many participants used the first round to warm-up to more intense physical activity, and perhaps as a result of this gradual exercise in round one of baseline appeared to have the largest number of pauses. Examining pausing at the round level does not provide any insight as to whether there were common pausing patterns within the 5-second interval data for each round. A more thorough 5-second bin level analysis is required to get at this information.

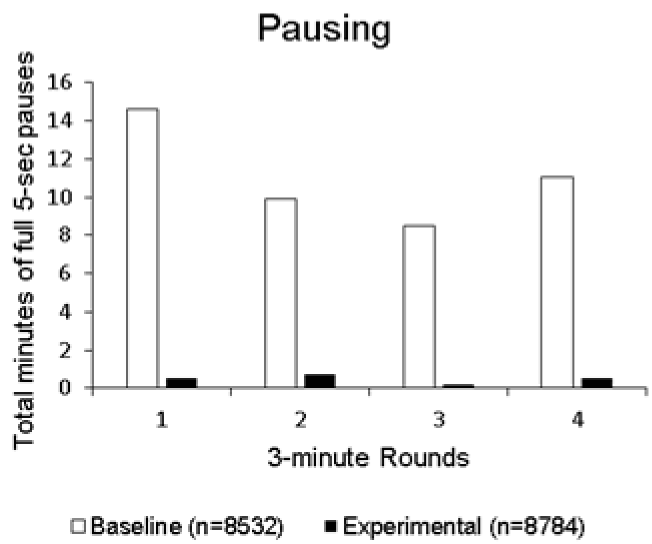

Figure 9. Total pausing in minutes from full 5-second pauses in each round for baseline and experimental sessions.

Rounds consisted of 36 5-second intervals, and pauses within rounds could have been allocated to specific intervals within the round. One way to visualize this information is to separate the pause data by each 5-second bin interval. In Figure 10, a majority of the pauses occurred in the last 5-seconds of the round, in the period 175-180 seconds. The majority of pausing was localized to the last 5-second interval for both baseline and experimental sessions, however, overall pausing was much lower in the experimental phase.

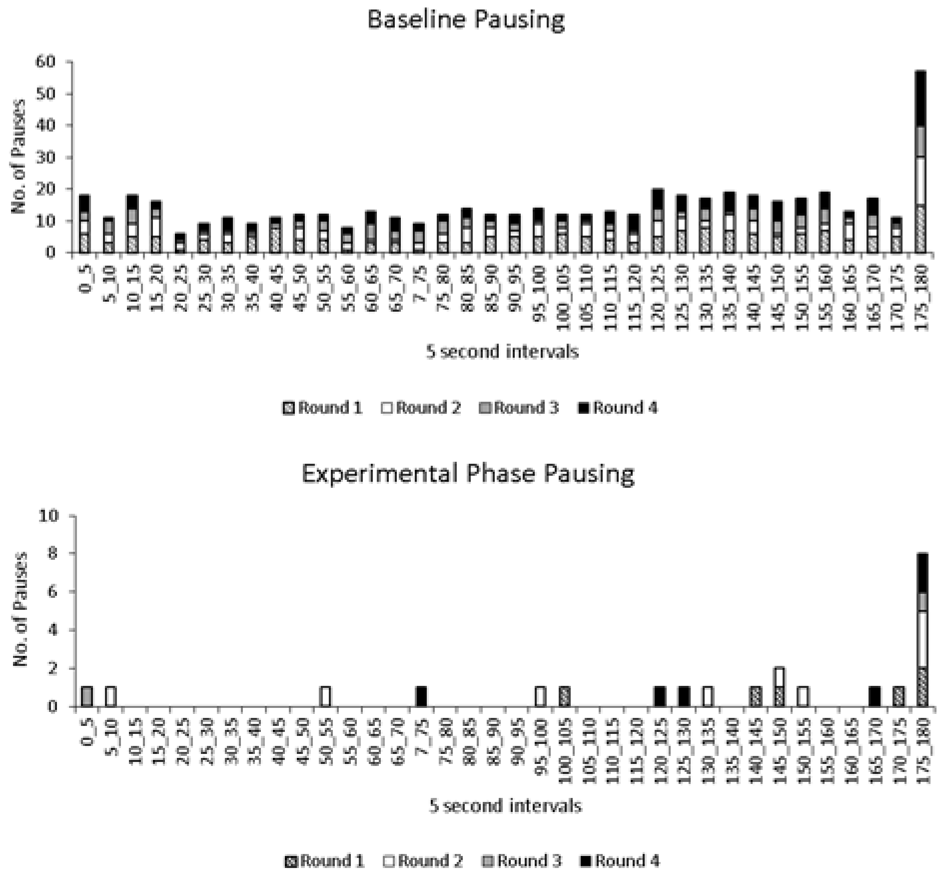

Figure 10. Pausing delineated by 5 second bin intervals for each of the 3-minute rounds.

Activity, Consumer Acceptability, and Biometric Data

Participants completed a weekly activity self-report (see Appendix F) to determine if weekly activity outside of the structured session had altered. Throughout the study only participant 4 indicated a change in weekly activity during the first week of baseline, otherwise each participant indicated that they had not altered their activity outside of the session. Reported satisfaction of the workout experience did not seem to alter whether in baseline or the intervention condition, but participants endorsed that the overall difficulty increased during the intervention stage. The consumer acceptability post assessment indicated that participants ranked the audio features of the feedback as more motivational to the workout. The rank order according to what participants perceived as most valuable for motivating them to workout harder was as follows: (1) audio speed, (2) audio volume, (3) visual color change, and (4) the visual round timer. However, some did find the visual changes motivating, and therefore a majority preferred a combination of the two feedback modalities (see items in Appendix G). Seven of the eight agreed with the statement that the device was worth a modest investment (one strongly agreed), and 100% agreed that the workout was more enjoyable with the feedback in place. When asked how much more than $100 would participants willingly to pay for the feedback features, the average additional expenditure was $122 (range 30-300).

Table 3

Biometric data pre and post intervention for the eight participants.

Participant Activity	Measures	*Pre*	*Post*
1 (F)	Height (Feet' inches'')	5' 8"	-
	Age (years)	25	-
Sedentary	Weight (lbs.)	137	133
	Fat Content (%)	25.4	25.3
2 (F)	Height (Feet' inches'')	5' 3.5"	-
	Age (years)	23	
Somewhat active	Weight (lbs.)	145.8	140
	Fat Content (%)	31.4	30.5
3 (F)	Height (Feet' inches'')	5' 5"	-
	Age (years)	20	-
Active	Weight (lbs.)	153.8	**X**
	Fat Content (%)	34.7	**X**
4 (F)	Height (Feet' inches'')	5' 1"	-
	Age (years)	30	-
Somewhat active	Weight (lbs.)	118	127
	Fat Content (%)	21.2	27
5 (M)	Height (Feet' inches'')	5' 10"	-
	Age (years)	28	-
Active	Weight (lbs.)	161.2	159.9
	Fat Content (%)	10.4	15.2
6 (M)	Height (Feet' inches'')	5' 11"	-
	Age (years)	33	-
Active	Weight (lbs.)	178.6	182
	Fat Content (%)	13.1	18.5
7 (F)	Height (Feet' inches'')	5' 1"	-
	Age (years)	29	-
Somewhat active	Weight (lbs.)	124	127
	Fat Content (%)	22	26
8 (F)	Height (Feet' inches'')	5' 3.5"	-
	Age (years)	18	-
Sedentary	Weight (lbs.)	142.2	142.2
	Fat Content (%)	32	30.7

Table 3 depicts the biometric data collected in baseline and experimental phases. There were issues with some of the bioelectric data collected. Data collection for the first round collection began at the beginning of November and ended in the second week of

January. This resulted in two major holidays where there were understandable breaks in collection, and unfortunately, participants 4 (+9 lbs) and 6 (+3.4 lbs) gained weight. P1 who opted to exercise three sessions a week completed the study before the Christmas break and lost 4 lbs. Initially, a finger pulse heart rate and Sp02 monitor was used to record resting heart-rate and blood oxygen data, but there were accuracy issues with the device.

DISCUSSION

Professional boxers can throw roughly 150 punches per minute in a bout, although not all land successfully. This requires substantial training to achieve such performance levels, and contingent music/ visual feedback appeared to be effective at motivating participants to increase both the speed and force of their punches. Despite only increasing the number of baseline punches (63.5/ min) in the experimental phase (87.5/ min) by 24 per minute for the group, this is a significant increase when taking into account the length of a session (12 minutes), the concordant increase in force, and the amateur/ casual exerciser status of the participants. For the group, an additional 288 punches per session, each being on average 400 N more forceful compared to baseline, was the aggregate outcome from this seemingly small increase. Given, that both force and frequency increased in the experimental phase, these can be conceptualized as gains in workout intensity.

Beyond the general finding that music can substantially enhance physical performance (Terry et al., 2012), manipulation of the tempo of songs can serve to increase the speed of physical activity, at least with cycling (Waterhouse et al., 2009). This study extends current sports psychology research by aligning performance of a physical activity to contingent changes in music and visual stimuli. In this study participants were informed of the relationship between the contingent music/ visual conditions, but many conjugate preparations are operative without instruction. Participants can be aware of the relationship between their performance and the contingent music/ visual cues, while benefitting from its enhancing effects above that of music alone. It might be interesting to determine if these performance gains would occur without explicit instruction, thus highlighting the intuitive nature of conjugate schedules.

Many conjugate schedules operate by fading a reinforcing stimulus proportionally to lower activity in one response dimension. Few studies have examined the effect of conjugate schedules that provide both reinforcing, and aversive stimuli, when a performance threshold has been crossed, but this type of manipulation merits further investigation because of its ubiquity in the real-world. In this study there may have been thresholds where stimulus changes were aversive, as defined by a drop of in performance as a result of overexposure to the contingent music change. Unfortunately, it is challenging to determine, in this study, at which point falling below a goal became aversive to each participant, although all participants reporting that they disliked the maximal distortion prior to the study. In some cases, there were unpredictable responses to hearing the music distortion, such as in the case of P1, who started laughing initially to the contingent music feedback. This response faded completely after two sessions, and this coincided with an increase in performance, as indicative of the rapid increase in force of punches.

Regrettably, data were not collected on the participants' exposure to stimuli changes resulting from falling below the performance benchmark, as it relates to the duration in time of the exposure, and the number of bouts (instances of going below individualized criterion levels). This would provide more detail regarding whether the individual maintained performance increases due to escaping an aversive contingency, or by accessing their unaltered music playlist (positive reinforcement). To some degree, this information can be garnered if a data point happened to fall below the goal benchmark, which would imply more than 50% of the time for that round would have contained augmented music and visuals cues. Fortunately, this occurred rarely, and in most instances resulted in an increase in performance, except in the case for the 11^{th} session for P3. This participant happened to be the only individual that did not return to complete a 12^{th} session. Perhaps this was a result of increased exposure to the aversive elements of the contingent music condition.

Generally, many participants with early exposure to the experimental phase attained early increases in both speed and force. Unsurprisingly, the relationship between speed and intensity of punches seemed to switch at a specific higher performance thresholds, which could indicate a tipping point in exhaustion i.e. participants when below peak performance experienced both gains in force and frequency, until they were at the ceiling performance where gains in force forfeited gains in speed and vice versa. Specifically, participants who started out with baseline forces below 1500 N experienced gains in both force and frequency, but after reaching an asymptote in performance levels, there appeared to be an opportunity cost (e.g. decrements in speed) for further increases in force. For instance, P1 had notable speed drops with her higher force readings in the last session, and in P8's final phase B data delineates increases in force were offset by decreases in speed. This implies a heavy motivational component before attaining larger physical strength and conditioning training associated with long-term physical exercise.

Notably, some of the best responders were somewhat active or sedentary in contrast to those that reported as active. Anecdotally, those that reported that they were sedentary committed to scheduled activity because they were excited about the novelty of the exercise research. The two male participants that identified as physically active had smaller improvements from baseline to intervention, or were already on an increasing trend during baseline. Those that already exercise frequently and regularly enough have habituated to the initial aversive effects of physical activity and find exercise less aversive and more reinforcing – these individuals might experience fewer benefits from the response contingency (but note that they reported that they preferred the experimental phase). This might also suggest that the participants who did not have an extensive history of physical exercise might benefit the most from this type of response contingency. Alternatively, real performance gains may have been obscured for more active participants by the nature of the activity selected, and perhaps using another indices of exercise, like time to exhaustion, could have revealed if there were performance gains that remained hidden by using our 12 minute activity requirement.

Despite differing treatment effects per participant, in the consumer acceptability section, all responded that they preferred the feedback package, indicating that performance can be maintained using the system even when no performance gains are obtained by the more seasoned exercisers. Self-reported emotions appear to be more positive using music-video exercise interventions, than when they are delivered separately (Bird, Hall, Arnold, Karageorghis, & Hussein, 2016). This finding was consistent in our research, as participants seemed to prefer the package, although when forced to rank the components they perceived as most motivational, the audio features were more highly valued.

So far the results confirm that augmented music and visuals can serve to motivate users to workout harder, and in some cases returning to unaltered music reverts the user back to slower/ weaker punches. Interestingly, depending on the user, performance gains can either be permanent (see P8), or temporary (see P7), between conditions.

Recruitment for the study was relatively effortless, and interest from participants maintained a high level of participant engagement and completion (only one dropout). The struggle to maintain and adhere to an exercise regimen is part of the struggle in accessing the health benefits accrued from long-term physical activity. Increasing exercise adherence could reduce the number of chronic diseases such as, heart disease, obesity, and type 2 diabetes, where eating and exercising are the least invasive strategies to prevent many of these illnesses. Music as a stimulus when used in exercise programs can remain interesting by being altered via conjugate schedules, without having to wait for the release of an upcoming song to maintain novelty in a workout. If such arrangements reduce reinforcer redundancy and increase interactivity, then it may be possible to minimize adherence issues faced when assessing structured activities.

Limitations

Due to the short duration of the study, and because there was no maintenance or follow-up, it was not possible know whether the device improved performance in the long-term. Not all punches were captured by the device, as indicated by the pause analysis, and only with the concordant observation by the researcher was it possible to determine that only in the last 5-seconds did participants stop activity prematurely. Device sensitivity only allowed capturing punch data, for both force and frequency, of those punches that were above 623 N. While punching demonstrably increased above 623 N for participants after exposure to the experimental phase, as indicated by the pause analysis, this does not mean that all punches were registered by the device. In a standard punching bag workout, many start shadow-boxing without a bag, and move to gradually heavier bags, therefore, the fact that the first session in baseline resulted in more pausing would be expected if participants were gradually increasing their physical activity. However, the data does suggest without prompting from the device, participants' would be more likely to punch below that force threshold, or 'pull their punches' when fatigued.

Performance benchmarks for the experimental phase were set in manner where participants were able to direct the goal setting i.e. feedback from the participant regarding perceived difficulty could reduce the future goal. While this does mirror the autonomy of an exerciser's ability to reduce resistance on a gym machine, it could have resulted in some individuals having smaller gains by inflating their perceived difficulty. Furthermore, the goal change for force and speed could have been automated by the device in a more consistent manner, but rapid goal acceleration could have resulted in higher drop-out. This study relied on self-report measures to detect changes in global weekly activity. Although, a majority of participants reported no changes in physical activity, this could be an artifact of the tool, in that responding that there were no changes in activity resulted in having to fill in fewer details. Additionally, participants may not have been able to self-monitor subtle changes in their activity levels. However, a wearable sensor, like the FitBit, could have been used to offer some concurrent validity to the self-report measure.

Combining the contingent music/visual package allowed for an assessment of the package as a whole. However, this methodology did not offer information regarding which was the functional component in enhancing exercise performance. When forced to rank each component of the experimental phase, a majority of participants reported preferring the contingent music rather than the visuals, only one indicated that they preferred the visual screen color changes.

The variables assessed in this study were restricted for the sake of increasing experimental control, for example, the exercise room was an indoor laboratory landscape without windows. Ecologically, this did not mirror a real-world exercise environment or some of the operative variables used to motivate physical performance. Incorporating social interaction, by using competitive leaderboards which are sometimes used in community based fitness apps, could be an interesting dimension to explore in future research in an effort to enhance the external validity of this research to more active exercisers.

In the experimental phase when the music speed was increased, it was not possible to maintain the consistency of the pitch for each 5-second sound packet, and therefore it is possible that the pitch changes resulting from the increased speed was a functional component in maintaining performance levels. This is a limitation because this is a stimulus dimension that was not measured during the intervention, and therefore when discussing the speed alterations, it could be implicated as a causal variable. While, it was prudent to offer participants their own choice of music, even if the average bpm was relatively similar for our selected music, some music genres vary substantially within a song. There are more beat variations in electronic dance music and dubstep (usually there are beat "drops" where music slows down only to speed up) and this could have influenced performance. Participants anecdotally disliked discontinuity in the music, and some songs took a longer time to switch between tracks. Many reported that the break in the music, caused by the intermission between songs, was the most challenging period to maintain performance. Splicing these songs in a playlist and minimizing time between songs could be an interesting variable to analyze especially, because devices that play music do not remove this pause between songs.

Although, the bag was anchored to a weight, this did not completely negate the bag from spinning, which could have inflated the force reading. This is why the researcher was present in all sessions to monitor the appropriate use of the punching bag. Furthermore, through continued use of the heavy bag, an indent in the bag began to appear, creating a concave in the bag's shape, which may have slightly altered the position of the sensors. To counter this issue, before each session the researcher would hit the bag from the sides to minimize the indent. Using a wearable device, such as sensors in the boxing gloves, in lieu of sensors on the heavy bag, could have corrected for this minor issue.

Future Research

Recognizably, it is of interest to examine if contingent music/visual feedback enhances performance in other activities besides boxing, and further research is required to investigate if this feedback system can be applied successfully. Future research should investigate whether customizing the aversive audio consequences, so that they are individualized (i.e. selecting the play speed augmentation factor), results in larger performance gains. One of the advantages of audio-feedback compared to visual is that it does not require re-directed attention, and because it does not need mounting, it can more easily accompany alternative activities, like running. In order to alter music contingently with a physical activity gym equipment, like treadmills, stationary bikes, rowing machines, elliptical machines and steppers might enable the best data to be tracked, and allow for the safe listening of music without safety issues compared to activity outside the gym. For example, matching force with resistance or foot landing, speed with miles per hour, and accuracy with balance or foot placement, could be integrated into contingently altering volume, music speed, and music pitch respectively. If contingent music is interactive with the user's exercise then the feedback can intuitively be interpreted without the need for verbal feedback, which in some instances could be intrusive to a workout. However, when learning a new physical activity, verbal feedback would be more advantageous than adjusting music, which might be more successful at maintaining, or increasing, an already learned activity. For example, even after watching the safety boxing tip video, participants still needed reminding from the researcher regarding safe punching behavior for the first session in baseline.

One limitation of the study reported herein is that the IV was really a multi-component package consisting of 1) adjustable music volume; 2) adjustable music tempo; 3) visual feedback; and 4) a response contingency relating exercise performance to the sensory changes in items 1, 2 and 3. A component analysis should be conducted to parse out the potential gains of each element of the package. This information would be beneficial in eliminating any redundancies from non-functional components, or provide evidence as to why all parts of the package are included.

Regarding the generalization of the effects of the treatment package delivered in the experimental phase, it is reasonable that components might impact users differentially based on their physical activity history. Therefore, it would be important to extend this line of scientific inquiry to other groups and demographics to ascertain what elements of the package are functional in enhancing an exercise regimen. Although this study avoided recruiting athletes, using another performance measure, such as VO2 max, rather than a set workout could allow more detailed analysis regarding ergogenic effects of the feedback system. However, it should be noted that athletes' preferences may differ from casual exercisers based on their motivation for working out. For example, it is plausible that data based information could be more reinforcing to this group, such as a graphical summary, considering that such data relays information related to successful competition. It is common practice after running heats, for athletes to look at their lap times to determine if they have achieved a faster time.

In synopsis, this research has demonstrated the technical feasibility of increasing the force and frequency of punching, using both individualized performance goals, and delivering contingent music/ visual feedback to participants. Integrating behavioral analytic technology into future exercise devices could be a cost-effective means to disseminate automated feedback packages allowing users to access the reinforcing effects conferred by long-term physical activity, while overcoming the aversive (uncomfortable physiological stimuli) start-up costs of beginning an exercise program.

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Appendix A: Recruitment Flyer

Recruitment Flyer: Advertising compensation for participation

PUNCH A BAG!
ROCK OUT!
GET PAID!

Participate in a research study about exercise.

Contact us to see if you qualify!!!

Email Neil at neil.deochand@wmich.edu or call the Behavioral Medicine Laboratory

(269) 387-4492

This study is approved by the WMU HSIRB. Protocol number XXXXX. Principle Investigator: Dr. Wayne Fuqua.
Appendix B: Human Subjects Institutional Review Board Consent

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Appendix B: Informed Consent

Western Michigan University
Department of Psychology

Principal Investigator:	R. Wayne Fuqua, PhD
Student Investigator:	Neil Deochand
Title of Study:	**A study evaluating human performance using a punching bag feedback device**

You have been invited to participate in a research project titled "*A study evaluating human performance using a punching bag feedback device.*" The project is supervised by Dr. Wayne Fuqua. This consent document will explain the purpose of this research project, and will go over all of the time commitments, the procedures used in the study, and the risks and benefits of participating in this research project. Please read this consent form carefully and completely and please ask any questions if you need more clarification.

What are we trying to find out in this study?
The purpose of this study is to assess the effect of real-time performance audio and visual feedback upon exercise behavior while working out with a punching bag.

Who can participate in this study?
Individuals aged 18-45 years of age are eligible to participate if they also indicate an interest in working-out more frequently, prefer to listen to music when they exercise, and have no health complications that prevent them from engaging in moderate physical activity involving a punching bag.

Where will this study take place?
The study will take place on the WMU campus, in the Behavioral Medicine Laboratory in Wood Hall 2740.

What is the time commitment for participating in this study?
If you choose to participate you will be asked to attend weekly sessions for a semester. Each session is a time-commitment of 45-60 minutes. We would like for you to complete 12 sessions but you will be able to complete up to 24 sessions. Your total time participating in the study could approximately be 9-24 hours.

What will you be asked to do if you choose to participate in this study?
If you choose to participate in the study and sign the informed consent form, we will have you complete a validated health history questionnaire. You will be asked to watch videos on stretching, safe punching, and correct stance while punching. Before each exercise session you will be asked to physically stretch, and then you will have the opportunity to punch a bag and engage in physical activity for a period of 12 minutes. At points before and after your activity you will place a finger-tip pulse oximeter on a finger and take a heart rate and Sp02 reading.

What information is being measured during the study?

We are testing a device that has been patented by the investigators to examine its effect upon exercise behavior. Primarily we will be collecting data on the force and frequency of punches in exercise sessions. This is recorded by the punching bag device and transmitted wirelessly to a computer. However, we will be recording self-report measures related to your physical activity risk, and general physical activity, as well as other biometric data outlined below.

Oxygen Consumption/ Heart Rate: During each visit to the laboratory, we will measure how much oxygen (Sp02) your body uses, and your heart rate while resting and after exercise. To do this, we will place a finger-tip pulse oximeter on a finger and take a reading. There should be no discomfort from having to clip the device to a finger for short period of time (10 seconds or more).

Measuring Height and Weight: There are no known risks associated with the measurement of height and body weight.

Assessing Percent Body Fat via Bioelectric Impedance Analysis on a scales is non-invasive and as comfortable as standing on a set of scales. It involves measuring electrical impedance to evaluate fat content and is less invasive than other techniques like calipers, anthropometric measurements, or hydrostatic weighing.

What are the risks of participating in this study and how will these risks be minimized?

As in all research, there may be unforeseen risks to the participant. You will be asked to engage in a maximum of 12 minutes of activity, which might result in some physical discomfort. Another anticipated risk to you experience psychological discomfort when the investigator records some of the biometric data (weight, height, heart rate etc.). If an accidental injury occurs, appropriate emergency measures will be taken.

Moderate-Intensity Exercise: Exercise may cause feelings of fatigue, light-headedness, and an overall feeling of discomfort. There is also a risk for muscle soreness and musculoskeletal injuries (muscle pulls, strains). The exercise may be stressful but is generally easily tolerated by individuals and is not dangerous for healthy individuals. The investigator(s) will be certified in first-aid and CPR emergency procedures. Also, we will be monitoring your activity in case of an emergency.

Medical health risks are minimized to 0.1 incidents out of every 10,000 maximal exercise tests in a younger healthy population. Our exercise test has rest periods embedded into the exercise resulting in a maximum of 12 minutes engaging in physical activity. In order to minimize these risks, we will confirm that you are classified as “low-risk” using the health history questionnaire. Also, we will have you stretch and go through a warm-up routine before the exercise to reduce the risk for musculoskeletal injuries. Lastly, an investigator will always be in the room monitoring your activity and be ready to assist.

Other Risk Considerations: Participation in this study could take approximately 9-24 hours in time duration for the study, and will be spread across 14 weeks for each participant based on 12-24 sessions lasting 45-60 minutes. We would like for you to complete 12 sessions, but you may be invited to complete up to 24 sessions. Therefore this time commitment may be an inconvenience to you.

What are the benefits of participating in this study?
This project may add to the literature on how audio-feedback can differentially impact exercise behaviors relating to punching a heavy bag. There is a chance to earn a $25 Amazon e-gift card in compensation for every 12 sessions completed, while not having more than one unscheduled absence or two reschedules (more than 24 hour notice) over a 7 week period (maximum $50 in amazon gift cards if invited to return). During the course of the study you might learn about punching a heavy bag.

Are there any costs associated with participating in this study?
We would like for you to complete 12 sessions, but you may be invited to complete up to 24 sessions. There are no direct costs of participating in this study besides that it requires approximately 9-24 hours of your time (12-24 sessions lasting 45-60 minutes over a 14 week period) and therefore this may be an inconvenience to you.

Is there any compensation for participating in this study?
A $25 amazon gift card will be delivered to the participant via email at the completion of the study for every 12 sessions completed without having any one unscheduled absence or two reschedules (24 hours in advance of the schedule change) over a 7 week period (maximum $50 in amazon gift cards if invited to return). You will have to provide your email address for delivery of the card, however, this information will be kept confidential.

Who will have access to the information collected during this study?
All of the information collected from you is confidential. That means that your name will not appear on any papers on which information for the study is recorded. A code name will be assigned to your data but there will be no means to link this code to your responses and biometric data. All other forms will be retained for at least three years in a locked file in the principal investigator's office. The data may be used in conference presentations or manuscripts for publication in peer-reviewed journals, but no identifying information will be reported.

What if you want to stop participating in this study?
You can choose to stop participating in the study at any time 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.

Should you have any questions prior to or during the study, you can contact the primary investigator, Dr. R. Wayne Fuqua at 269-387-4474 or wayne.fuqua@wmich.edu. 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 document. The risks and benefits have been explained to me. By signing this form I am indicating that I have no known health condition(s) or am I taking any medication that would interfere with strenuous physical activity. I agree to take part in this study.

____

Please Print Your Name

______________________________ ______________________________

Participant's signature Date

Appendix C: Human Subjects Institutional Review Board Approval Letter

HSIRB Approval Letter

WESTERN MICHIGAN UNIVERSITY

Human Subjects Institutional Review Board

Date: September 20, 2016

To: Wayne Fuqua, Principal Investigator
Neil Deochand, Student Investigator for dissertation

From: Amy Naugle, Ph.D., Chair

Re: HSIRB Project Number 16-04-16

This letter will serve as confirmation that your research project titled "Evaluating Human Performance Using a Punching Bag Feedback Device" has been **approved** under the **expedited** 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: This research may **only** be conducted exactly in the form it was approved. You must seek specific board approval for any changes in this project (e.g., ***you must request a post approval change to enroll subjects beyond the number stated in your application under "Number of subjects you want to complete the study***)." Failure to obtain approval for changes will result in a protocol deviation. 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.

Reapproval of the project is required if it extends beyond the termination date stated below.

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

Approval Termination: September 19, 2017

1903 W. Michigan Ave., Kalamazoo, MI 49008-5456
PHONE: (269) 387-8293 FAX: (269) 387-8276
CAMPUS SITE: 251 W. Walwood Hall

Appendix D: Physical Activity Screening Tool

Physical Activity Screening Tool

<u>BACKGROUND QUESTIONS:</u> Check the box that corresponds to the answers that best match your description.

THIS INFORMATION CONTAINED HEREIN WILL BE CONFIDENTIAL AND WILL BE SEEN ONLY BY THE INVESTIGATORS.

What is your sex?
☐ Male ☐ Female

How old are you? ______________

Provide the name and number of an emergency contact Name ______________
Phone ______________

<u>ACTIVITY</u>
When you engage in aerobic exercise, how much time do you typically spend in the activity?

1. Less than 20 minutes
2. 20-30 minutes
3. 30-60 minutes
4. More than 60 minutes

How many times a week do you engage in aerobic activity (at least 20 continuous minutes)? Examples are fast walking, hard cycling, running, swimming and vigorous sports.

1. Never
2. Less than 1 time a week
3. 1-2 times a week
4. 3 or more times a week

Do you participate in strength training activities (e.g. weight lifting/ body weight exercises)?

1. Yes
2. No

If yes, how would you describe your strength training activities (weight lifting)?

1. Not very vigorous
2. Somewhat vigorous
3. Quite vigorous
4. Very vigorous

How would you rank your fitness level?

1. Athletic
2. Active
3. Somewhat Active
4. Sedentary

Are you interested in increasing your physical activity levels?

1. Yes
2. No

Please indicate what types of sports activities do you regularly engage in?

- Walking,
- Hiking,
- Jogging,
- Running,
- Swimming
- Bicycling,
- Skateboarding,
- Rollerblading,
- Jumping rope,
- Boxing,
- Dancing,
- Tennis,
- Football,
- Soccer,
- Hockey,
- Basketball,
- Other _______________

(Exclusion Section)*

Have you trained extensively on a heavy bag before i.e. have you used a punching bag as a means of working out?

1. Yes
2. No

Do you like to listen to music when you exercise or engage in physical activity?

1. Yes
2. No

Do you have a visual or auditory impairment?

1. Yes
2. No

Do you use tobacco	☐ Yes	☐ No	Cigarettes	____	per day____
			Smokeless	____	per day____
			Pipe	____	per day____
			Cigars	____	per day____
			E-cigarettes	____	per day____

Have you quit smoking within the past 3 months?

1. Yes
2. No

Name your top 10 playlists to listen to when you work-out……………………………………

There is a chance to earn a $25 Amazon e-gift card in compensation for every 12 sessions completed without an unexcused absence or two reschedules (over 24 hour notice is given to researcher) over a 7 week period (maximum $50 if invited to compete second set), provide your email below:

____

=>Now complete the ACSM questionnaire<=

To be filled out by Investigator

Measure	**Baseline**	**Post-Intervention**
Weight	__________lbs	__________lbs
Height	____’_____’	N/A
Arm Span/ length	__________cm	N/A
Fat Content	__________%	__________%
Resting Hear Rate	__________bpm	__________bpm
Exercise Heart Rate	__________bpm	__________bpm
Time taken for resting rate	__________seconds	__________seconds

Appendix E: ACSM Screening Questionnaire

AHA/ACSM Health/Fitness Facility Pre-participation Screening Questionnaire

Assess your health status by marking all true statements

History

You have had:

______________ a heart attack
______________ heart surgery
______________ cardiac catheterization coronary
______________ angioplasty (PTCA)
______________ Pacemaker/implantable cardiac defibrillator
______________ rhythm disturbance
______________ heart valve disease
______________ heart failure
______________ heart transplantation
______________ congenital heart disease

Symptoms:

______________ You experience chest discomfort with exertion.
______________ You experience unreasonable breathlessness
______________ You experience dizziness, fainting, or blackouts
______________ You take heart medications

Other health issues

______________ You have diabetes
______________ You have asthma or other lung disease
______________ You have burning or cramping sensation in your lower legs when walking short distances
______________ You have musculoskeletal problems that limit your physical activity.
______________ You have concerns about the safety of exercise
______________ You take prescription medication(s).
______________ You are pregnant.

If you marked any of these statements in this section, consult your physician or other appropriate health care provider before engaging in exercise. You may reed to use a facility with a medically qualified staff.

______________ Cardiovascular risk factors
______________ You are a man older than 45 years.
______________ You are a woman older than 55 years, have had a hysterectomy, or are postmenopausal
______________ You smoke, or quit smoking within the previous 6 months.
______________ Your blood pressure is >140190 mm Hg.
______________ You do not know your blood pressure.
______________ You take blood pressure medication.
______________ Your blood cholesterol level is >200 mg/dl.
______________ You do not know your cholesterol level.

______________ You have a close blood relative who had a heart attack or heart surgery before age 55 (father or brother) or age 65 (mother or sister).

______________ You are physically inactive (i.e., you get <30 minutes of physical activity on at least 3 days per week).

______________ You are >20 pounds overweight

If you marked two or more of the statements in this section you should consult you physician or other appropriate health care provider before engaging in exercise. You might benefit from using a facility with a professionally qualified exercise staff to guide your exercise Program.

______________ None of the above

You should be able to exercise safely without consulting your physician or other appropriate health care provider in a self-guided program or almost any facility that meets your exercise program needs.

From: Balady, G. J., Chaitman, B., Driscoll, D., Foster, C., Froelicher, E., Gordon, N., ... & Bazzarre, T. (1998). Recommendations for cardiovascular screening, staffing, and emergency policies at health/fitness facilities. *Circulation, 97*(22), 2283-2293.

Appendix F: Weekly Activity and End of Session Evaluation

Weekly Activity Assessment

Did your physical activity alter this week?

1. Yes
2. No

Have there been any changes in your health status that would prevent you from engaging in physical activity

1. Yes
2. No

Do you know of any other reason why you should not engage in physical activity?

1. Yes
2. No

If Yes to Question 1 fill the below out:

When you engage in aerobic exercise, how much time did you typically spend in the activity?

1. Less than 20 minutes
2. 20-30 minutes
3. 30-60 minutes
4. More than 60 minutes

How many times in the past week did you engage in aerobic activity (at least 20 continuous minutes)? Examples are fast walking, hard cycling, running, swimming and vigorous sports.

1. Never
2. Less than 1 time a week
3. 1-2 times a week
4. 3 or more times a week

Did you participate in strength training activities (weight lifting)?

1. Yes
2. No

If yes, how would you describe your strength training activities (weight lifting)?

1. Not very vigorous
2. Somewhat vigorous
3. Quite vigorous
4. Very vigorous

How would you rate your overall workout experience?

O Very satisfied O Somewhat satisfied O Unsure O Not Satisfied O Very Dissatisfied

How physically challenging was the workout?

O Very Challenging O Somewhat Challenging O Unsure O Not Challenging O Very Unchallenging

Appendix G: Consumer Acceptability

Consumer Acceptability Post Assessment

Please read the items carefully and identify the response that best matches your endorsement. Do you agree with the following statements?

The music volume change in response to my work out, increased my motivation to work out.

1) Strongly Agree 2) Agree 3) Neutral 4) Disagree 5) Strongly Disagree

The music speed change in response to my work out, increased my motivation to work out.

1) Strongly Agree 2) Agree 3) Neutral 4) Disagree 5) Strongly Disagree

The visual feedback increased my motivation to work out.

1) Strongly Agree 2) Agree 3) Neutral 4) Disagree 5) Strongly Disagree

The overall customized workout experience involving both audio and visual feedback increased my motivation to work out?

1) Strongly Agree 2) Agree 3) Neutral 4) Disagree 5) Strongly Disagree

The enhanced boxing system is worth a modest investment to improve my workout.

1) Strongly Agree 2) Agree 3) Neutral 4) Disagree 5) Strongly Disagree

---

Rank the feedback options based on how motivating you found them to be during your workout.

1. Audio speed
2. Audio volume
3. Visual Color Change
4. Visual Round Timers

Please indicate whether you agree with the following statements:

I preferred the audio feedback component of the device

1. Strongly agree 2. Agree 3. Neutral 4. Disagree 5. Strongly Disagree

I preferred the visual feedback component of the device

1. Strongly agree 2. Agree 3. Neutral 4. Disagree 5. Strongly Disagree

I preferred the combination of audio and visual feedback of the device

1. Strongly agree 2. Agree 3. Neutral 4. Disagree 5. Strongly Disagree

My general daily physical activity levels increased compared to before working out with the bag?

1. Strongly agree 2. Agree 3. Neutral 4. Disagree 5. Strongly Disagree

Was working out more enjoyable as a result of the feedback from the punching bag device?

1. Yes
2. No

A heavy bag can cost $100, how much more would you be willing to pay for the interactive features of the device? _________
How interested would you be in having these interactive features available to you while engaging in other preferred physical activities?

2. Very interested   2. Somewhat Interested   3. Neutral   4. Not Very Interested   5. Not at all Interested

Please share any other comments related to your experience in the space provided.