Effect of isochronic tone tempos on physiologic recovery rates after cardiovascular exercise

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Abstract

Emotional music has been found to affect physiological responses during exercise in the form of physical performance and recovery, but the effects of music tempo, specifically, on these factors are still unconfirmed. We designed a study to test if isochronic tones administered at two different beats per minute (BPMs) could influence physiological recovery time to baseline after strenuous endurance exercise. We predict that listening to an isochronic tone with a faster tempo will lead to a longer recovery time after exercise compared to listening to both a tone at a slower tempo and the control of white noise during recovery. We also predict that listening to an isochronic tone with a slower tempo will lead to a longer recovery time than the control, but a shorter recovery time than when listening to isochronic tone with a faster tempo. After recording data from 10 subjects, our results indicate that listening to varying tempos of isochronic tones during recovery after cardiovascular exercise does not significantly affect the rate of decline to resting levels of blood pressure, heart rate, and respiratory rate. This leads us to believe isolating additional variables such as volume, genre, or emotional response to music selections in future studies may provide insight into how music selection can impact an individual's recovery rate post-exercise.

Introduction

Many people enjoy listening to music while they exercise, as they feel it propagates the proper mental state and atmosphere for a workout (North et. al. 2004). Studies have shown this preference to be substantial, as listening to music elicits emotional, neurological, and cardiorespiratory changes (Shea 1996). Similar physiological responses, such as increased cardiorespiratory activity, can also be seen in individuals during and after periods of endurance exercise.

Emotional music has been found to affect physiological responses during exercise in the form of physical performance and recovery, but the effects of music tempo, specifically, on these factors are still controversial (Labbe et. al. 2007) (Fossum et. al. 2015). A prior study found that listening to isochronic tones (pulses of a single, short, repeated tone) elicits a response in the autonomic nervous system, increasing the heart rate of resting individuals compared to the same resting individual not listening to the tone (Krabs et. al. 2015). Expanding on this study, we designed a study to test if isochronic tones of varying beats per minute (BPM) influenced physiological recovery time to baseline after strenuous endurance exercise. We predict that listening to an isochronic tone with a faster tempo will lead to a longer recovery time after exercise compared to listening to both a tone at a slower tempo and the control of white noise during recovery. We also predict that listening to an isochronic tone with a slower tempo will lead to a longer recovery time than the control, but a shorter recovery time than when listening to isochronic tone with a faster tempo.

For our study, we defined baseline as the measured heart rate, respiratory rate, and blood pressure values obtained from the subject at rest prior to activity. Heart rate, respiratory rate, and blood pressure measurements were used to assess the subject's physiological response to exercise since all three increase during exercise (Brooks et. al. 1971). We chose to use isochronic tones in this study in order to eliminate the possibility of an emotional response to a specific music genre or song, thus isolating tempo as the independent variable affecting physiological response.

Methods

The 10 participants for this study were recruited from the Physiology 435 class at the University of Wisconsin-Madison. Each participant filled out a consent form before participating in the study. The researchers explained the exercise procedure the participant needed to perform to complete the study and answered any questions. After questions were answered, the participants were told not to speak throughout the study and to look straight forward to avoid any distractions or disruptions in physiological measurements. The Respiratory SS5LB was then attached to the Biopac Systems MP36 and the other end was wrapped underneath the armpits and above the participant's nipples, where the maximum respiratory expansion was observed to measure respiratory rate. Next, the participant sat down on the Gold's Gym Cycle Trainer 390R stationary bike and the pedals were adjusted to leg length. The Electrocardiogram (.5 Hz-35 Hz) was connected to the Biopac Systems MP36 and the three leads were attached to the participant's left calf, right calf, and right wrist to measure heart rate. A 10 Series + Automatic blood pressure monitor was wrapped around the participant’s left arm and placed on a chair just below chest level. Beats By Dre Solo HD On-Ear Headphones were placed over the participant’s ears with the audio cord connected to a laptop for sound.

While the participant was seated with their feet planted on the ground, the researchers measured the participant’s baseline heart rate, respiratory rate, and blood pressure simultaneously for thirty seconds in complete silence. The researchers then randomized one of the three sounds to first play through headphones for the participant using randomnumbergenerator.com. The three sounds were “STUDY POWER” by Relaxing White Noise, 60 BPM and 160 BPM metronomes by metronomeonline.com. White noise was used as the positive control since complete silence was not feasible due to background noise. The participant was shown a sign saying “START,” which signaled them to begin biking between the range of 12 and 14 mph, as instructed before beginning the study. The bike’s resistance was initially set at six, and after one minute of cycling, was increased to 10. This was done to prevent shocking participants with immediate intense exercise. After three and a half total minutes of cycling, the participant was shown a sign saying “STOP,” and at that moment, the researchers began playing the randomized sound through the participant’s headphones. As previously told, the participant placed their feet flat on the ground and remained silent while their blood pressure was taken every 45 seconds, heart rate every 60 seconds, and respiratory rate every 60 seconds for the next six minutes. Six minutes was thought to be enough time to allow all participants to reach baseline after three and a half minutes of exercise. The participant was given a two-minute break to take off the headphones and relax between trials, but had to remain seated on the bike, to ensure the basal measurements would be the same at the start of the next trial.

The procedure was then repeated using the next two predetermined auditory sounds. Figure 1 shows the timeline of the procedure. After the three trials were completed, the participant filled out a brief questionnaire asking their age, gender, if they smoked, how often they exercised each week, and which type(s) of exercise(s) they regularly participated in. Additionally, normalizing exertion between subjects was not determined to be essential. Each participant is being subjected to each experimental condition, so varying individual exertion is not a confounding variable when analyzing results, as recovery times will be normalized because each participant is being subjected to all three experimental conditions during recovery.

Materials

We took blood pressure measurements at both baseline and after activity with a 10 series+ automatic blood pressure monitor (model #: BP791IT (HEM-7222-ITZ); manufactured by OMRON Healthcare, INC. Lake Forest, IL 60045). We collected subject respiratory and heart rate with the BIOPAC data acquisition unit (model #: MP36E1204002760; manufacturer: BIOPAC Systems, INC. Goleta, CA 93117) and respiratory effort transducer (model #: MP3X-45; part #: SS5LB; manufacturer: BIOPAC Systems, INC. Goleta, CA 93117). The BIOPAC data acquisition unit was connected to a lead set (part #: SS2LB**)** which led to general-purpose electrodes placed on the participants (part #: EL503). These electrodes collected heart rate data when placed on the right wrist and both of the inner calves of each subject. Subjects used the Gold's Gym Cycle Trainer (model #: 390R; manufacturer: ICON Health and Fitness, INC. Logan, UT 84321) for the exercise component. The isochronic tones used in the study were administered through Beats By Dre Solo HD On-Ear Headphones.

Results

We used a Chi-squared test for testing if the rate of returning to baseline differed for each of the three variables (heart rate, blood pressure, and respiration rate) with each of the three sounds. We found no statistical significance for the difference of decline back to baseline between subjects for each physiological response.

The Chi-squared test for returning to baseline for heart rate was found to be 3.75 using degrees of freedom of 2 with a p-value of 0.1534. Of all 10 participants, only 3 returned back to baseline heart rate after the first trial and only 1 returned back to baseline heart rate in trials 2 and 3.The Chi-squared test we ran for blood pressure returning to baseline was found to be 1.92 using degrees of freedom of 2 with a p-value of 0.3829. The Chi-squared test for returning to baseline for respiration rate was found to be 1.90 using degrees of freedom of 2 and a p-value of 0.3867. The average recovery time for respiration can be seen in Figure 2. The standard deviations for fast, slow, and white noise were respectively, 0.80,1.41, and 1.15. Patients that did not return to baseline in each trial were not included in the Figure 2 data. The average recovery time for blood pressure can be seen in Figure 3. Standard deviation for fast, slow, and white noise were 2.24, 1.63, and 1.78 respectively. Participants that did not return to baseline in each trial were not included in the Figure 3 data. Figures 4, 5, and 6 correspond to the proportion of individuals for each treatment (treatment 1 is slow tempo, 2 is white noise, 3 is fast tempo) that returned to their own baseline for blood pressure, heart rate, and respiration rate, respectively. The standard deviations showed overlap among every bar graph, including average recovery time measurements along with a low number of individuals returning to baseline, means no significant conclusions can be drawn from the study.

The brief post-study questionnaire given to the participants at the end of the study provided the researchers with more personal information about the participants studied. Among the 10 participants, there were 5 males and 5 females, all 10 were non-smokers, and their average combined age was 21.4. The average amount of workouts performed each week per participant was 4.1, with the types of exercises including running (7 participants), weight lifting (7), core (1), and elliptical (1).

Discussion

Our results indicate that listening to varying tempos of isochronic tones during recovery after cardiovascular exercise does not significantly affect the rate of decline to resting levels of blood pressure, heart rate, and respiratory rate. All p-values are greater than 0.05, showing insignificant variability, so we are unable to reject the null hypothesis that there is no significant correlation between isochronic tone tempo and physiological recovery rate after exercise. Our hypothesis that listening to an isochronic tone with a faster tempo will lead to a longer recovery time after exercise compared to listening to both a tone at a slower tempo and the control of white noise during recovery cannot be accepted. Additionally, our hypothesis that listening to an isochronic tone with a slower tempo will lead to a longer recovery time than the control, and a shorter recovery time than when listening to isochronic tone with a faster tempo cannot be accepted. In the Krabs et. al paper discussed in our introduction, isochronic tones influenced the heart rate of study participants while at rest. The lack of supporting evidence in our findings suggests that the physiological effect of exercise takes priority over the effect of isochronic tones on the autonomic nervous system. Our study results were further limited due to the long period of time it took one participant to participate in all three trials, leading to a small sample size.

Our study controlled for interpersonal variation since all study participants were subjected to all three experimental conditions. This made sure variability in physical fitness and exercise ability between individuals did not significantly affect our data since we measured the physiologic recovery time back to each subject's baseline measurements for each experimental condition. The individual analyzing the data was kept blind from the subject's experimental treatment in order to further control biased results for the time taken to reach baseline.

Heart Rate

No significance was found for the return of heart rate back to baseline after exercise. In fact, heart rate rarely returned back to baseline for any of our subjects, indicating we need to extend the recovery period to allow full recovery to baseline measurements. However, this time to return to baseline might be so long as to not be practical. It could also indicate that our subjects experienced a learned effect, that they knew they needed to perform three trials total, leading us to believe there is an epinephrine feed-forward mechanism in our body keeping heart rate high when we know exercise is coming soon. Cooling all the way down to resting heart rate between trials could decrease epinephrine levels and decrease an individual's performance by causing the individual to expend more energy to increase their heart rate again and revert blood flow to skeletal muscles. Due to the small amount of individuals that actually returned to their baseline heart rate, we were unable to confidently analyze physiological recovery times in regards to heart rate.

Blood Pressure

No significance was found for the return of blood pressure back to baseline. To measure blood pressure we used an automated blood pressure cuff; one advantage of this is that we were able to eliminate human error and bias while enabling us to take multiple recordings. Technological errors did occur, however, due to cuff malfunction inducing errors in the timing of our measurements. If we missed a complete data point due to technological malfunction we averaged the values from the neighboring recorded values to make an estimate of the measurement.

Respiratory Rate

No significance was found for the respiratory rate recovery time in fast and slow tempo tones relative to the control condition of white noise. Insignificance could be due to misalignment of the belt, leading to uniformly skewed data since the belt was not adjusted on each subject between trials. Not adjusting the belt between subjects, although possible discomfort from the belt may have occurred between trials, controlled for varying respiration rates, but could have led to irregular breathing patterns of subjects and thus no significance in our respiratory data set.

Conclusion and Future Studies

Insignificant results in our experiment indicate that the tempo of the music an individual listens to have no significant effect on their physiological recovery rates post-exercise. However, prior studies have found that varying music tempos have a significant effect on physiological recovery rate post-exercise (Labbe et. al. 2007) (Fossum et. al. 2015). These results indicate that another variable involved in the music selection may be responsible for the significant effect on physiological measurements.

In subsequent studies, alternate exercise methods should be used that give rise to higher heart rates for longer periods of time. This would allow for more data to be collected following the exercise regiment for a more accurate analysis. It would also help to have the subjects participate in this experiment over several days to ensure each subject begins each trial at their normal baseline measurements rather than slightly raised, since many did not return to baseline after their initial exercise trial. Further experimentation could also expose patients to the isochronic tone tempos throughout the entire experiment, allowing for longer exposure that may be needed in order to have a significant effect on physiological responses.

Isolating additional variables such as volume, genre, and personal preference or emotional response to music selections in future studies may also provide insight into how music selection can impact an individual's recovery rate post-exercise.

Figures

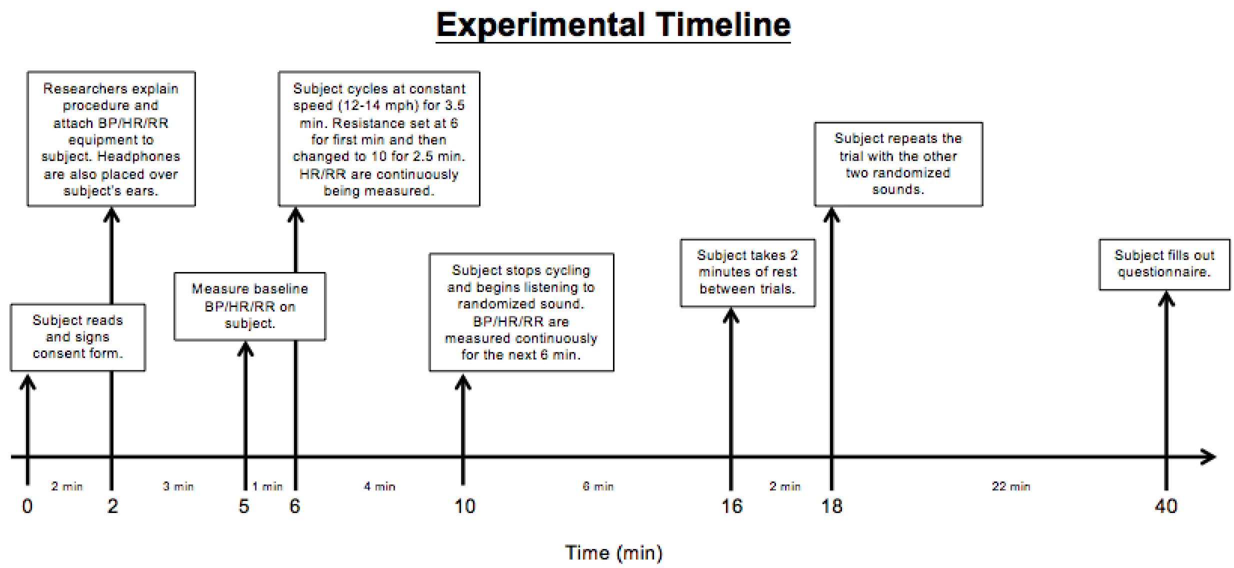

Figure 1. This figure shows the timeline of the experimental procedure for each participant involved in the study.

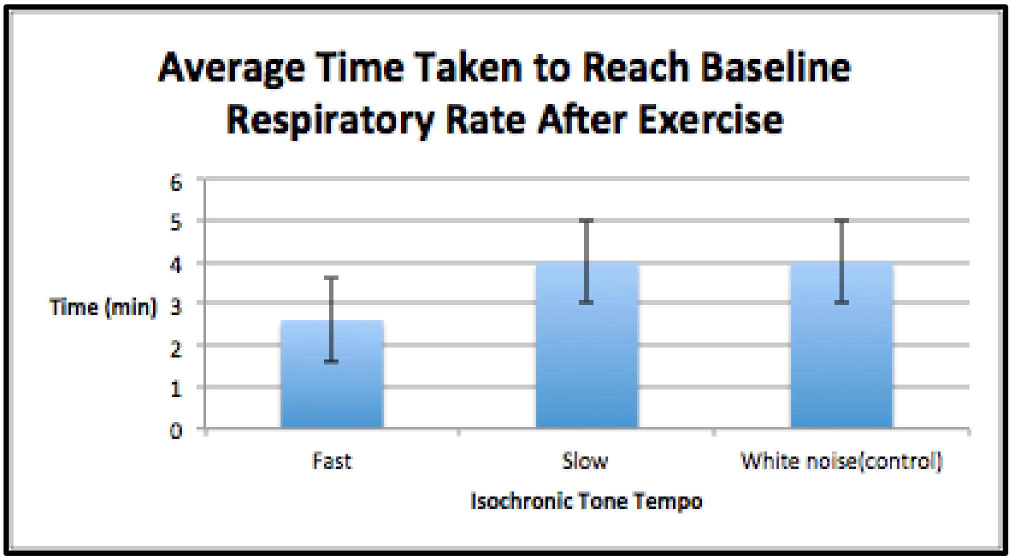

Figure 2. This figure shows the average time it took all participants to recover to baseline respiratory rate after their exercise in this study.

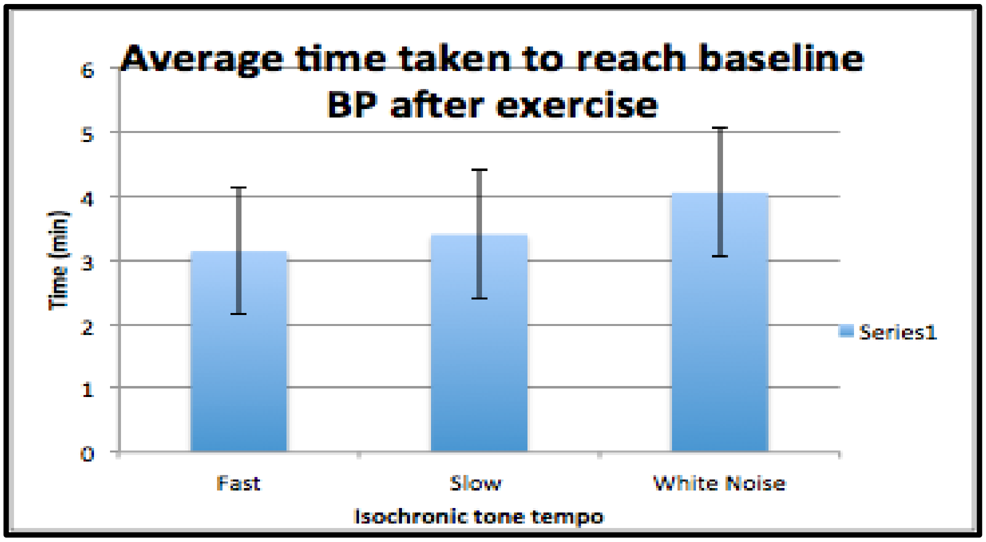

Figure 3. This figure shows the average time it took all participants to return to their baseline blood pressure after exercise in this study.

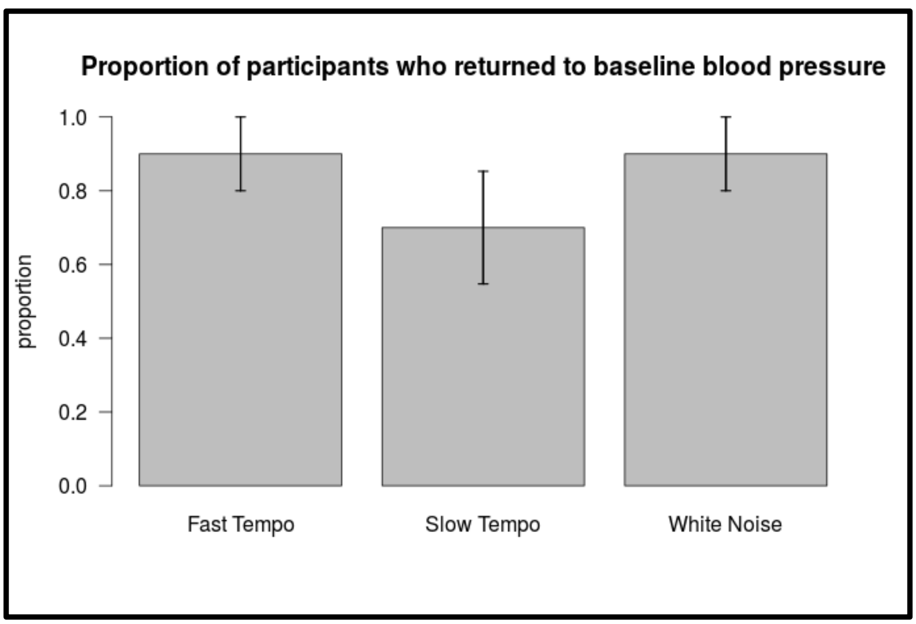

Figure 4. This figure shows the proportion of individuals for each treatment (fast tempo, slow tempo, and white noise) that returned to their baseline blood pressure.

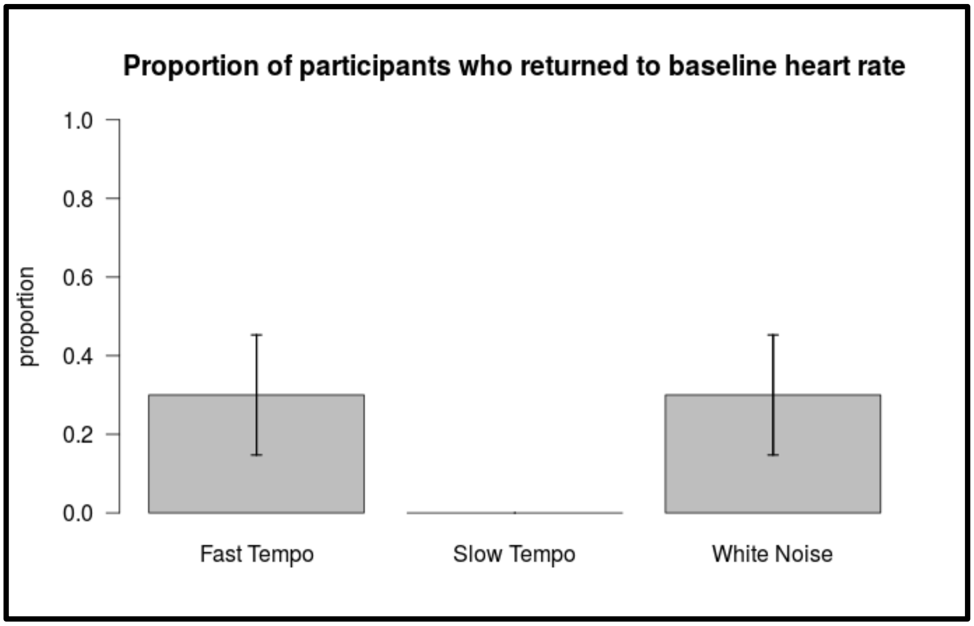

Figure 5. This figure shows the proportion of individuals for each treatment (fast tempo, slow tempo, and white noise) that returned to their baseline heart rate.

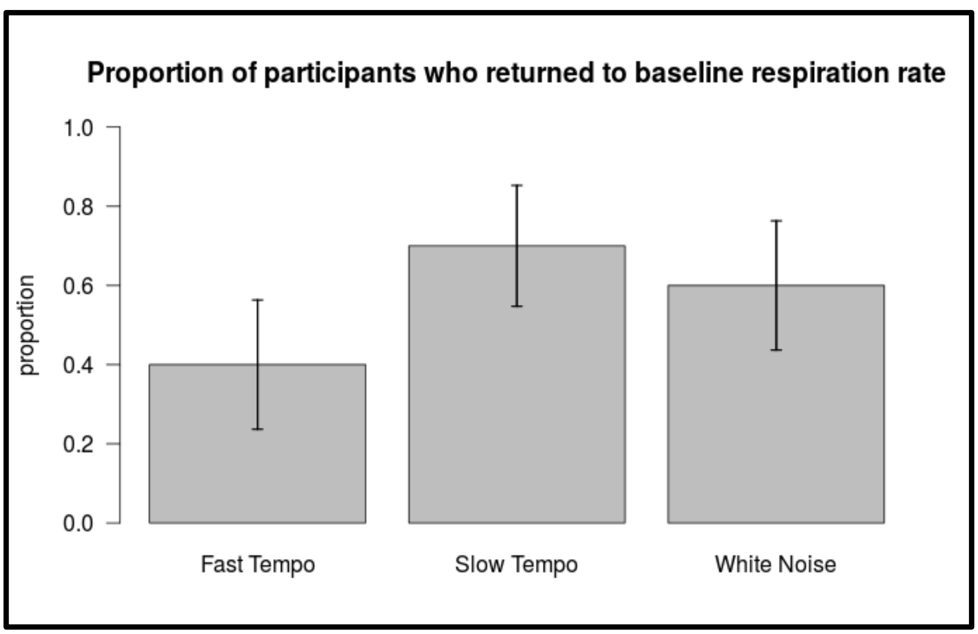

Figure 6. This figure shows the proportion of individuals for each treatment (fast tempo, slow tempo, and white noise) that returned to their baseline respiration rate.

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