This is the accepted version of the publication Tso ITH, Law JCL, Wong TWL. Music-Assisted Training for Dart Throwing Novices: Post-Training Effects on Heart Rate and Performance Accuracy. Perceptual and Motor Skills. (Volume: 129 issue: 1) pp. 120-133.
 DOI: 10.1177/00315125211050629.

Music-Assisted Training for Dart Throwing Novices: Post-Training Effects on Heart Rate and Performance Accuracy

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Running head: Music and Dart-throwing

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Word count: 3306 words

Abstract

While previous research has suggested that lowering athletes' heart rates can enhance sports performance, it is unknown whether slow-paced music might induce a lower heart rate and thereby improve some types of motor performance. In this study, we investigated the effects of different types of music during dart-throw training on both heart rate and dart-throwing performance in 45 (*M* age = 19.7, *SD* = 0.31 years) novice dart throwers who were randomly assigned to either a Slow Music Group (SMG), a Fast Music Group (FMG), or a Control Group (CG). All participants completed three dart-throwing blocks - Pre-Test, Practice, and Post-Test. During the Practice block, participants practiced dart-throwing with either slow-paced, fast-paced or no music according to their assigned group. We recorded the participants' heart rates and total dart-throwing accuracy scores during Pre-Test and Post-Test. Music-assisted dart-throw training with slow-paced music was effective in significantly inhibiting a performance-related increase in heart rate and was associated with the greatest dart throwing improvement after training.

Keywords: music; dart-throwing; heart rate; sport performance; psychomotor training

Introduction

Sports activities have long been recognized for their benefits to physical and mental health (Biddle & Asare, 2011; Janssen & LeBlanc, 2010). Owing to technological advances that give easy access to high quality music and to increased evidence that music can enhance sports performance, individuals striving for excellence in sports have begun integrating music into sports activities (Ballmann et al., 2021; Elliott et al., 2014; Hutchinson et al., 2018; Karageorghis & Terry, 1997). Elite athletes have incorporated a habit of listening to music before a competition, as demonstrated by "The Baltimore Bullet" – Michael Fred Phelps II in the 2000 Sydney Olympics. It is not rare to see people listening to music during exercise at all sport levels, but is this kind of practice truly beneficial or just preferred?

Some prior research examining this question has found music-assisted practice to be effective at performance improvement in several circumstances. Thornby et al. (1995) established that when participants listened to music, they exercised for a longer period than when hearing no music or hearing noise. Szmedra and Bacharach (1998) showed that fast-paced music (versus silence) increased time spent exercising, the amount of work accomplished, and participants' heart rates. Nethery et al. (1991) found that participants who exercised with music reported lower perceived exertion than when they were provided with other attention distracters or no distractors. Results from another study showed positive psychobiological effects to music listening during physical activity, in terms of reduced muscle tension and greater blood flow (Terry et al., 2020).

More than 10 years after his first research in this area, Nethery (2002) posited that exertion during exercise was lower in the presence of music than with no music, with video or in sensory deprivation conditions. Along with similar findings from other researchers, there has been an increased appreciation for the interrelated nature of music listening and sports performance. Potential benefits of music listening while training were described by

Rejeski's Parallel-Processing model in 1985, theorizing that music could increase endurance by inhibiting the adverse psychological feedback that is associated with physical exertion and fatigue (Karageorghis & Terry, 1997; Rejeski, 1985). Similarly, information-processing theory has assumed that humans have a limited attention capacity, and music may act as a positive distractor that reduces vulnerability to tiring distracters (Edworthy & Waring, 2006; Karageorghis & Terry, 1997).

Previous research found that both increased tempo and music volume elevated perceived urgency, thereby activating the sympathetic nervous system (Hellier et al., 1993). Since heart rate is a strong indicator of increased physiological responses (Lacey & Lacey, 2017), Edworthy & Waring (2006) suspected that faster tempo music would induce a higher sympathetic nervous system response and increase heart rate, and they showed that participants who ran on a treadmill while listening to slow and quiet music for 10 minutes showed a significantly slower heart rate than those who listened to fast, loud music. Copeland and Franks (1991) also revealed that slow, soft music induced a lower heart rate, a longer time to reach exhaustion and a lower rated perceived exertion (RPE) compared to fast, loud music. However, most previous studies related to music and performance have been based on endurance sports (e.g., running and cycling), with few studies having investigated the effects of different types of music on sports requiring high mental effort and motor precision, such as dart-throwing and archery (Karageorghis et al., 2019; Radlo et al., 2002; Terry et al., 2020).

Among the very few prior studies that have investigated the effects of music-assisted training on performance in mentally demanding sports, Dorney et al. (1992) found that sport performers who trained with various music genres (e.g., classical), when compared to those who trained without music, demonstrated a significantly lower heart rate during a subsequent performance. Similarly, Hsieh et al. (2010) showed that, following music-assisted training, skilled shooters exhibited heart rate deceleration before shooting that appeared to induce better shooting accuracy. Consistent with this finding, Boutcher and Zinsser (1990) considered heart rate deceleration a few seconds before executing an accuracy-related motor task to be an important marker of focused attention. Heart rate deceleration among top-performing athletes just before motor execution has been associated with improved performance in a variety of precision sports, including golf, rife shooting, and archery (Aggarwala & Dhingra, 2017; Hatfield et al., 1987). Yet, these accuracy-related sports also required special techniques with complicated equipment from skilled practitioners, meaning that potential performance facilitating effect of music through a music-induced heart rate reduction among novice participants engaged in a simpler precision activity has not been well-investigated (Aggarwala & Dhingra, 2017; Hatfield et al., 1987).

Dart-throwing is an accuracy-related motor task that can be safely completed by novice participants without a requirement for technical handling of complicated sport-specific equipment. As it is still unknown whether listening to slow-paced music during training might induce a lower heart rate and improved performance among novice dart throwers, as was previously demonstrated among top-notch athletes in other sports (Aggarwala & Dhingra, 2017; Hatfield et al., 1987), we aimed, in this study to determine post-training effects on heart rate and dart throwing performance among young, novice dart throwers who listened to various music genres during training. We hypothesised that slow- versus fast-paced music or no music during dart-throw training would inhibit heart rate and improve performance. We expected our results to provide insights and inspire slow music training applications for enhancing novice players' sport performance in various mental-effort sports.

Method

Participants

Through convenience sampling, we recruited 45 healthy young adult research participants (*M* age = 19.7, *SD* = 0.31 years) in Hong Kong. No participants had previous dart-throwing experience (i.e., they were novice dart-throwers) or any known visual, neurological, or orthopaedic impairment in the past six months that might affect their ability to throw darts. We informed all participants of the nature of the research, and each participant signed an informed consent form prior to their involvement in any research procedure. Ethical approval of the study protocol was granted by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (reference number: UW-18-158).

Outcome Measures

Average heart rate. We measured the participants' real-time average heart rates by a heart rate monitor belt with a polar watch (Polar E86, Polar Electro, Kempele, Finland). We measured the average heart rate as the average level between the start and end points of the dart-throwing training block, and we recorded their average heart rate during both the Pre-Test and Post-Test blocks using the unit of beats per minute (BPM). We used the average heart rate because this metric reflected the participants' heart rate throughout the whole Pre-Test and Post-Test blocks.

Total accuracy scores of dart-throwing. We asked participants to throw darts onto a dart board that was set up according to the official darts rules from the British Darts Organization (BDO, 2016). To index accuracy, we assigned a higher score if the dart landed closer to the bull's eye. Scores ranged from 0 to 80 for each dart-throwing attempt, where 80 was scored for darts that landed directly on the bull's eye, and ten points were deducted for darts that landed in concentric circles every 2.5 cm from the bull's eye. There were no negative scores. As all participants threw 15 darts during testing, and each throw was scored from 0 to 80, the range of each participant's total score was 0 - 1200, with higher scores representing higher accuracy.

Procedure

Each participant engaged in a single experimental session lasting approximately 30 minutes, comprised of signing an informed consent form, undergoing a Pre-Test block (15 dart throws), a Practice block (10 sets of 15 dart throws) and a Post-Test block (15 dart throws), with instructions to throw darts onto a dart board and obtain as many points as they could. This setup was designed according to the stipulated standards of the British Dart Organization (BDO, 2016). The throw line was set 2.41 meters away from the dartboard, and the dartboard was set 1.76 meters from the floor to the center of the bull's-eye (BDO, 2016). Participants were required to wear the heart rate monitor belt with a polar watch (Polar E86, Polar Electro, Kempele, Finland) to record their average heart rate. We assessed all outcome measures (i.e., average heart rate and total dart-throwing accuracy score) during the Pre-Test and Post-Test blocks.

We randomly assigned participants to either the Slow Music Group (SMG), Fast Music Group (FMG), or the Control Group (CG) by block randomization. We asked the participants to finish the Pre-Test block in which they were required to complete 15 dart throws in the controlled indoor environment. The controlled indoor environment was a laboratory room with no visual or audio distractions. We assessed the outcome measures of average heart rate and total dart-throwing accuracy scores. Following this, we asked participants to complete a Practice block that consisted of 10 sets of 15 throws in their assigned group. We asked the participants in each group (SMG, FMG, and CG) to listen to the selected slow-paced music, fast-paced music, or no music during their Practice block. The assigned music was played during the entire Practice block in which the order of soundtracks was identical for all participants in the same group. For the SMG, the music materials were played at 60 BPM, which has been found to be effective for inducing relaxation and reducing anxiety by causing brainwaves and heart rate to synchronize with the rhythm (Summers et al., 1990). The selected songs for the SMG were Marconi Union and Lyz Cooper – Weightless, Airstream – Electra, DJ Shah – Mellomaniac (Chill Out Mix), Enya – Watermark and Coldplay – Strawberry Swing. Conversely, songs with 120 BPM were recognized as fast-paced and were applied in the FMG (Palit & Aysia, 2015). The selected FMG songs were David Guetta & Sia – Titanium, Daft Punk – Harder, Better, Faster, Stronger, Bastille – Pompeii, Coldplay – Speed of Sound, and One Direction – Live While We're Young. The CG completed the Practice block without any music. We allotted a 2-minute break after the tenth set of practice in the Practice block for participants in all groups. After the break, participants were again asked to perform 15 dart throws in the controlled indoor environment as the Post-Test block. We reassessed the outcome measures of average heart rate and total dart-throwing accuracy scores.

Data analysis

We conducted all statistical analyses using the Statistical Package for the Social Sciences (SPSS 24.0; IBM Corp., Armonk, NY, USA), and we considered a p-value of < 0.05 as statistically significant. We computed descriptive statistics (means and standard deviations) for all outcome measures. We used a series of 3x2 Group (FMG, SMG, CG) x Block (Pre-Test, Post-Test) Analyses of Variance (ANOVA) with repeated measures to examine the differences among the three music groups in two different blocks for the main outcome measures of average heart rate and the total dart-throwing accuracy. To further elucidate the relationship between heart rate change and dart-throwing accuracy, we conducted a post-hoc correlational analysis (Spearman's Rho correlation) between the change in heart rate (i.e., Post-Test minus Pre-Test) and the change in total dart-throwing accuracy scores (i.e., Post-Test minus Pre-Test).

Results

Descriptive Statistics

Table 1 shows the participants' descriptive characteristics for age, average heart rate and total dart-throwing accuracy scores (see Table 1).

Table 1 near here

Average Heart Rate

We found a significant group by block interaction effect on average heart rate (F (2, 42) = 13.6, p = .001, η_p^2= .39). There was a statistically significant increase in average heart rate from Pre-test to Post-test for participants in the FMG (F (1, 14) = 25.3, p = .001) and CG (F (1, 14) = 72.5, p = .001) but not in the SMG (F (1, 14) = 4.5, p > .05) (see Figure 1, upper panel). This finding suggests that slow-paced music during training (the SMG experience) inhibited the increase in heart rate during dart-throwing performance after training, as compared with FMG and CG.

Total Dart-Throwing Accuracy Scores

There was no significant group by block interaction effect (F (2, 42) = 1.03, p = .37, η_p^2= .05), but the mean improvement of the total dart-throwing accuracy scores from Pre-test to Post-test was highest for participants in the SMG (mean improvement = 137.33), compared with the FMG (mean improvement = 38) and the CG (mean improvement = 98) (see Figure 1, lower panel).

Figure 1 near here

Correlational analysis

We found a significant moderate and negative correlation between the pre-test to post-test change in heart rate and change in total dart-throwing accuracy scores ($rs[45] = -.34$, $p = .02$). A steeper fall in heart rate was associated with a higher increase in dart-throwing accuracy at Post-Test and vice versa.

Discussion

Our aim in this study was to investigate the after-effects of listening to different music genres (with different BPMs) during training on young, novice participants' post-training heart rates and dart-throwing accuracy. We hypothesized that listening to slow-paced music during dart-throw training would inhibit the increase in heart rate and improve dart-throwing performance on post-testing, compared with listening to fast-paced music or hearing no music during training.

Our FMG and CG participants demonstrated a statistically significant increase in heart rate during post-test dart-throwing. The FMG illustrated a relatively smaller (but statistically insignificant) rise in heart rate compared to the CG. Thus, all music (regardless of genre or BPM) may have *some* "inhibiting" effect on heart rate. However, a previous study showed that both classical and fast modern genre music slowed down heart rate during dart-throwing (Dorney et al., 1992). Since our SMG group did not show the increased heart rate during post-training dart-throwing, our result partially supported our hypothesis. Slow-paced music during dart-throwing training inhibited the heart rate increase otherwise experienced by the FMG and CG participants during post-testing. Regarding the observed elevation in heart rate in the FMG and CG condition, it is not abnormal to experience elevated heart rate after physical activity such as participation in dart-throwing, as this task involves energy expenditure by various bodily movements, such as shoulder flexion, elbow extension and etc.

(Caspersen et al., 1985). Furthermore, emotional arousal during post-testing may have been a contributing factor for a heart rate increase (American Heart Association, 2018). Various investigators found that loud music can stimulate arousal level, while soft, slow music might reduce arousal level during sports performance (Karageorghis et al., 1996; Terry et al., 2020). According to the Yerkes and Dodson (1908) Inverted-U Theory of Arousal Level, individuals might experience increased arousal when the task out-matched the participants' perceived self-efficacy and skill levels.

All three groups (SMG, FMG, and CG) demonstrated an improvement trend in total dart-throwing accuracy after training, but the SMG participants obtained the highest change in their post-test vs. pre-test dart-throwing accuracy scores (*M* improvement = 137.33) compared with the FMG (*M* improvement = 38) and CG (*M* improvement = 98) participants. There was no interaction effect from the 3x2 Group (FMG, SMG, CG) x Block (Pre-Test, Post-Test) Analysis of Variance (ANOVA) with repeated measures for the main outcome measure of the total dart-throwing accuracy scores. Perhaps with further specific practice or in a study with a larger sample and more statistical power, we might have seen statistically better dart-throwing accuracy in the SMG, compared with the FMG and CG over training blocks. However, this assertion remains speculative, as we found only a non-significant trend in this direction.

Total post-test dart-throwing accuracy scores for all groups were improved pre-test scores, to the practice principle of motor learning (Duffy et al., 2004). Our practice session (150 total throws) was more extensive than in other similar studies (i.e., around 80 throws; Marchant et al., 2009). Although it is likely that these accuracy improvements were due to deliberate practice, it is also noteworthy the SMG participants' accuracy improvements tended to be the highest among the three groups. This trend toward greater SMG improvement may be related to a decreased stress level for these participants, associated with the effects of slow-paced music listening during dart-throwing training on an inhibited increase in heart rate post-training. This trend echoes the findings of a previous study indicating that listening to songs with slow music tempo (i.e., 60 bpm or lower) was associated with significantly lower stress level than hearing no music (Matthews, 2012) and another study showing that a high level of stress was associated with a decrease in selective and divided attention (Vedhara et al., 2000). Nevertheless, perhaps because of insufficient statistical power, our results reflected only a non-significant trend in improvement among SMG participants. Of relevance to these considerations, our correlational analyses revealed that a slower heart rate was associated with higher dart-throwing accuracy after training, suggesting that heart rate may be an influential factor in dart-throwing accuracy. However, further studies are required to examine other factors that might be associated with the effects of music on dart-throwing and other mentally demanding sports.

Limitations and Directions for Further Research

Among this study's limitations, we did not have a no-practice control condition to examine other practice variables that might have elicited inhibitory or facilitating heart-rate or performance effects. Second, the exercise intensity of our dart throwing practice may have been different in slow-paced and fast-paced music conditions, meaning that speed, exertion and/or arousal during practice may have had carry-over effects into post-testing. Third, the participants varied familiarity with or preference for music was an uncontrolled variable. Fondness for and relatability of music have been found to affect an individual's concentration and physiological response levels (Matthews, 2012), and dart-throwing is an accuracy-related motor task that could be influenced by factors affecting attention and heart rate (Hatfield et al., 1987). To eliminate any bias associated with the song's familiarity, future studies might optimize an original soundtrack with computer-generated musical notes that could be edited, to play at a fast or slow pace. Furthermore, in our study, the Polar E68 heart rate belt and polar watch may record at a five-second interval and not be the most accurate measurement of average heart rate. Future studies might adopt more advanced measurement technology such as the Polar H10 model, or employ the gold standard of non-invasive heart rate measurement by utilizing an electrocardiogram (ECG) (Phua et al., 2012). Additionally, as noted above, future studies should utilize larger participant samples and consider multiple- versus single-session training to improve statistical power and best optimize potential training effects. Finally, it should be noted that this cross-sectional and correlational study has established an association but not a definitive causal effect between listening to slow paced music during training and reduced heart rate and improved performance effects at post-testing.

Conclusion

Our hypotheses of a greater effect on post-test heart rate and dart-throwing accuracy after listening to slow-paced versus either fast-paced or no music during dart-throw training were partly met in this study. Slow-paced music during training significantly inhibited an increased heart rate during post-test throwing, but we did not show a statistically significant improvement in dart-throwing accuracy for this group, as there was only a statistically non-significant trend toward accuracy improvement among participants in our SMG relative to those in FMG and CG. Further research is needed with a larger participant sample, varied degrees of deliberate practice (e.g., multi- versus single-session dart-throwing in training), more precise measurements, and/or controls over participants' music familiarity and/or preference. Meanwhile, data from this study provide important evidence that music pace during music-assisted training has significant potential for enhancing motor performance of mentally demanding motor tasks, even when participants are novices and the motor task requires no complex sports equipment.

Acknowledgements

The authors are thankful to Miss May Leung and Miss Connie Cheng for their assistance in the study.

Declaration of Conflicting Interests

The authors declare no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors received no financial support for the research, authorship, and/or publication of this article.

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Table

Table 1. Pre-Test Participant Characteristics by Group Assignment

Variables	Groups		
	FMG (*n*=15)	SMG (*n*=15)	CG (*n*=15)
Age (Years)	19.60 (0.99)	19.94 (1.24)	20.00 (1.00)
Average Heart Rate Pre-Test (BPM)	80.13 (6.78)	84.93 (12.48)	79.73 (6.69)
Average Heart Rate Post-Test (BPM)	87.20 (8.84)	87.40 (12.33)	92.13 (5.48)
Total Dart-Throwing Accuracy Scores Pre-Test (Scores)	604.00 (138.34)	628.00 (161.03)	604.00 (223.25)
Total Dart-Throwing Accuracy Scores Post-Test (Scores)	642.00 (122.37)	765.33 (150.28)	702.00 (139.96)

Note. FMG = Fast Music Group; SMG = Slow Music Group; CG = Control Group; BPM = Beats Per Minute

Figure

Figure Legend

Figure 1 Upper Panel: Participants' Average Heart Rate (BPM) by Group Assignment at Pre-Test and Post-Test. Lower Panel: Participants' Total Dart-Throwing Accuracy Scores by Group Assignment at Pre-Test and Post-Test.

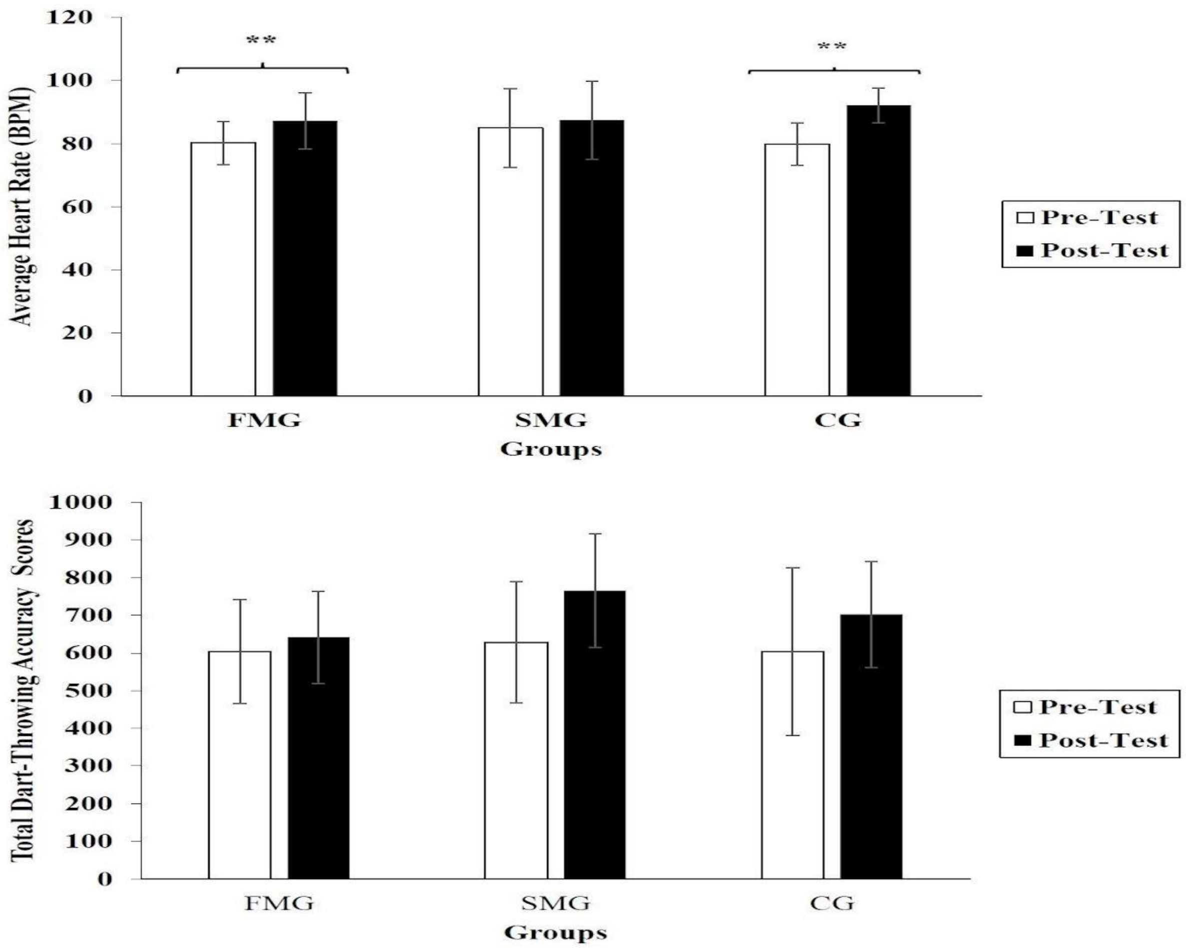

Figure 1

Note. FMG = Fast Music Group; SMG = Slow Music Group; CG = Control Group; BPM = Beats Per Minute

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