Effects of Synchronous Music on 400-Metre Sprint Performance

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Abstract

The aim of the present study was to investigate the effects of motivating and oudeterous (neither motivating nor demotivating) synchronous music on 400-metre sprint performance while controlling for the potential confound of pre-performance mood. A panel of volunteer Caucasian males (n = 20; mean age = 20.5, s = 1.2 years) rated the motivational qualities of 32 musical selections using the Brunel Music Rating Inventory-2. An experimental group of volunteer Caucasian males (n = 36; mean age = 20.4, s = 1.4 years) completed three 400-metre time trials under conditions of motivational music, oudeterous music and a no-music control. Pre-performance mood was assessed using the Brunel University Mood Scale (BRUMS). A series of repeated measures (RM) ANOVAs with Bonferroni adjustment revealed no differences in the BRUMS subscales. A RM ANOVA on the 400-metre times showed a significant effect ($F_{1.24,42.19} = 10.54$, $P < 0.001$, $\eta^2 = .24$) and follow-up pairwise comparisons revealed differences between the synchronous music conditions and the control condition. This finding supported the first research hypothesis, that synchronous music would yield superior performance to a no-music control, but not the second hypothesis, that performance in the motivational synchronous music condition would be superior to that in the oudeterous condition. It appears that synchronous music can be applied to anaerobic endurance performance among non-elite sportspersons with considerable effect.

Introduction

Music is a source of motivation and inspiration that is much valued within the realms of sport and exercise. Given the ubiquity of music in such environments, its application as a mild but perfectly legal ergogenic aid has raised considerable interest among researchers over the last four decades (for reviews see Karageorghis and Terry, 1997; Lucaccini and Kreit, 1972). To date, synchronous music has been used extensively in the context of structured exercise classes; however, it has seldom been used in a structured and systematic way in the sports domain. One notable exception concerns the celebrated Ethiopian athlete Haile Gebreselassie who famously synchronised his stride rate to the rhythmical pop song *Scatman* when breaking the indoor 2000-metre world record in February 1998 (Karageorghis, 1998).

The synchronous use of music involves performing repetitive movements in time with its rhythmical elements such as the beat or tempo. By way of contrast, the asynchronous use of music involves performing while listening to music playing in the background - without any *conscious effort* to stay in time with the rhythm (Karageorghis and Terry, 1997). Hence, the synchronous use of music is a conscious process that is contingent upon an individual's rhythmic ability in maintaining strict time (McAuley and Semple, 1999).

To date, research has demonstrated the efficacy of both asynchronous music (Copeland and Franks, 1991; Ferguson *et al.*, 1994) and synchronous music (Anshel and Marisi, 1978; Karageorghis and Jones, 2000; Mertesdorf, 1994; Michel and Wanner, 1973) in the context of long-duration exercise tasks; however, there is a distinct dearth of research into the effects of music on anaerobic endurance.

According to Karageorghis *et al.* (1999), suitable music for sport- and exercise-related tasks is characterised by strong rhythmic features. In their conceptual framework addressing the motivational qualities of music, rhythm is deemed to be of higher importance than other components of music such as familiarity and extra-musical associations. This assertion has been strongly supported in subsequent research (Atkinson *et al.*, 2004; Karageorghis *et al.*, in press a, in press b; Priest *et al.*, 2004). Furthermore, the synchronization of music with exercise tasks has been associated with increased work output (Anshel and Marisi, 1978; Karageorghis and Jones, 2000; Michel and Wanner, 1973).

Anshel and Marisi (1978) conducted the first-ever experimental study investigating the effects of synchronous music. They compared synchronous and asynchronous music conditions using a cycle ergometer endurance task. The synchronous music condition elicited significantly longer endurance than the asynchronous music and control conditions. A limitation of this study was that relatively little consideration was given to the musical preferences and musical background of participants and thus, a rather arbitrary choice of “popular rock” was made. A further limitation, and one acknowledged by the authors themselves, was that a male experimenter tested female participants. This may account for female participants’ underperformance when compared to males, despite the fact that males and females cycled at relative workloads.

Motivational and Oudeterous Music

Karageorghis *et al*. (1999) indicated that the key characteristics of motivational music are that it has a fast tempo (>120 beats$\cdot$min^{-1}) and strong rhythm, while it enhances energy and induces bodily action. They operationalised *oudeterous music* as that which is neither motivating nor demotivating. This operationalization was necessary owing to the confusion that would have resulted through simply using the term *neutral music*, which has connotations that transcend the motivational qualities of music (cf. neutral colours, neutral emotions, neutral point of view, etc.).

The conceptual framework underlying the use of asynchronous motivational music in exercise and sport devised by Karageorghis *et al*. (1999) indicated three main hypotheses, all of which bear some relevance to the present study of synchronous music. First, music can be used to alter psychomotor arousal and thus can act as either a stimulant or sedative. Second, music narrows a performer's attention and consequently diverts attention from sensations of fatigue (cf. Hernandez-Peon, 1961). Third, music enhances the positive dimensions of mood (e.g., happiness, vigour) and tempers the negative dimensions (e.g., anger, depression, tension).

Karageorghis and Terry (1997) explained the synchronization between musical tempo and human movement in terms of the predisposition humans have to respond to the rhythmical elements of music. Essentially, musical rhythm replicates natural movement-based rhythms. Indeed, musical rhythm relates to the periodicities of the human body such as respiration, heart beat, walking and so on (Bonny, 1987). Smoll and Schultz (1978, 1982) asserted that one of the most important components underlying motor skill acquisition and performance is rhythm. Humans perform motor tasks at a preferred tempo that reflects their optimum level of temporal and rhythmic accuracy and biomechanical efficiency.

Coordinating Music with Physical Activity

In their applied study of functional (task-oriented) music, Kodzhaspirov *et al.*, (1986) indicated that for maximum effect, musical tempo should simulate the activity being undertaken. Thus, high intensity activities such as weightlifting or sprinting require correspondingly high tempi. Berlyne (1971) provided a detailed explanation of this phenomenon based on the hypothesis that the arousal potential of stimuli determines preference. Essentially, during vigorous activity there will be stronger preferences for high tempo music owing to increases in physiological arousal (cf. Karageorghis *et al.*, in press a; North & Hargreaves, 1997).

Limitations in Past Research

In their review, Karageorghis and Terry (1997) summarised the main limitations in past research[1] as: a) a lack of justification of musical selections in terms of both the experimental task and sociocultural background of participants; b) non-reporting or non-standardisation of music intensity; c) the selection of inappropriate dependent measures; d) intrusive testing protocols that possibly masked any likely effect of music; and e) experimental tasks that were difficult to standardize (e.g. aerobic dance exercise).

Most previous research efforts examining the ergogenic effects of music have been confined to controlled laboratory environments (e.g., Anshel and Marisi, 1978; Atkinson *et al.*, 2004; Copeland and Franks, 1991; Karageorghis and Jones, 2000). The present study addressed the effects of synchronous music in an ecologically valid setting – 400-metre track running – while attempting to account for the limitations that have plagued past research. An asynchronous condition was not included owing to theoretical propositions pertaining to the efficacy of in-task asynchronous music during high intensity tasks (Karageorghis and Terry, 1997; Rejeski, 1985). Specifically, beyond anaerobic threshold, physiological cues dominate attention thus rendering music listening ineffective as a dissociation strategy. This proposition has received unequivocal support in empirical studies (Boutcher and Trenske, 1990; Tenenbaum *et al.*, 2004).

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[1] Only limitations pertaining to the specifics of the present study are included. Readers are referred to the original paper for a full exposition of limitations in previous research.

On the basis of previous findings (Anshel and Marisi, 1978; Karageorghis and Jones, 2000; Mertesdorf, 1994; Michel and Wanner; 1973) and theoretical predictions (Karageorghis *et al*., 1999), two hypotheses were tested. First, that the motivational music synchronous condition would elicit faster 400-metre times than the oudeterous synchronous music condition and control condition. Second, that both music conditions were expected to elicit faster times than a no-music control condition.

Method

Stage 1 – Music Rating: Participants

A music rating panel comprised of a purposive sample of male sports science undergraduates (*n* = 20; mean age = 20.5, *s* = 1.2 years) from Brunel University, West London. They selected the motivational and oudeterous music tracks used in the experimental phase of the study (Stage 2). To ensure a level of cultural homogeneity (Karageorghis and Terry, 1997), these participants were Caucasian and brought up in Great Britain. Furthermore, they were of the same age group as the intended experimental participants sampled in Stage 2.

Apparatus, Measures and Procedures

The authors selected 140 up-tempo tracks that had reached the *Official UK Top 40* (compiled by the British Music Industry) between August 1999 and June 2002. The tracks were then recorded from compact discs onto a mini-disc (Sony MDW74CRG) using a hi-fi system (Sony CMT-CP505MD). A DJ mixer unit (Numark 940 XL) and dual deck player (Numark 8868) were used to assess the tempo of each track. Tracks outside of the range 135-140 beats·bpm^{-1} were excluded (*k* = 8), as these would not correspond with participants' stride rates in Stage 2. The authors then recorded 90 sec excerpts from the remaining 32 tracks with each excerpt including at least one verse and one chorus (see Gluch, 1993).

The Brunel Music Rating Inventory-2 (BMRI-2: Karageorghis *et al*., in press b) was used to assess the motivational qualities of the 32 tracks. The BMRI-2 is a redesigned version of the original BMRI (Karageorghis *et al*., 1999) with each item referring to an action, a time, a context and a target (Azjen and Fishbein, 1977; e.g. "The rhythm of this music would motivate me during a sprint performance"). It is a single-factor, six-item instrument that possesses superior psychometric properties to the original BMRI. Participants respond on a 7-point Likert-type scale anchored by 1 ("strongly disagree") and 7 ("strongly agree"). Development of the BMRI-2 involved in-depth interviews to establish the initial item pool, which was subsequently examined using a series of confirmatory factor analyses. The mean alpha coefficient for the single factor reported by the authors is .89.

Using the BMRI-2, the music rating panel rated the 32 musical excerpts for their motivational qualities with reference to the 400-metre experimental task. The highest scoring track (*Chase the Sun* by Planet Funk) was used for the motivational music condition, and the lowest scoring was used for the oudeterous music condition (*Starlight* by Supermen Lovers). The selected excerpts were digitally altered to either slightly increase or decrease the tempo to ensure each of the six running ability groups used in Stage 2 had a tempo corresponding with their predicted 400-metre stride rate. The variations were graded in 1 beats$\cdot$min^{-1} units from 135-140 beats$\cdot$min^{-1}. This necessitated the production of 12 mini discs for Stage 2, which was undertaken with copyright permission from the music publishers.

Stage 2 – Experimental: Power Analysis

A power analysis (Cohen, 1988) was conducted to assist in the estimation of an appropriate sample size for the experimental group. With alpha set at .05 for a two-tailed test and power at .70, based on an estimated moderate size for the effect of synchronous music when compared to a no-music control (*d* = 0.6; Anshel and Marisi, 1978), it was calculated that 35 participants would be required. To account for the possibility of experimental mortality and multivariate outliers, one additional participant was recruited.

Participants

Participants comprised of a purposive sample of males drawn from a sports centre gymnasium in West Sussex, England (*n* = 36; mean age = 20.4, *s* = 1.4 years). They were a non-intact group that trained regularly at the gymnasium (independently of one another) and all participated as outfield players in team sports (not as team mates) that involved running, such as field hockey, rugby union and soccer. Participants stemmed from the same socio-cultural background, were Caucasian and brought up in Great Britain.

Measures

Pre-performance mood was assessed using the Brunel University Mood Scale (BRUMS; Terry *et al*., 1999). The BRUMS is a 24-item inventory which measures the six dimensions of mood as proposed by McNair *et al.* (1971): Anger, confusion, depression, fatigue, tension, and vigour. The “How do you feel right now?” response timeframe was used immediately prior to each 400-metre trial. Sample items for each subscale are as follows: Anger - “annoyed”, confusion - “uncertain”, depression - “unhappy”, fatigue - “tired”, tension - “anxious”, and vigour - “energetic”. Items were rated on a 5-point Likert-type scale anchored by 0 “not at all” to 4 “extremely”. The BRUMS has demonstrated sound psychometric properties through a progressive series of validation procedures (see Terry, Lane and Fogarty, 2003; Terry *et al*., 1999). Terry *et al.* (1999) reported the following Cronbach alpha coefficients for young athletes: anger - $\alpha = .80$; confusion - $\alpha = .86$; depression - $\alpha = .85$; fatigue - $\alpha = .82$; tension - $\alpha = .75$; and vigour - $\alpha = .79$.

Apparatus and Procedure

In order to standardise participants' work rate, a pre-test 400-metre sprint was undertaken a week before the first experimental trial. This had the secondary purposes of habituating participants to the experimental task and limiting any potential learning effects that might compromise internal validity. This pre-test consisted of one lap of a six-lane 400-metre all-weather running track at maximal speed. Each trial was timed using a handheld stopwatch (Nike Triax 26), and filmed using a digital video camera (Sony CCD-TRV69E Handycam Vision). More specifically, participants' lower limbs were filmed to facilitate measurement of stride frequency for the 400 metres. To ensure the accuracy of this process, a quad motorcycle (Yamaha Big Red 400) was used to transport the cameraperson around the track ahead of the participants.

The pre-test run enabled the researchers to rank participants in accordance with the number of strides it took them to complete 400 metres. Participants were then placed into one of six stride rate groups and assigned a lane that would remain the same for each experimental trial. All six lanes of the track were occupied for each experimental trial.

Participants' individual times for 400 metres, along with the number of strides taken, were used to calculate a stride frequency to be used during the experimental phase of the study. The range of strides taken to complete the distance was 306-326 (mean stride rate = 312, $s = 20$ strides). To facilitate synchronous use of the music, the number of strides taken by each participant was halved in order that each musical beat corresponded with one stride cycle. Thus, during each musical *bar* or *measure* that contained a standard four beats (4/4 time signature), participants took eight individual strides (four stride cycles) with the foot of the leading leg making contact with the ground on each beat.

Prior to the scheduled start time for each group, participants were given a 10 min warm-up period, which was followed by administration of the BRUMS at individual desks. Thereafter, participants were brought under starter's orders and given the starting commands: "On your marks", "set" followed by a bang produced by a Neuff Mousetrap starting device. A standardised gap of 2 sec was left between the warning signal ("set") and the stimulus ("bang").

Three research assistants timed the participants using a handheld stopwatch. These assistants were *UK:Athletics*-trained timekeepers and the first author checked the inter-timer reliability prior to commencement of the study. The check involved the use of six male athletes (mean age = 22.7, $s = 2.1$ years) who trained at the test site but were not involved in the experimental phase of the study. All three timekeepers timed each athlete for a 400-metre time trial. The mean standard deviation representing the range of times for each athlete was 0.047 sec.

The study adopted a repeated measures design with testing scheduled at the same time and day of the week over consecutive weeks. Participants were instructed to follow identical patterns of activity and diet with no other vigorous physical activity permitted prior to each trial. Furthermore, they were not permitted to eat a meal within two hours prior to testing. Their adherence to these instructions was checked verbally prior to the commencement of each trial. On the "set" command, participants started the musical excerpt by pressing the "play" button on a walkman (Sony MZ-R90 MD). The intensity of the music was standardised at Level 16. For the no-music control condition, participants listened to white noise (a blank mini disc) at the same intensity as the music and were instructed to run the distance as fast as they could. Other than this, all procedures were identical.

During the 4-week duration of the study, only the first author, three trained research assistants, and the participants were present at the track. Participants arrived individually at pre-arranged times in accordance with the stride frequency group to which they had been assigned. Test conditions were administered to each stride frequency group in counterbalanced order. As there were six stride frequency groups exposed to three conditions, the conditions were administered to each group in a different order. Each group was randomly assigned an order by having its number (1-6) drawn from a hat.

Data Analysis

Data were screened for accuracy, checked for univariate outliers using z scores $> \pm 3.29$ and multivariate outliers using the Mahalanobis distance test (at $P < 0.001$; Tabachnick and Fidell, 2001). The BRUMS raw scores were normalised for male adult athletes (Terry *et al.*, 2003) and checks were made for the parametric assumptions that underlie repeated measures (RM) ANOVA. To compare pre-performance mood across conditions, a series of RM ANOVAs was used with Bonferroni adjustment ($P < 0.008$) in order that differences between individual BRUMS factors could be added as covariates in the analysis of the 400-metre time trial data as necessary. Following checks for the relevant assumptions (Tabachnick and Fidell), differences in times between conditions were assessed using a single-factor RM ANOVA. Follow-up multiple comparisons with Bonferroni adjustment were used to identify where differences lay.

Results

BMRI-2 Scores

The BMRI-2 scores for the motivational music condition (*Chase The Sun*) and oudeterous music condition (*Starlight*) tracks were compared using a paired-samples *t* test to ensure that they differed significantly. Results revealed a large difference between the motivational quotients of these selections ($t_{19} = 22.10$, $P < 0.001$).

BRUMS scores

Outlier checks revealed two univariate outliers ($z > \pm 3.29$) however following examination of the corresponding *T* scores, which fell within two standard deviations of the mean score of 50, the authors decided to neither delete the cases nor modify the scores, as they did not represent extreme mood in absolute terms. Each of the BRUMS subscales satisfied the assumption of sphericity (across conditions) other than tension (Mauchly's $W = 0.807$, $P < .05$, $\varepsilon = 0.84$) for which a Greenhouse-Geisser adjustment was made. RM ANOVAs for each of the BRUMS subscales with Bonferroni adjustment revealed no significant differences (anger: $F_{2,68} = 1.61$, $P > 0.05$; confusion: $F_{2,68} = 0.01$, $P > 0.05$; depression: $F_{2,68} = 0.88$, $P > 0.05$; fatigue: $F_{2,68} = 0.02$, $P > 0.05$; tension: $F_{1.676,56.980} = 0.05$, $P > 0.05$; vigour: $F_{2,68} = 0.74$, $P > 0.05$). Therefore, none of the BRUMS subscales were used as covariates in the analysis of the 400-metre time trial data.

400-Metre Time Trial Results

Mahalanobis's distance test revealed one multivariate outlier ($P < 0.001$), which was subsequently removed from the dataset. Tests of the distributional properties of the data in each cell of the analysis revealed one minor violation of normality. Specifically, there was significant ($P < 0.01$) positive kurtosis for the control condition data (see Table 1). Keppel (1991) suggested that ANOVA is sufficiently robust to withstand such minor violations of normality; therefore, we decided not to apply logarithmic transformation. Mauchly's test of sphericity was significant for the time trial data (Mauchly's $W = 0.39$, $P < 0.001$, $\varepsilon = 0.93$) indicating a need for Greenhouse-Geisser adjustment.

The RM ANOVA revealed large differences between conditions ($F_{2,68} = 10.54$, $P < 0.01$, $\eta^2 = .24$) indicating that 24% of the overall variance in 400-metre times was attributable to manipulation of the independent variable. Follow-up pairwise comparisons revealed differences between the motivational music condition and control condition (95% confidence interval = –1.14 - –0.21, $P < 0.01$) and the oudeterous music condition and the control condition (95% confidence interval = –0.50 - –0.12, $P < 0.01$), but no difference between the motivational music condition and the oudeterous music condition (95% confidence interval = 0.12 - 0.50, $P > 0.05$).

**** Insert Table 1 about here ****

Discussion

The purpose of the present study was to investigate the effects of synchronous music on 400-metre time trial performance. The potential confound of pre-performance mood was controlled for; although no differences were found in any of the six BRUMS subscales between conditions. The first research hypothesis was supported given that times in the motivational and oudeterous synchronous music conditions were shorter than those in the no-music control condition. However, the second research hypothesis was not supported as there was no significant ($P > .05$) difference between synchronous performance in response to motivational and oudeterous music. Collectively, the present results indicate that synchronization of a rhythmical anaerobic motor task to music can have a strong impact on performance regardless of the motivational quality of the music played.

The present findings support those of Anshel and Marisi (1978) who showed differences between synchronous and control conditions using a cycle ergometer endurance task. The findings also support Karageorghis and Jones (2000) who reported large differences in cycle ergometry endurance between motivational synchronous music and a flashing light control. The lack of difference between the motivational and oudeterous conditions may, in part, be due to the fact that the present task was exclusively anaerobic in nature. Therefore, participants only appeared to benefit from the pacing effect that the music elicited rather than other aspects such as melody, style or instrumentation (Karageorghis *et al.*, in press b).

Past research has shown that beyond anaerobic threshold, physiological cues dominate attentional processes and thus external cues such as music become less salient (Rejeski, 1985; Tenenbaum et al., 2003). This phenomenon appears to impact on ratings of perceived exertion but not upon in-task affect to the same extent. Ostensibly, in the present study, the motivational qualities of the music had no impact on work output. However, had the sample size been slightly larger, it appears highly likely that a statistically significant difference would have emerged; in estimating an appropriate sample size, power was set at the lower end of the recommended range for the behavioural sciences (.70 - .80; Green, 1991, p. 502).

Another factor which may account for the lack of difference between the two synchronous music conditions is that they were both characterised by a relatively high tempo (135-140 beats$\cdot$min^{-1}). This was necessary owing to the stride rate of the participants; however, because rhythm response is the strongest predictor of the motivational qualities of music (Karageorghis *et al.*, 1999), and tempo is an integral aspect of this, the additional qualities of the music such as melody, style and instrumentation may have been less effectual in this context. During a submaximal effort, it is likely that participants would have greater awareness of the non-rhythmic elements of the music (cf. Copeland and Franks, 1991).

Limitations of the Present Study

With a high impact and extremely vigorous activity such as 400-metre sprinting, it is difficult to achieve perfect synchronization with a musical stimulus. This is particularly the case over the first 20 metres while participants are accelerating and in the last 50 metres when blood lactate levels begin to hamper performance. Hence, it is acknowledged that although every effort was made to ensure perfect synchronization, there would have been some minor variations. Moreover, related to this, although none of the trials was conducted in wet conditions, wind speed and wind direction could not be standardised between trials and this may be an additional source of error (Quinn, 2004). Conducting the research indoors would have circumvented this problem however there is not, as yet, a 400-metre indoor track available in the UK.

Participants' performances were measured with hand-held stopwatches; although trained timekeepers operated these, it is acknowledged that electronic timing would have improved the reliability of the times. However, hiring such equipment on four occasions would have proved prohibitively expensive. Finally, to maintain external validity, participants completed each trial in groups of six. It is possible that a natural tendency to compete may have compromised slightly the internal validity of the study. This threat to internal validity was preferred to the potential lack of motivation had participants been required to complete the task individually.

Implications and Recommendations

The main practical implication of the present study is that the use of synchronous music can have a considerable effect on the performance of rhythmical anaerobic motor tasks. There is a clear trend emerging in the literature, which suggests that music is a genuine ergogenic aid, at least among non-elite sportspeople. Practitioners seldom tap the ergogenic properties of synchronous music. The synchronous application of music could be extended to elite sportspeople, in particular track athletes and cyclists who can use music to regulate effort exertion (Atkinson *et al.*, 2004). Moreover, the effects of synchronous music on females should be given greater attention by researchers. The females in Anshel and Marisi's (1978) study underperformed in the presence of a male experimenter. As the present experimenters were also male, they chose to examine male participants only.

A further implication is that synchronous music may be more beneficial in submaximal rhythmic motor tasks as, according to past research (Boutcher and Trenske, 1990; Copeland and Franks, 1991), the ergogenic effect should be coupled with significant psychophysical benefits such as reduced ratings of perceived exertion and enhanced in-task affect. An extension of the present study would entail examining the impact of variable music tempo on performance. Specifically, music tempo can be linked to a desired pace so that the tempo fluctuates in accordance with desired work-rate. In relation to this, it would be useful to have more physiological data to complement the performance-related data that now exist to reveal the physiological mechanisms that underlie the synchronization effect. How do indices such as heart rate, oxygen uptake and blood lactate levels differ between synchronous and asynchronous applications of music?

A further extension of the present study would entail an examination of the interaction between pre-performance mood and 400-metre performance across music trials. This could be achieved through the use of mood-regulation strategies to standardise mood in order that one group of participants would have positive mood and another negative mood thus adding an additional between-subjects factor. This would facilitate an investigation of the degree to which mood moderates the impact of synchronous music on anaerobic endurance performance. Similarly, if mood measures were taken immediately post-performance, this would shed light on the mediating role that mood may have in the music-performance relationship (cf. Karageorghis *et al.*, 1999).

It appears that the application of synchronous music, in addition to being a recommended accompaniment for athletic training, is also potentially valuable in the domain of public health. The use of walking programmes with steadily increasing beats or analogous cycle/rowing ergometer programmes should be explored further. The health and fitness industry has become quite adept at exploiting the benefits of asynchronous music and music video, but the power of synchronous music is relatively untapped beyond the confines of aerobic dance exercise studios.

Finally, given that the dichotomy of motivational and oudeterous music was based on a conceptual model that addresses the antecedents and consequences of listening to asynchronous music (Karageorghis *et al.*, 1999), it appears timely and warranted for researchers to address in greater depth the theoretical premise underlying the use of synchronous music. Although we have explained the rather unexpected finding of a lack of difference between motivational and oudeterous music conditions predominantly in terms of the high workload associated with 400-metre sprinting, an equally plausible explanation is that the way in which the music was selected was not entirely appropriate for synchronous use. Thus, further theory development would shed light on issues specific to synchronous music and enable practitioners to tap its ergogenic properties with greater precision.

Conclusions

The present findings provided support for the first research hypothesis given that 400-metre sprint performance in synchrony with music was superior to performance with a no-music control condition. However, the second hypothesis was not supported, as performance to motivational synchronous music was not superior to that with oudeterous synchronous music. The findings complement a growing body of evidence suggesting that, at least with non-elite participants, synchronous music can engender a considerable ergogenic effect (Anshel and Marisi, 1978; Karageorghis and Jones, 2000). The major implication is that synchronous music, regardless of its motivational qualities, can enhance anaerobic endurance. The pacing effect could potentially be applied to a wide range of physical tasks to regulate effort exertion and to make such tasks more pleasurable. Future research should extend this line of enquiry to other rhythmic activities and assess whether the purported benefits of music apply equally to females and to elite athletes. Moreover, it would be potentially fruitful to explore the impact of varying music tempo in activities that vary in their intensity.

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Table 1 Descriptive statistics and ANOVA for 400-metre time trials (sec) under conditions of motivational music, oudeterous music and a no-music control

Condition	Std. Skew.	Std. Kurt.	Mean$\pm s$	$F_{1.24,42.19}$	Source of dif.	η_p^2
Motivational (A)	0.61	-1.62	72.27±1.39			
Oudeterous (B)	1.06	1.88	72.64±1.20	10.54**	A,B < C	.24
Control (C)	1.72	2.66*	72.95±1.24			

Note. Std. Skew. = standard skewness, Std. Kurt. = standard kurtosis, η_p^2 = partial eta squared. Greenhouse-Geisser adjustment was applied to the F test and Bonferroni adjustments were applied to the pairwise comparisons.

* $P < 0.01$, ** $P < 0.001$.