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Psychophysical and Ergogenic Effects of Synchronous Music During Treadmill Walking

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The present study examined the impact of motivational music and oudeterous (neutral in terms of motivational qualities) music on endurance and a range of psychophysical indices during a treadmill walking task. Experimental participants (N = 30; mean age = 20.5 years, SD = 1.0 years) selected a program of either pop or rock tracks from artists identified in an earlier survey. They walked to exhaustion, starting at 75% maximal heart rate reserve, under conditions of motivational synchronous music, oudeterous synchronous music, and a no-music control. Dependent measures included time to exhaustion, ratings of perceived exertion (RPE), and in-task affect (both recorded at 2-min intervals), and exercise-induced feeling states. A one-way repeated measures ANOVA was used to analyze time to exhaustion data. Two-way repeated measures (Music Condition × Trial Point) ANOVAs were used to analyze in-task measures, whereas a one-way repeated measures MANOVA was used to analyze the exercise-induced feeling states data. Results indicated that endurance was increased in both music conditions and that motivational music had a greater ergogenic effect than did oudeterous music ($p < .01$). In addition, in-task affect was enhanced by motivational synchronous music when compared with control throughout the trial ($p < .01$). The experimental conditions did not impact significantly ($p > .05$) upon RPE or exercise-induced feeling states, although a moderate effect size was recorded for the latter ($\eta_p^2 = .09$). The present results indicate that motivational synchronous music can elicit an ergogenic effect and enhance in-task affect during an exhaustive endurance task.

Keywords: asynchronous music, pace setting, aerobic efficiency, rhythm

Among the numerous initiatives aimed at tackling the prevalence of inactivity and obesity in contemporary Western society (e.g., Jain, 2004; Swinburn, Gill, & Kumanyika, 2005), the combination of music and physical activity has received serious consideration (Edworthy & Waring, 2006; Crust & Clough, 2006; Karageorghis, Jones, & Stuart, 2008; Szabo, Small, & Leigh, 1999). Accordingly, during the last decade, there has been a sharp increase in the number of studies

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examining the psychophysical and ergogenic effects of music in sport and exercise. This is evidenced by the small number of related studies ($k = 13$) cited in the review of Karageorghis and Terry (1997), which covered research conducted over the 25-year period since Lucaccini and Kreit's (1972) review. In the subsequent decade, at least 43 related studies have been published.

Relatively few studies have investigated the impact of *synchronous* music (Anshel & Marisi, 1978; Hayakawa, Miki, Takada, & Tanaka, 2000; Simpson & Karageorghis, 2006). The use of synchronous music entails the conscious performance of repetitive movements in time with the rhythmical elements of music such as beat or tempo (Simpson & Karageorghis). In selecting synchronous music, most researchers have discounted qualities of the music beyond its tempo and rhythmical structure. Accordingly, a key focus of the current study will be an examination of the motivational qualities of music in order to gauge whether the application of carefully selected music can confer benefits that exceed those elicited by the synchronization effect alone.

Researchers have consistently shown that synchronous music yields significant ergogenic effects in non–highly trained participants. Such effects have been demonstrated in bench stepping (Hayakawa et al., 2000), cycle ergometry (Anshel & Marisi, 1978), callisthenic-type exercises (Uppal & Datta, 1990), 400-m running (Simpson & Karageorghis, 2006), and in a multiactivity circuit task (Michel & Wanner, 1973). Independent of such research, there has been a wave of commercial activity focused on the development of walking programs that use synchronous music to engender health benefits (e.g., www.run2r.com) or as part of a cardiac rehabilitation program (e.g., www.positiveworkouts.com). Exercise prescriptions of this nature are made without an empirical or theoretical basis, and, in common with much of the previous research in this area, without due consideration of the motivational qualities of musical tracks.

One of the earliest and arguably best designed studies (Anshel & Marisi, 1978) compared synchronous and asynchronous (background) music using a cycle ergometer endurance task. Synchronous music yielded longer endurance than either asynchronous music or a no-music control ($d = 0.6$ for synchronous vs. control). However, the music was chosen somewhat arbitrarily from the "popular rock category" (p. 111) without any apparent consideration of the musical preferences and sociocultural background of the participants. In addition, a limitation acknowledged by the authors themselves was that a male experimenter tested female participants. This might well explain why female participants underperformed when compared with their male counterparts, despite the fact that both genders worked at relative workloads. In the current study, we sought to overcome this possible limitation by ensuring gender compatibility between participants and experimenters.

Motivational and Oudeterous Music Selections

Karageorghis, Terry, and Lane (1999) developed a conceptual framework to predict the motivational effects of asynchronous music and an associated measure of the motivational qualities of music known as the Brunel Music Rating Inventory (BMRI). They indicated that the main characteristics of motivational music are that it has a fast tempo (>120 beats per minute [bpm]) and strong rhythm, which increase energy and induce bodily action. They operationalized the term *oudeterous music* to describe music that lacks motivational qualities (*oudeterous* = "neutral" in Greek). A body of work has been built on this conceptual distinction with the aim of examining the psychophysical and ergogenic effects of music according to its motivational qualities (e.g., Crust & Clough, 2006; Elliott, Carr, & Orme, 2005; Elliot, Carr, & Savage, 2004; Karageorghis, Jones, & Low, 2006; Karageorghis et al., 2008; Simpson & Karageorghis, 2006). In such studies, the BMRI or its derivatives (e.g., BMRI-2; Karageorghis, Priest, Terry, Chatzisarantis, & Lane, 2006) have been used as a tool to select music for use in experimental trials. This procedure has added an objective component to the selection of music for experimental protocols that has enhanced the scientific rigor of experimental work.

The conceptual framework devised by Karageorghis et al. (1999) posited three main hypotheses, all of which are relevant to the current study. First, music can change psychomotor arousal levels and thus be used as either a stimulant or sedative (Bishop, Karageorghis, & Loizou, 2007; Karageorghis, Drew, & Terry, 1996). Second, music narrows attention and can reduce the awareness of bodily sensations of fatigue (cf. Rejeski, 1985). This results in lower ratings of perceived exertion (RPE) during low- and moderate-intensity exercise (Boutcher & Trenske, 1990; Szmedra & Bacharach, 1998). It is important to note that workload mediates psychophysical responses to external stimuli; therefore, music is hypothesized to be ineffectual at high exercise intensities (Tenenbaum, 2001). Third, music enhances positive mood dimensions such as happiness and vigor while reducing the negative dimensions such as anger, depression, and tension (Boutcher & Trenske; Edworthy & Waring, 2006; Hayakawa et al., 2000).

The Synchronization Effect

Reviewers have explained the synchronization between musical tempo and human movement in terms of the human predisposition to respond to the rhythmical qualities of music (Karageorghis & Terry, 1997; Lucaccini & Kreit, 1972). Ostensibly, musical rhythm can replicate natural movement-based rhythms. Wilson and Davey (2002, p. 177) noted that even when people sit motionless, "it is often very difficult to suppress the natural urge to tap the feet or strum the fingers along with the beat of the music." Moreover, musical rhythm relates to the various periodicities of human functioning such as respiration, heart beat, and walking (Bonny, 1987), the third of these being the focus of the current study.

In addition to the benefits associated with asynchronous (background) music detailed within the conceptual framework of Karageorghis et al. (1999), it has been proposed that the physiological mechanisms that underlie the ergogenic effects of synchronous music are related to a reduction in the metabolic cost of exercise by promoting greater neuromuscular or metabolic efficiency (Smoll & Schultz, 1978; Szmedra & Bacharach, 1998). To date, researchers have not examined the efficacy of walking synchronously to music despite the potential benefits of this mode of exercise for the general population. Similarly, no study has examined the psychophysical or ergogenic properties of motivational music vs. oudeterous music in this context. Such an investigation would make a potentially valuable contribution in terms of testing extant theory (Karageorghis et al., 1999; Karageorghis, Priest et al., 2006) and informing practice.

Purpose and Hypotheses

The purpose of the current study was to examine the effects of two experimental conditions, motivational synchronous music and oudeterous synchronous music, and a no-music control condition on four dependent measures: time to exhaustion, ratings of perceived exertion (RPE), in-task affect, and exercise-induced feelings states. Based on previous findings (Anshel & Marisi, 1978; Simpson & Karageorghis, 2006) and theoretical predictions (Karageorghis et al., 1999; Karageorghis, Priest et al., 2006), four hypotheses were tested: (a) Time to exhaustion would be highest in response to motivational synchronous music, second highest in the oudeterous synchronous music condition, and lowest in the no-music control condition; (b) at the first measurement point only, RPE would be lower in the motivational music condition when compared with the oudeterous music and control conditions; (c) in-task affect would be most positive during the motivational music condition up to the midpoint of the task whereas the oudeterous music condition would yield more positive in-task affect than the control also up to the midpoint; and (d) exercise-induced feeling states would be most positive following the motivational music condition whereas oudeterous music would yield more positive feeling states than the control.

Method

Ethical Approval

All procedures employed in this study were cleared in accordance with the published guidelines of the Brunel University Ethics Committee. Participants read an information sheet and were required to provide written informed consent before the commencement of testing.

Stage 1: Music Selection

Participants. A sample of 100 volunteer sports science undergraduates (50 women and 50 men, mean age = 20.5 years, *SD* = 1.5 years), who were Caucasian and brought up in the United Kingdom, were used to identify a pool of artists for use in the experimental protocol of Stage 2. Further, a music-rating panel was used to rate tracks by the artists who were identified as being most appropriate for Stage 2. This panel comprised four female and four male sports science undergraduates (mean age = 20.9 years, *SD* = 1.5 years). All participants involved in the music selection procedure matched the profile of the intended pool of experimental participants in terms of their age profile and sociocultural background (see Karageorghis & Terry, 1997).

Instrumentation. The music rating panel used the BMRI-2 (Karageorghis, Priest et al., 2006) to rate the motivational qualities of the music selections. The BMRI-2 is a redesigned version of the original BMRI (Karageorghis et al., 1999), which assesses the motivational qualities of music. Each BMRI-2 item refers to an action, a time, a context, and a target (e.g., "the style of this music [i.e., rock, dance, jazz, hip-hop, etc.] would motivate me during exercise") (Ajzen & Fishbein, 1977). It is a single-factor, six-item instrument that has demonstrated psychometric properties superior to those of its predecessor. Participants respond on a 7-point Likert scale anchored by 1 (*strongly disagree*) and 7 (*strongly agree*). The mean Cronbach alpha coefficient reported by the authors for the single factor was .89.

Music Selection Procedure. The 100 undergraduate participants were requested to give the names of three preferred music artists who were associated with music that would be appropriate for an exercise task. Subsequently, the most frequently mentioned artists were used by the authors to make specific track selections for the music rating panel. The criteria for these selections were based on the five recommendations of Karageorghis, Priest, et al. (2006, p. 907). In addition, to be appropriate for the synchronous walking task, tracks had to be in the tempo range 113–137 bpm. This ensured that when tracks were recorded, mixed, and standardized at a tempo of 125 bpm, there would be no discernable attenuation in the fidelity of sound.

To give experimental participants a choice of musical idiom for the treadmill walking task, 30 rock and 30 pop selections that met the entry criteria were played to the music-rating panel to establish appropriate selections for the motivational and oudeterous music conditions. The BMRI-2 was administered to members of the panel and they were asked to rate the motivational qualities of the music with reference to the demographic profile of the intended participant pool and experimental task.

Participants heard a 90-s excerpt of each track that included at least one verse and one chorus (see Gluch, 1993). The music was delivered in a laboratory using a CD player (CD-A500; Tascam, Tokyo, Japan) and wall-mounted speakers (Control Pro Mk 1; JBL, Château du Loir, France). Music intensity was standardized at 65 dB at ear level using a decibel meter (GA 102 Sound Level Meter Type 1; Castle Associates, Scarborough, UK). Participants were seated 1 m apart in a semicircular formation and given 30 s to rate each of the 60 tracks.

The nine highest rated pop and rock tracks were used for the motivational music, whereas the nine lowest rated rock and pop tracks were used for the oudeterous music condition. (Details of the 18 tracks used in the experimental phase of this study can be requested from the first author.) To confirm that the motivational and oudeterous selections differed in terms of their motivational quotients and that the two idioms did not, a 2 (Motivational Qualities) × 2 (Idiom) repeated-measures ANOVA was computed and this confirmed that there were significant differences for the motivational quotients of the music (motivational vs. oudeterous; $F[1, 8] = 23{,}997.37$, $p < .001$, $\eta_p^2 = 1.00$), but not between the two idioms (pop vs. rock; $F[1, 8] = 0.02$, $p > .05$, $\eta_p^2 = .002$).

Stage 2: Experimental Investigation

Power Analysis. A power analysis was conducted to establish appropriate sample size. With alpha set at .05 and power at .80 to protect beta at four times the level of alpha (Cohen, 1988) and based on an estimated large effect size for the effect of synchronous music when compared with a no-music control (η_p^2 = .24; Simpson & Karageorghis, 2006), it was calculated that approximately 25 participants would be required.

Participants. To account for experimental dropout, noncompliance with the specifics of the protocol, and multivariate outliers, 30 volunteer participants—15 women (mean age = 20.3 years, *SD* = 0.8 year) and 15 men (mean age 20.9 years, *SD* = 1.1 years)—were selected from the body of sports science undergraduates at Brunel University. Participants were Caucasians brought up in the United Kingdom. They were drawn from running-based sports such as field hockey, rugby union, and soccer to maintain some homogeneity in terms of their aerobic fitness and suitability for the experimental task of treadmill walking to exhaustion. Only out-field players were used from team sports (i.e., no goalkeepers).

Apparatus and Instrumentation. A treadmill (GXC200; Powerjog, Brigend, UK) was used for testing along with the CD player/speakers and decibel meter used in Stage 1. A white overhead projector screen (1.72 m × 1.82 m; Miralyte; Harkness Screens Ltd., Fredericksburg, VA) was positioned immediately in front of the treadmill to ensure that the experimental environment was visually sterile. Music intensity was standardized at 75 dB (ear level), which is safe from an audiological perspective (see Alessio & Hutchinson, 1991) and sufficiently loud so as not to be obscured by the noise of the treadmill. A target heart rate (HR) of 75% of maximum heart rate reserve (maxHRR) was assessed by means of a HR monitor (FS 1; Polar, Kempele, Finland) attached to the chest of each participant and sensor held by the experimenter. A hand-held stopwatch (Triax 26; Nike, Eugene, OR) was used in each phase of the study.

Time to exhaustion was measured using a hand-held stopwatch from the point that participants reached 75% maxHRR until voluntary exhaustion. Heart rate was measured every 2 min using a HR monitor as this was deemed to be the most valid nonintrusive measure of work intensity. Specifically, HR measures were used as a manipulation check to ensure that participants worked at the predesignated level of intensity (75% maxHRR) and reached exhaustion in each of the three conditions.

Ratings of perceived exertion was assessed verbally every 2 min using the 11-point version of the RPE scale with ratio properties (Børg, 1982), which ranges from 0 (*nothing at all*) to a 10 (*very very hard*), followed by a dot (•) at *maximal*. The validity of the scale in terms of its correlation with standard physiological indices (e.g., blood lactate, oxygen uptake, and respiratory exchange ratio) has been satisfactorily demonstrated (r = .80 to .95; Børg). The scale has also been shown to have both high intratest (r = .93) and retest (r = .83 to .94) reliability (Børg, 1998).

In-task affect was measured using Hardy and Rejeski's (1989) bipolar Feeling Scale, which was designed specifically for exercise. This is an 11-point single-item scale ranging from +5 (*very good*) to −5 (*very bad*) with a midpoint of 0 (*neutral*). The validity of the Feeling Scale was demonstrated by its authors in a series of three studies. Specifically, the single affect dimension (positive vs. negative) was validated using a discriminant function analysis: The positive affect subscale of the Multiple Affective Adjective Checklist (Zuckerman & Lubin, 1985) was used to discriminate with 95.2% accuracy between two matched groups of participants who were instructed to check adjectives associated with either "good" or "bad" feeling states. The Feeling Scale also demonstrated negative correlations with HR ($r = -.70$; $p < .05$), respiratory rate ($r = -.62$; $p < .05$), and oxygen uptake ($r = -.69$; $p < .05$) at various exercise intensities.

Postexercise feeling states were assessed using Gauvin and Rejeski's (1993) Exercise-induced Feeling Inventory (EFI). This 12-item instrument was developed to access four subjective states that occur in conjunction with acute bouts of physical activity, namely, positive engagement (e.g., "happy"), revitalization (e.g., "refreshed"), tranquility (e.g., "peaceful"), and physical exhaustion (e.g., "tired"). Responses are provided on a 5-point Likert scale anchored by 0 (*do not feel*) and 4 (*feel very strongly*). Gauvin and Rejeski reported satisfactory psychometric properties for the EFI, which included the following Cronbach alpha coefficients: revitalization = .77, tranquility = .78, positive engagement = .72, and physical exhaustion = .81. Moreover, Karageorghis, Vlachopoulos, and Terry (2000) reported satisfactory psychometric properties for the EFI in an exercise-to-music context.

Music Selection Procedure. Experimental participants were asked to select either the rock or the pop idiom for the two music conditions and were not permitted to switch between these idioms following their initial choice. Although tracks in the two music conditions differed significantly ($p < .001$) in terms of their motivational qualities, their tempi were digitally altered to 125 bpm using a computer software package (DJ Twist & Burn v. 1.01; Acoustica, Oakhurst, CA). During a pilot trial of the experimental protocol, it was established that this tempo corresponded with a suitable stride rate for treadmill walking for the intended pool of participants.

Pretest and Habituation Trial. It was necessary for participants to walk on a treadmill at a velocity that would elicit an exercise intensity of 75% maxHRR. Through piloting, this was established as an appropriate intensity for three reasons: (1) it was the highest intensity at which a synchronous walk could be consistently maintained without forcing participants to run and thus compromise the synchronous nature of the task, (2) to assess psychophysical responses to music in the early stages of the task without requiring participants to work at intensities involving significant anaerobic contribution to the overall energy expenditure. Music is much less effective as a dissociation tool at high exercise intensities owing to the preeminence of physiological cues (Boutcher & Trenske, 1990; Rejeski, 1985; Tenenbaum et al., 2004), and (3) it was likely to allow participants to engage in each trial for at least 8 min but not to continue beyond 30 min. Earlier piloting of the protocol indicated that there was much greater variability in endurance times even at marginally lower intensities.

To establish participants' maximal HR, they were required to complete a Bruce protocol (Bruce, Blackman, Jones, & Strait, 1963). The protocol entails increases in treadmill velocity and incline every 3 min until the participant reaches voluntary exhaustion. To confirm that voluntary exhaustion was reached, HR and RPE measures were taken in each stage. At the point that participants indicated that they had reached a point of exhaustion, maximal HR and RPE measures were recorded. Without exception, participants reached the end of Børg's (1982) scale (i.e., "maximal") at the point of voluntary exhaustion.

The mean maximal HR obtained was 198.64 bpm (*SD* = 6.2 bpm) indicating that, overall, participants had reached their maximal aerobic power. In calculating the exercise HR of 75% maxHRR that would be required in each of the three conditions, HRR was established (see McArdle, Katch, & Katch, 2001) by application of the Karvonen formula (Karvonen, Kentala, & Mustala, 1957). In addition, V_{O2max} was predicted from the results of the Bruce protocol, and this was used to determine the starting treadmill gradient for each participant in the experimental phase of the study.

The second stage involved habituating each participant to the treadmill walking task and this occurred a week after administration of the Bruce protocol. The treadmill gradient, rather than its velocity, was altered to increase exercise intensity. The rationale for this procedure was to enable all participants to synchronize their stride rate with music played at 125 bpm. Participants spent approximately 20 min on the treadmill during the habituation trial, during which they walked at 75% maxHRR, had the experimental protocol explained to them, and were afforded an opportunity to ask questions.

Experimental Trial. There were two experimental conditions and one control condition scheduled at the same time of day for each participant over consecutive weeks. Conditions consisted of walking at 75% maxHRR during synchronous motivational music, synchronous oudeterous music, and a no-music control. Participants were required to follow identical patterns of activity and diet, and not to engage in other vigorous physical activity before the trial on each test day. Further, they were asked to refrain from eating a meal within the 2 hr before testing. The order of conditions was randomized for each participant and they engaged in the experiment individually in the presence of a same-sex experimenter (cf. Anshel & Marisi, 1978).

At the first test session, participants were given a choice of either rock or pop music derived from the artists earlier rated by their peers as being the most appropriate. These included the performers Bon Jovi, Queen, and Red Hot Chili Peppers (rock) and Madonna, Michael Jackson, and Nelly Furtado (pop). Participants were asked to stretch in preparation for the treadmill walking task, and, while on the treadmill, they were instructed to look straight ahead at the large white screen.

Participants performed a 2-min warm-up at a speed of 3.0 kph (kilometers per hour) with no music and at an incline that was determined by their predicted V_{O2max}. The starting inclines were based on performance in the Bruce protocol with three possible inclines for each gender: women—12.0%, 12.5%, and 13.0%; men—12.5%, 13.0%, and 13.5%. Following warm-up, the music was initiated and participants walked at a constant 6.0 kph for the duration of the experimental test until exhaustion. The treadmill gradient was raised gradually until participants reached target HR and maintained it for 1 min. In addition, in the experimental trials, participants were instructed to keep their stride rate in synchrony with music tempo so that the foot of their dominant leg came into contact with the treadmill belt in time with the first beat of each bar. All musical selections were composed in *common time* (i.e., four crotchet [quarter-note] beats to the bar, or 4/4).

Following 1 min of steady-state synchronous walking at 75% maxHRR, timing of endurance began using the hand-held stopwatch, participants' HR was recorded, and an experimenter administered the RPE and Feeling State scales.

Ratings of perceived exertion and in-task affect were subsequently recorded every 2 min until voluntary exhaustion. Heart rate was also assessed at 2-min intervals to monitor work intensity. After a 2-min warm-down on the treadmill, participants were offered a drink and then administered the EFI. The total time spent by each participant on the treadmill during each experimental trial ranged from 7:33 to 31:00 min. Participants were debriefed as to the precise purpose of the study once all data had been collected.

Data Analysis

The data were screened for univariate outliers using z scores > ±3.29 and, where relevant, for multivariate outliers using the Mahalanobis distance method with $p < .001$ (Tabachnick & Fidell, 2007). These procedures were completed for each separate analysis and for each cell within each analysis. In addition, relevant checks were made to ensure that the data were suitable for parametric analysis. A one-way repeated-measures ANOVA was applied to endurance time data. Because participants endured the treadmill task for different lengths of time, to facilitate analysis of the in-task data (RPE and affect), means were computed for three points in the trial: 2 min after the start, the midpoint measurement, and 2 min before voluntary exhaustion. Two-way repeated measures 3 × 3 (Music Condition × Trial Point) ANOVAs were applied to RPE, in-task affect, and HR data. The HR ANOVA was used as a manipulation check; therefore, an additional trial point was used at voluntary exhaustion to facilitate this. A one-way repeated-measures MANOVA was applied to EFI subscale scores.

Results

Upon initial examination of the results, it was evident that two participants (one woman and one man) had not followed instructions and had ceased walking when working at only a moderate intensity (RPE of 5 and 6 respectively). Consequently, these participants' data were not included in further analyses. Checks for outliers revealed multiple univariate outliers for two cases (both men), which were also deleted from the data set. Tests of the distributional properties of the data in each cell of each analysis revealed violations of normality in 3 of the 33 cells (9.1%; all at $p < .05$). However, ANOVA and MANOVA are sufficiently robust to deal with such minor deviations from normality (Keppel & Wickens, 2004).

Interaction Effects

The interaction of Music Condition × Trial Point for RPE was nonsignificant, $F(4, 100) = 1.44$, $p > .05$, $\eta_p^2 = .05$, as was the same interaction for in-task affect, $F(4, 100) = 2.24$, $p > .05$, $\eta_p^2 = .08$. The Music Condition × Trial Point interaction for HR indicated no differences, $F(6, 150) = 1.62$, $p > .05$, $\eta_p^2 = .06$.

Main Effects

There was a main effect for music condition on endurance time, $F(1.62, 40.44) = 15.13$, $p < .001$, $\eta_p^2 = .38$, with this accounting for 38% of the variance. Pairwise comparisons revealed differences between motivational synchronous and oudeterous synchronous conditions, motivational and control conditions, as well as oudeterous and control conditions (see Table 1 and Figure 1).

There was a main effect for trial point on RPE, $F(2, 50) = 230.31$, $p < .001$, $\eta_p^2 = .90$; as expected, RPE increased significantly at each measurement point through the trial (see Table 2). There was a main effect for music condition on in-task affect, $F(2, 50) = 6.33$, $p < .01$, $\eta_p^2 = .20$, with music condition accounting for 20% of the variance. Pairwise comparisons indicated that the only significant ($p < .01$) difference was between the motivational synchronous and no-music conditions. There was also a main effect for trial point on in-task affect, $F(1.24, 31.09) = 180.31$, $p < .001$, $\eta_p^2 = .88$; as expected, in-task affect decreased significantly at each measurement point through the trial (see Table 2).

There were no differences in HR across conditions, indicating that participants worked at comparable levels, $F(1.98, 40.49) = 1.15$, $p > .05$, $\eta_p^2 = .04$. There was also no main effect in the repeated-measures MANOVA used to analyze the four EFI subscales, Wilks's $\Lambda = .84$, $F(8, 94) = 1.09$, $p > .05$, $\eta_p^2 = .09$.

Discussion

The main aim of the current study was to investigate the effects of motivational and oudeterous synchronous music on time to exhaustion, RPE, and in-task affect during a treadmill walking task, and exercise-induced feelings states immediately after the task. Results indicated that the music conditions impacted significantly only upon time to exhaustion ($p < .001$) and in-task affect ($p < .01$). Although the MANOVA used to analyze exercise-induced feeling states yielded nonsignificant ($p > .05$) omnibus statistics, the experimental manipulation was associated with a moderate effect size ($\eta_p^2 = .09$). As expected, the HR manipulation check did not reveal any differences, indicating that participants worked at comparable levels across conditions. Moreover, HR reached ~193 bpm at the end of each trial, thus confirming that participants worked to a point very close to physical exhaustion (~199 bpm). The findings for task endurance were in the expected direction and in accordance with theoretical predictions (see Karageorghis et al., 1999) in that motivational music led to the greatest endurance and the oudeterous music to lesser endurance, whereas the no-music condition elicited the least endurance; therefore, Hypothesis "a" was accepted. Notably, the music manipulation accounted for 38% of the variance in endurance time, thus underlining the significance of this stimulus as a potential ergogenic aid in walking performance. Moreover, the motivational music elicited a 15% increase in treadmill endurance over control and a 6% increase over oudeterous music. The effect size reported herein for task performance is much larger than that reported in an earlier study ($\eta_p^2 = 0.24$; Simpson & Karageorghis, 2006), which employed a similar design but examined a short-duration activity (400-m running).

Research Hypothesis "b," pertaining to RPE, was refuted given that at the first measurement point, the expected Condition × Trial Point interaction did not emerge (see Table 2). However, this analysis was underpowered (observed power = .43), which is a factor likely to have prevented the interaction from reaching statistical significance. Past research has indicated that asynchronous music reduced RPE by ~10% over a no-music control during submaximal exercise (e.g., Nethery, 2002; Potteiger, Schroeder, & Goff, 2000; Szmedra & Bacharach, 1998)

Table 1 Descriptive Statistics, Repeated-Measures ANOVA for Endurance Time, and Repeated-Measures MANOVA for Exercise-induced Feeling Inventory (EFI) Subscales

Dependent Variables	Condition	*M*	*SD*	*F* ratio (*df*)	η_p^2
Endurance (min)	Motivational music	17.84	7.20		
	Oudeterous music	16.84	6.64	15.13** (1.62, 40.44)	.38
	No-music control	15.56	5.93		
Revitalization	Motivational music	4.23	2.78		
	Oudeterous music	4.50	3.25	1.18 (2, 50)	.05
	No-music control	3.73	3.42		
Tranquility	Motivational music	5.35	2.46		
	Oudeterous music	5.62	2.04	3.75* (2, 50)	.13
	No-music control	4.54	2.44		
Positive engagement	Motivational music	5.88	2.39		
	Oudeterous music	5.85	3.07	2.12 (2, 50)	.08
	No-music control	5.00	2.64		
Physical exhaustion	Motivational music	8.81	2.79		
	Oudeterous music	8.77	2.41	.00 (2, 50)	.00
	No-music control	8.77	2.79		

EFI omnibus statistics: Wilks's $\Lambda = 0.84$, $F(8, 94) = 1.09$, $p > .05$, $\eta_p^2 = .09$

Note. The *F* test for endurance was subjected to Greenhouse–Geisser adjustment. η_p^2 = partial eta squared.
$^*p < .05$. $^{**}p < .001$.

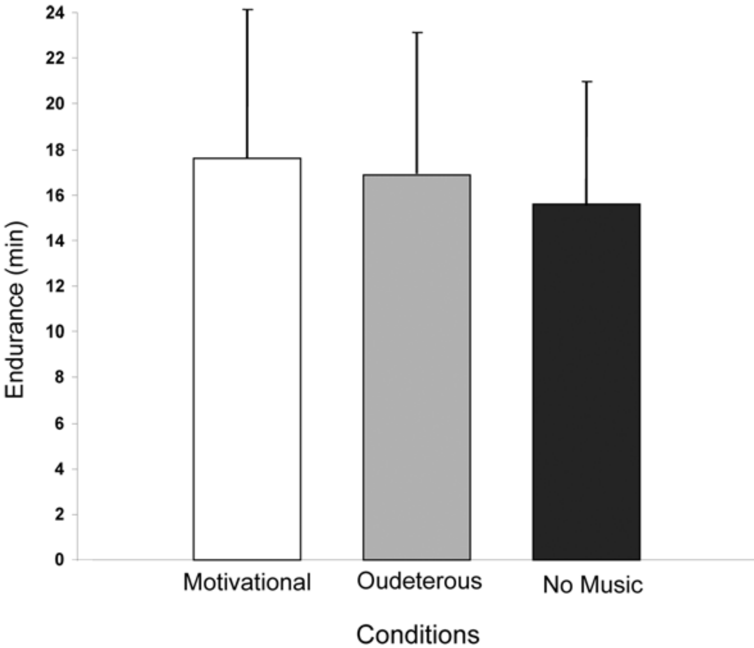

Figure 1 — Means and *SD*s for treadmill walking endurance under conditions of synchronous motivational music, synchronous oudeterous music, and a no-music control.

but not at high or close-to-maximal intensities (Boutcher & Trenske, 1990; Schwartz, Fernhall, & Plowman, 1990; Tenenbaum et al., 2004). In the current study, the means for RPE at the first point of measurement (see Table 1) indicate that the benefit derived from walking in synchrony with motivational music, when compared with control, was 19%. At the midpoint, the benefit was reduced to only 3%, which is indicative of the attentional switching that is induced by high-intensity exercise (Rejeski, 1985). It is also plausible that the attentional capacity required to maintain synchronous movement during the onset of fatigue contributed to the nonsignificance of the interaction effect. In the use of synchronous music, there may be an additive effect associated with reductions in RPE through *active* (keeping movements in time) and *passive* (music listening) attentional manipulation (cf. Johnson & Siegel, 1987).

The nonsignificant interaction for in-task affect indicates that Hypothesis "c" should be refuted. However, close examination of the results (see Table 1) shows that the main effect for music condition was so strong ($\eta_p^2 = .20$) that it may have obscured the expected interaction effect ($p = .07$; $\eta_p^2 = .08$; observed power = .64). Ostensibly, the motivational music enhanced in-task affect throughout the entire duration of the task and not only until the midpoint as was hypothesized. This supports the notion that although music may not moderate *what* one feels during high-intensity exercise, it can moderate *how* one feels it (cf. Hardy & Rejeski, 1989). Despite the fact that music cannot reduce RPE at high exercise intensities, it is possible that if the motivational qualities are sufficiently high, the

Table 2 Descriptive Statistics and Repeated-Measures ANOVA for In-task Measures (RPE and Affect)

		2 min after start		Trial midpoint		2 min before end	
Dependent Measure	**Condition**	***M***	***SD***	***M***	***SD***	***M***	***SD***
RPE	Motivational music	2.46	1.39	5.48	1.62	8.50	1.27
	Oudeterous music	2.88	1.14	5.75	1.17	8.50	1.14
	No-music control	3.04	1.61	5.63	1.62	8.38	1.42
Affect	Motivational music	2.42	2.14	–.12	1.97	–3.04	1.19
	Oudeterous music	1.55	1.82	–.67	1.30	–3.38	1.17
	No-music control	1.38	2.00	–1.46	1.39	–3.42	1.30
Music Condition × Measurement Point interaction effects:							
RPE	$F(4, 100) = 1.44, p > .05, \eta_p^2 = .05$						
Affect	$F(4, 100) = 2.24, p > .05, \eta_p^2 = .08$						
Music Condition main effects:							
RPE	$F(2, 50) = 0.58, p > .05, \eta_p^2 = .02$						
Affect	$F(2, 50) = 6.33, p < .001, \eta_p^2 = .20$						
Measurement Point main effects:							
RPE	$F(2, 50) = 230.31, p < .001, \eta_p^2 = .90$						
Affect	$F(1.24, 31.09) = 180.31, p < .001, \eta_p^2 = .88$						

Note. The *F* test for the measurement point main effect for in-task affect was subjected to Greenhouse–Geisser adjustment. η_p^2 = partial eta squared.

music may temper the potentially negative impact of high-intensity exercise on affect (Boutcher & Trenske, 1990; Elliott et al., 2004).

Rejeski (1985) posited that, at higher exercise intensities, the response to an affective stimulus such as music is attenuated by the internal feedback with which it competes. Notably, the present findings counter his prediction inasmuch as motivational music impacted significantly upon in-task affect throughout an *exhaustive* endurance task (see Table 2). The implication is that the affective response to music might be more powerful than is currently thought. A further possibility is that such results may be specific to the walking modality as opposed to other exercise modalities such as running, which may have different attentional demands (Tenenbaum et al., 2004).

It is apparent that although fatigue-related symptoms predominate attentional processing at high intensities, appropriate music can make the interpretation of such symptoms more positive (cf. Karageorghis, Jones et al., 2006). The next part of the research question was whether the positive influence of music played during the task would have an impact upon the appraisal of exercise-induced feelings immediately after the task. Omnibus statistics indicated that the EFI scores did not differ significantly in response to experimental conditions; therefore, Hypothesis "d" was refuted.

The motivational qualities of the music did not impact at all upon how participants felt after the task. Nonetheless, the nonsignificant omnibus statistics appear to be attributable to the physical exhaustion subscale of the EFI, on which scores were invariant across conditions (see Table 1); this was possibly because participants worked to exhaustion, which rendered the music inconsequential in terms of how fatigued they felt. An examination of mean scores for revitalization, tranquility, and positive engagement (see Table 1) indicates that the two experimental conditions consistently yielded higher means than the control condition.

Limitations of the Present Study

One of the main limitations that affected the current study and indeed past work examining the effects of synchronous music (e.g., Anshel & Marisi, 1978; Hayakawa et al., 2000; Simpson & Karageorghis, 2006) concerned the participants' ability to maintain strict time with musical tempo. On occasion, participants required prompting from an experimenter to ensure that the foot of their dominant leg came in contact with the treadmill on the first beat of each bar. In addition, participants endured the treadmill walking task for vastly differing lengths of time. Endurance time ranged from 7:33 to 31:00 min, which is indicative of participants' differing levels of aerobic fitness or task motivation or both. This potential threat to internal validity could be overcome through the use of participants who are more homogeneous in terms of their aerobic fitness. However, this would in turn restrict the generalizability of any subsequent findings.

It was apparent from the results supplementing the main analyses that the analyses for some variables were underpowered, in particular, the Music Condition $\times$ Trial Point interaction for RPE (observed power = .43) and the music condition main effect for the EFI subscales (observed power = .48). In addition, it is acknowledged that the present exercise intensity of 75% maxHRR was at the upper level of the range at which music is likely to exert any influence on RPE (Rejeski, 1985; Tenenbaum, 2001).

Another limitation evident in the analyses was the inclusion of physical exhaustion, on theoretical grounds (see Gauvin & Rejeski, 1993), with the remaining EFI subscales in a multivariate analysis. The use of an exhaustive task resulted in no variability in physical exhaustion across conditions, which meant that it obscured the impact of synchronous music on the exercise-induced feeling states composite variable. It may have been more advantageous to employ measures based on the circumplex model of affect (Russell, 1980) to be consistent with the in-task measure of affect used.

Moreover, the EFI has been subject to some criticism on account of lacking a clear theoretical underpinning and the questionable rigor with which its content validity was established (Ekkekakis & Petruzzello, 2001). Gauvin and Rejeski (2001) issued a defense of the instrument based partly on the relative simplicity of the circumplex model of affect that was advocated by Ekkekakis and Petruzzello, the strong psychometric properties of the EFI, and its extensive use by exercise psychology researchers. However, Ekkekakis and Petruzzello (2004) defended their initial criticisms, and doubts over the validity of the EFI remain.

Practical Implications of the Present Findings

The present findings illustrate the potential benefits associated with walking in time to a musical tempo and provide strong support for the adoption of this modality of exercise; notably, the commercial programs currently available are not grounded in empirical evidence. The key message for exercise practitioners is that the motivational qualities of music have considerable bearing on how long participants might endure a repetitive activity and their feelings during the task. However, the present findings also suggest that these motivational qualities do not significantly affect how participants might feel *after* a bout of exercise.

If the increased endurance attributable to the synchronous use of motivational music were to accrue over time, it would be likely to lead to improvements in aerobic fitness and greater energy expenditure. Such improvements would be above and beyond those accrued during walking without musical accompaniment or walking to music devoid of strong motivational qualities. This training effect is notwithstanding the additional influence that music may promote in terms of enhanced exercised adherence by dint of improvements in positive affect (Boutcher & Trenske, 1990; Elliott et al., 2004).

The present findings are particularly noteworthy for public health practitioners given that walking is a popular form of exercise that is often incorporated into the rehabilitation programs of those in a primary care setting (e.g., cardiac patients and those suffering from obesity). Hence, motivational synchronous music may serve as an important tool to underpin current initiatives of Western governments to improve public health and lessen the financial burdens on public health services.

Conclusions and Recommendations

Findings of the current study indicate that although the motivational qualities of synchronous music appear to have a strong influence on work output and how one feels during exercise, they have no effect on exercise-induced feeling states. There was no carry-over effect associated with motivational music, which may be due in part to the limitations in the EFI identified by Ekkekakis and Petruzzello (2001, 2004). The use of measures of affect that correspond with each other—for example, those based on the circumplex model (Russell, 1980)—both during and after an exercise task would provide a more coherent assessment of affect.

Given the consistently positive findings associated with use of synchronous music in the laboratory, it is timely for researchers to extend their investigations to real-life situations such as walking in parkland or while watching music videos. Such investigations might also address differences in perceived exertion between submaximal synchronous and asynchronous applications of music as the present findings indicate that synchronous music may be more effective in regulating this variable at a moderate workload.

To isolate the specific effects of synchronizing movement to music as opposed to other forms of temporal stimuli, future studies might include a visual stimulus such as a flashing light or an auditory stimulus such as a metronome in addition to a no-music control. A measure of attention could also be added to facilitate investigation of how participants with different attentional styles respond to music; indeed, it has been postulated that dissociators are more likely than associators to derive benefit from external attentional stimuli (Morgan & Pollock, 1977). Such work would be facilitated by the development of a conceptual framework oriented specifically toward the use of synchronous music.

Finally, researchers can build on the present findings by attempting to assess the effects of motivational synchronous music in a primary or secondary care setting (e.g., a physiotherapy or cardiac clinic). Such a progression would test the robustness of the current findings in an externally valid setting and thus form a bridge between the scientific work being undertaken and the practical benefits that may be reaped through the judicious use of motivational music in society at large.

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