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Psychological, Psychophysical, and Ergogenic Effects of Music in Swimming

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Highlights

- We assess the effects of asynchronous music in a swimming time trial.
- We had two contrasting music conditions and a no-music control.
- Participants swam significantly faster when exposed to either music condition.
- Both music conditions led to significantly higher state motivation.
- Use of asynchronous music had an ergogenic effect in the order of 2%.

Abstract

Objectives: Existing work using dry land exercise-related activities has shown that the careful application of music can lead to a range of benefits that include enhanced affect, lower perceived exertion, greater energy efficiency, and faster time trial performances. The purpose of this study was to assess the psychological, psychophysical, and ergogenic effects of asynchronous music in swimming using a mixed-methods approach.

Design: A mixed-model design was employed wherein there was a within-subjects factor (two experimental conditions and a control) and a between-subjects factor (gender). The experimental component of the study was supplemented by qualitative data that were analysed using inductive content analysis.

Methods: Twenty six participants ($M_{\text{age}} = 20.0$ years, age range: 18–23 years) underwent a period of habituation with Speedo Aquabeat MP3 players prior to the experimental phase. They were then administered two experimental trials (motivational and outdeterous music at 130 bpm) and a no-music control, during which they engaged in a 200-m freestyle swimming time trial.

Results: Participants swam significantly faster when exposed to either music condition relative to control ($p = .022$, $\eta_p^2 = .18$). Moreover, the music conditions were associated with higher state motivation ($p = .016$, $\eta_p^2 = .16$) and more dissociative thoughts ($p = .014$, $\eta_p^2 = .16$).

Conclusions: Findings supported the hypothesis that the use of asynchronous music during a high-intensity task can have an ergogenic effect; this was in the order of 2% when averaged out across the two experimental conditions. The use of music, regardless of its motivational qualities, resulted in higher self-reported motivation as well as more dissociative thoughts.

Keywords: Anaerobic endurance, affect, asynchronous music, entrainment, exercise psychology

Music use is widespread in the sport and exercise domain and advances in underwater MP3 player technology have led to its burgeoning popularity in swimming and other water-based activities. A lineage of work has assessed the psychological, psychophysical, and ergogenic effects of music in a range of dry land activities that include 400-m running (Simpson & Karageorghis, 2006), cycle ergometry (Anshel & Marisi, 1978), indoor rowing (Rendi, Szabo, & Szabó, 2008), treadmill walking (Karageorghis et al., 2009), and long-distance running (Terry, Karageorghis, Mecozzi Saha, & D'Auria, 2012). Psychological effects relate to how music influences mood, affect, emotion, attitudes, cognition, and behavior. Psychophysical effects concern the reduction of perceptions of physical effort, which, in the music-related literature, are most often assessed using ratings of perceived exertion (RPE). Ergogenic effects relate to the use of music to improve physical performance by either delaying fatigue or increasing work capacity; this results in higher-than-expected levels of endurance, power, productivity, or strength (see Terry & Karageorghis, 2011).

Extant work has shown that music use is not effective for some people under certain circumstances (e.g., while learning new skills) and might even be contraindicated in some instances (e.g., when it might distract users from safety-relevant information, such as on public roads; see Karageorghis & Priest, 2012a, 2012b for a review). Also, a “vitamin model” wherein a particular piece of music can be prescribed to engender certain perceptual, cognitive, or emotional responses in a listener, does not apply to this field of scientific endeavour (Sloboda, 2008). There are multiple considerations that researchers need to take into account when selecting music and these include socio-cultural, task-related, and personal factors (see e.g., Karageorghis & Terry, 1997; North & Hargreaves, 2008). Much of the preliminary work in this field was characterized by a lack of sensitivity to such factors; music was viewed in a manner akin to any other auditory stimulus wherein little consideration was given to its aesthetic qualities (e.g., Anshel & Marisi, 1978; Boutcher & Trenske, 1990).

Unsurprisingly then, such early research yielded a string of equivocal results.

Early work was also characterized by an atheoretical approach which led Karageorghis and his associates to develop a conceptual framework and an assessment tool – the Brunel Music Rating Inventory – through which the motivational qualities of music could be standardized for experimental tasks (see Terry & Karageorghis, 2011 for a review). The scope of the first conceptual framework (Karageorghis, Terry, & Lane, 1999) was limited to the *asynchronous* application of music. This is relevant to the present study and concerns the use of music without a performer's conscious effort to synchronize their movements with the rhythms of that music. The framework encompassed four factors arranged in a hierarchical order that were thought to contribute to the motivational qualities of a piece of music: *rhythm response*, *musicality*, *cultural impact*, and *association*. Rhythm response and musicality denote auditory properties of music and were thus termed *internal factors*, whereas cultural impact and association pertain to social and cultural influences on our interpretation of music and were thus termed *external factors*.

The framework indicated that the main benefits associated with the asynchronous use of music were arousal regulation, reductions in RPE, and enhanced mood. It has received broad support in the literature (e.g., Atkinson, Wilson, & Eubank, 2004; Crust, 2008) and was modified by Terry and Karageorghis (2006) to include a range of additional benefits that came to light during the period from 1999 to 2006 (e.g., dissociation, flow experience, and enhanced work output). The 2006 framework also embraced the *synchronous* application of music wherein there is a conscious effort by the athlete/exerciser to synchronize their movements with the rhythmical qualities of music.

High-intensity activity with asynchronous music

A number of studies have examined the application of music during high-intensity activities and a range of benefits have been associated with both the asynchronous and

synchronous applications of music. For example, Tenenbaum et al. (2004) used asynchronous music conditions of rock, dance, and “inspirational music” in apposition to a no-music control. These conditions did not impact upon endurance or perceptions of exertion during a high-intensity running task that was conducted on both a treadmill and on a cross-country course. The authors reasoned that the high intensity of the running tasks prevented participants from being able to derive benefit from the musical accompaniment. Nonetheless, relatively little attention was given to the selection of the music used.

Numerous studies have used cycle ergometer tasks in examining the effects of music. For example, Atkinson et al. (2004) played trance music to their participants while they engaged in a 10-km time trial and reported that it had an ergogenic effect during the first 3 km when perceptions of exertion were relatively low. RPE was higher during the music condition, which might be attributed to the fact that participants achieved finish times that were, on average, 22 s faster with music. Along similar lines, Hutchinson et al. (2011) administered a motivational music condition during a Wingate anaerobic cycle ergometer test and found that it increased peak and mean power relative to the control, while also positively influencing affect and self-reported state motivation.

Employing a 500-m rowing time trial, Rendi et al. (2008) reported that the fastest times were observed when participants listened to a fast-tempo excerpt from Beethoven’s 7th symphony. Interestingly, a slow-tempo excerpt from the same symphony also resulted in faster completion times when compared to the control condition. Participants in this study reported that they had not previously used music in training; this may have elicited a novelty effect indicating the need for a habituation period. One recent study examined the effects of music on swimming using underwater MP3 players (Tate, Gennings, Hoffman, Strittmatter, & Retchin, 2012). The researchers found that self-selected music improved time trial performance in both sprint (50 m; ~1% improvement) and long-distance freestyle swimming

(800 m; ~1% improvement). As the authors concede, self-selection of music presents a threat to internal validity as participants invariably select music that has a wide variety of psychoacoustic properties. Moreover, participants were not habituated to using the MP3 device and physiological measures were not taken to verify their workload across trials. Each of these limitations was addressed in the design of the present study.

High-intensity activity with synchronous music

Simpson and Karageorghis (2006) applied two synchronous music conditions (*motivational* and *oudeterous* [meaning motivationally neutral]) during a 400-m sprinting task. The motivational condition elicited faster times when compared against the no-music control, as did the oudeterous condition, albeit to a lesser degree (.9% vs. .4% improvements over control respectively). Hence, both the synchronization effect *and* the motivational qualities of the music appeared to benefit performance in this instance. Karageorghis et al. (2009) extended the 400-m study using a similar design to investigate the psychophysical and ergogenic effects of synchronous music during treadmill walking. Participants began the task at 75% of their maximum heart rate and continued until volitional exhaustion. Both motivational and oudeterous conditions elicited greater endurance than the no-music control (14.6% vs. 8.1% improvements over control respectively). The findings also showed that motivational music elicited higher affective valence scores to the point of voluntary exhaustion than oudeterous and control conditions, which yielded similar affective valence scores during the second half of the task.

Terry et al. (2012) used a treadmill running task comprised of three 4-min stages of progressively faster velocities and one maximal stage with a sample of elite triathletes. Participants were able to endure longer in the presence of two synchronous music conditions: self-selected motivational music, and an alternative that was neutral in its motivational qualities (18.1% vs. 19.7% improvements over control respectively). Furthermore, mood

responses and feeling states were more positive under the motivational music condition compared to either the neutral or no-music conditions. A potential limitation in this study was that participants self-selected rap music which typically has a relatively slow tempo (80–110 bpm), and thus may not have been entirely appropriate given the high-arousal state engendered by the task (see Karageorghis et al., 2011).

Mechanisms underlying the effects of music during high-intensity activity

The mechanisms underlying the effects of music were expounded in a recent two-part review paper (Karageorghis & Priest, 2012a, 2012b) therefore only an overview will be provided here: The limited capacity of the nervous system has a bearing on the effects of music on attention (see Rejeski, 1985). These limitations restrict the degree to which the human organism is able to process music during high-intensity activity when fatigue-related signals overwhelm the afferent nervous system. Studies have demonstrated that, although music moderates RPE at low-to-moderate intensities of exercise, it does not moderate RPE at intensities beyond anaerobic threshold (e.g., Bharani, Sahu, & Mathew, 2004; Boutcher & Trenske, 1990). Nonetheless, recent findings have served to challenge extant theory (e.g., Rejeski, 1985; Tenenbaum, 2001) insofar as appropriately selected music appears to moderate in-task affect during high-intensity activities (Hutchinson et al., 2011; Karageorghis et al., 2009). These findings were re-examined in the present study using a different exercise modality (swimming).

The present study applied music asynchronously to an all-out effort, hence there was a rather limited opportunity for synchronous movement or *entrainment* to the musical beat. Nonetheless, there is a strong tendency for entrainment to occur between human locomotion and the rhythmical qualities of music. In the realm of neuropsychology, Schneider, Askew, Abel, and Strüder (2010) indicated that commonalities exist between movement frequency during exercise and music tempo that are reflected by the frequency of

electroencephalographic delta activity. The authors asserted that the brain's role as principal regulator of locomotion, neurovascular control, and sensory integration explained the coincidence of music tempo and physiological processes. Experimental work using *fMRI* scanners has given considerable insight into the parts of the brain that might facilitate entrainment. For example, Kornysheva, von Cramon, Jacobsen, and Schubotz (2010) highlighted the involvement of premotor and cerebellar brain sectors during preferred vs. non-preferred musical rhythms. Moreover, it appeared that activity in the ventral premotor cortex was enhanced by a preferred tempo. This mechanism may facilitate the process of "tuning in" to an appealing musical beat and this can influence performance indices in speed-endurance tasks such as the one used in the present study.

Rationale, purpose, and hypotheses

Tentative evidence indicates that during supramaximal or all-out motoric tasks the motivational qualities of music have little bearing on performance outcomes but do influence psychological variables (e.g., Terry et al., 2012). So music per se influences performance in such tasks and although the aesthetic properties of music are seemingly processed and enter consciousness, they are not sufficiently potent to influence performance outcomes. This is an intriguing finding that requires further empirical investigation before evidence-based recommendations can be given to practitioners. The interaction of the motivational qualities of music with gender is also worthy of investigation given the condition by gender interactions reported in previous work (e.g., Anshel & Marisi, 1978; Karageorghis et al., 2010). The sport of swimming provides a novel research environment in which to explore these questions and advances in MP3 player technology have made such research possible (e.g., Tate et al., 2012). Moreover, swimming places a low load on weight-bearing joints and promotes cardiovascular fitness, therefore is a highly popular exercise modality.

The purpose of the present study was to assess the psychological, psychophysical, and ergogenic effects of asynchronous music in swimming. Despite the growing popularity of underwater MP3 players, to date there has been just one experimental study into the use of music in swimming (Tate et al., 2012) and this employed self-selected music, which presents a considerable threat to internal validity (see Karageorghis & Terry, 1997). The results of the present study will inform sport psychologists and exercise practitioners, as well as swimming coaches and their charges regarding the potential benefits or pitfalls associated with music use in swimming.

We hypothesized that two experimental conditions involving motivational and oudeterous music would yield superior psychological, psychophysical, and ergogenic effects when compared against a no-music control. Moreover, the motivational condition would yield superior psychological effects when compared against the oudeterous condition (c.f. Terry et al., 2012). We expected no differences in the psychophysical measures when the two music conditions were compared owing to the intensity level of the activity (see Rejeski, 1985; Tenenbaum, 2001). We did, however, expect differences in state attentional focus with both music conditions promoting more dissociative thoughts than the no-music control. Given the motoric nature of the experimental task, a significant Condition x Gender effect was not expected to emerge.

Methodology

Ethical clearance

Ethical approval was obtained from the first authors' institution prior to commencement of the study and participants provided written informed consent.

Stage 1: Music selection

Participants and procedure. A sample of 92 volunteer undergraduates (34 women and 58 men; $M_{\text{age}} = 20.3$ years, $SD = 1.1$ years) nominated six musical selections for use in

the experimental protocol of Stage 2. The 20 most frequently-recorded tracks were then rated according to their motivational qualities for swimming by a panel of 10 undergraduates (six women and four men; $M_{\text{age}} = 20.3$ years, $SD = .7$ years) using the Brunel Music Rating Inventory-2 (Karageorghis, Priest, Terry, Chatzisarantis, & Lane, 2006). This procedure was undertaken to ensure that tracks considered for inclusion in the habituation phase and for each experimental condition were equivalent in terms of their motivational qualities, and would differ significantly ($p < .05$) between experimental conditions. The 102 volunteers and panel members were representative of the proposed experimental participants in terms of age, gender breakdown, ethnicity, and socio-cultural background (Karageorghis & Terry, 1997). The tempo of tracks in both experimental conditions was standardized at 130 beats per minute (bpm). This was an appropriate tempo for the intensity of the activity from an experimental aesthetics perspective (see Karageorghis et al., 2011). Copyright permission was obtained from the music publishers to record the tracks for research purposes (see Table 1 for details of the experimental tracks). A full list of the 20 tracks used in the BMRI-2 rating exercise can be requested from the first author.

Stage 2: Experimental investigation

Based on a power analysis with alpha set at .05 and power at .8 (Cohen, 1988) and a large effect size (partial $\eta^2 = 0.21$; Karageorghis et al., 2010), a G*Power calculation using the SPSS option indicated that 22 participants would be required. An extra four participants were recruited in case of experimental dropout and/or deletions due to outliers.

Participants. The 26 volunteer participants comprised an even mix of Caucasian women and men ($M_{\text{age}} = 20.0$ years, $SD = 1.4$ years) from a collegiate swimming club. They were relatively homogeneous in terms of their age and sociocultural background, given the importance of these factors in terms of responsiveness to music (e.g., North & Hargreaves,

2008; pp. 103–105). They were also relatively homogenous in terms of their swimming ability as the majority (77%) participated at club level.

Apparatus. The length of half of an Olympic-size swimming pool and a separate 25-m pool were used for testing. The Olympic-size pool had a singular depth of 2 m and the bed of the 25-m pool sloped from 1.3 m to 3 m. The two pools had similar water temperature (~29°C), air temperature (~30°C), humidity (~60%), and water viscosity (~.92 mm²/s). An underwater MP3 player (Speedo Aquabeat 2.0 Underwater 4GB MP3 player) was used by each participant. Exercise heart rate was assessed by use of a waterproof heart rate monitor (Hosand Telemetry Heart Rate Monitoring Systems). Post-test interviews were recorded using a digital Dictaphone (Olympus digital voice recorder VN-8700PC).

Measures. *Attentional Focusing Questionnaire (AFQ)*. Preferred attentional style was determined using the AFQ (Brewer, Van Raalte, & Lidner, 1996, pp. 1–14) to enable participants with an extreme associative attentional style to be screened out; they are highly unlikely to benefit from a music intervention (Hutchinson & Tenenbaum, 2007). The AFQ consists of 30 items that tap three types of attention in a given context, and these items are rated on a 7-point scale ranging from 1 (*would not do at all*) to 7 (*would do a lot*). Sample items include: association – “monitoring specific body sensations”; dissociation – “singing a song in your head”; and distress “wishing the swim would end”. The authors of the AFQ reported acceptable internal consistency estimates for its three subscales: association – $\alpha = .79$; dissociation – $\alpha = .77$; and distress – $\alpha = .85$).

***Ratings of Perceived Exertion (RPE)*.** Peripheral (arm), central (chest), and overall RPE were assessed by means of Borg’s (1998) 11-point scale which ranges from 0 (*nothing*) to 10 (*extremely strong*). The scale has received widespread support in regard to its validity and reliability (see e.g., Noble & Robertson, 1996, pp. 71-73).

The Feeling Scale. In-task affect was assessed by use of Hardy and Rejeski's (1989) Feeling Scale, which is an 11-point, single-item scale ranging from +5 (*very good*) to -5 (*very bad*). The authors of the Feeling Scale comprehensively demonstrated its validity in a series of three studies that are detailed in their 1989 paper.

Felt Arousal Scale. Perceived activation was assessed using the Felt Arousal Scale of the Telic State Measure (Svebak & Murgatroyd, 1985), which is a single-item scale ranging from 1 (*low arousal*) to 6 (*high arousal*) based on a "how do you feel right now?" response set. The scale has exhibited correlations in the range .45 – .70 with the arousal scale of the Self-assessment Manikin and .47 – .65 with the arousal scale of the Affect Grid (see Ekkekakis, Hall, & Petruzzello, 2008).

Attention Scale. An amended version of Tammen's (1996) single-item Attention Scale was used to assess state association/dissociation. The bi-polar scale required participants to state a number between 0 (*Internal focus*) and 100 (*External focus*) to represent their predominant focus.

Motivation. An 11-point, single-item scale was used to measure state motivation (see Tenenbaum, Kamata, & Hayashi, 2007). The scale was anchored by 0 (*Not at all motivated*) and 10 (*Extremely motivated*), and based on a "how do you feel right now" response set. Tenenbaum et al. (2007) provide a strong rationale for the applicability of single-item scales, as long as they demonstrate high face validity. Using effort tolerance as a criterion, the authors report higher predictive validity of such scales (r 's > .50) when compared to reliable dispositional measures.

Flow State Scale-2 (FSS-2). A 9-item abbreviated version of the FSS-2 (Jackson, Martin, & Eklund, 2008) was used to assess flow state (e.g., "I do things spontaneously and automatically without having to think"). Items are presented using the instruction "Circle the number that best matches your experience" and attached to a 5-point Likert scale ranging

from 1 (*strong disagree*) to 5 (*strong agree*). Good internal consistency has been demonstrated for this instrument ($\alpha = .82$; Martin, Tipler, Marsh, Richards, & Williams, 2006) while Jackson et al. showed acceptable goodness-of-fit indices using confirmatory factor analysis.

Music liking. A single, 10-point music-liking item anchored by 1 (*I do not like it at all*) and 10 (*I like it very much*) was administered to each participant at the end of their final experimental trial using the instruction “Rate how much you like this track in the context of swimming a 200-metre freestyle time trial” (see Karageorghis et al., 2011).

Pre-test and habituation. Participants were screened for associative and dissociative attentional focus strategies in the swimming context using the AFQ. Participants were required to complete three 200-m freestyle swimming time trials in the experimental phase of the study. To this end, on recruitment (week 1), they were required to complete a 200-m freestyle time trial. Thereafter, there was a 3-week habituation phase during which participants were required to conduct their regular training regimen while using the MP3 players and heart rate monitors for at least one session per week or four sessions in total over 3 weeks. The music programme during the habituation phase comprised of tracks garnered from the music survey but not used during the experimental phase. The tracks were sequenced in the order: motivational, oudeterous, motivational, oudeterous, etc. A single music programme was used four times although the order of tracks for each habituation session was changed while maintaining the motivational–oudeterous pattern. Participants were required to hand the MP3 players to a researcher after each habituation trial. In week 4, a further performance measure was taken using the 200-m freestyle task to gauge the level of improvement during the habituation period and to minimize the influence of any possible task learning effects on the experimental phase (Harris, 2008, pp. 156–157). During this second

trial, participants wore heart rate monitors and an MP3 player that was switched off. The experimental measures were presented and explained by one of the experimenters.

Experimental trials. There were three experimental trials for each participant during which they were exposed to two music conditions (motivational and oudeterous) and a no-music control condition in a counterbalanced order. These trials took place on separate days with a 1-week gap between each and the music conditions were *asynchronous* in nature as the all-out effort required rendered any type of conscious synchronization difficult. Participants were required to follow identical patterns of activity (no other vigorous physical activity permitted) and diet prior to the trial on the day of the pre-test, the baseline measure, and on the days of the experimental trials. Further, they were asked not to eat within 2 hr prior to testing or consume caffeine within 12 hours. Each participant engaged in the 200-m freestyle swimming time trial individually in the presence of a same-sex experimenter (c.f. Anshel & Marisi, 1978).

Following a 5-min standardized warm-up period, the experimenter requested each participant to assume a starting position in the water, that entailed holding onto the side of the pool with their dominant hand. On immediate completion of the 200-m time trial, while still in the water, participants were administered peripheral, central, and overall RPE measures, the Feeling Scale, the Felt Arousal Scale, the attentional focus item to gauge the degree of association/dissociation during the time trial, the abbreviated FSS-2, and single-item motivation scale. At any given point of the experiment, two swimmers were tested in separate lanes and their starting times were slightly staggered in order to avoid any potential co-action effects. A researcher was available to provide any necessary verbal instruction during completion of the questionnaires. Participants were required to perform a 5-min cool-down at the end of each trial. At the end of their final experimental trial, participants responded to the music liking item with reference to the motivational and oudeterous tracks used during the

experimental protocol. A 30 s clip of each track was played to them to aid their rating. Each trial took ~15 min in total.

Post-test interview. In order to corroborate the findings with qualitative data and incorporate the viewpoints of the participants, a subsample ($n = 10$) with an even split of women and men was randomly selected and interviewed by a member of the research team. The interviews took place on university premises and lasted for ~15 min. A schedule of open-ended questions (which can be requested from the first author) was used to allow each participant's perspectives to emerge. Probing was used to elucidate the precise meaning given by each participant to their experiences during the testing. The interviews were recorded digitally and transcribed verbatim prior to analysis.

Data analysis

Data were screened for univariate and multivariate outliers. Following checks to ensure that the data were suitable for parametric analysis, mixed-model 3 x 2 (Condition x Gender) MANOVA and ANOVAs were applied to the dependent variables. Where Mauchly's test indicated violations of the sphericity assumption, Greenhouse–Geisser adjustments were made to the relevant F test. The post-test qualitative data were analysed using inductive content analysis (see Marshall & Rossman, 1999), which involves a process of open coding, creating categories, and abstraction (Elo & Kyngäs, 2007). An inductive content analysis was conducted by two of the authors and a peer debriefing was conducted by a third author to ensure the trustworthiness of the analysis.

Results

During participant screening, the AFQ identified one potential experimental participant as being an extreme associator (AFQ score = 44) therefore they took no further part in the study. A paired-samples t test to examine differences between trial 1 and trial 2 of the 200-metre freestyle task in the pre-test and habituation phase showed no significant

decrease in time, $t(25) = -1.928$, $p = .065$. Data screening indicated that there were no univariate or multivariate outliers. The data in each cell of each analysis ($k = 108$) were normally distributed (std. skewness and kurtosis $< \pm 2.58$). In the F tests associated with the mixed-model ANOVAs and MANOVAs, Mauchly's test indicated a violation of the sphericity assumption for the time variable, Mauchly's $W = .44$, $\epsilon = .64$, $p < .001$, therefore a Greenhouse-Geisser adjustment was made to the F test. Box's M test indicated violations for homogeneity of covariance for the time variable (Box's $M = 20.13$, $p = .008$), and the motivation variables (flow and state motivation; Box's $M = 46.12$, $p = .043$), therefore the Pillai's Trace omnibus statistic was used in both instances. Collectively, the diagnostic tests indicated that the assumptions underlying two-way, mixed-model ANOVA and MANOVA were satisfactorily met. Descriptive statistics for all dependent variables are presented in Table 2.

Interaction effects

The two-way interaction of Condition x Gender was nonsignificant in each ANOVA and MANOVA: time trial, $F(1.28, 30.85) = .17$, $p = .749$, $\eta_p^2 = .01$; RPE measures, Wilks's $\lambda = .89$, $F(6, 92) = .91$, $p = .489$, $\eta_p^2 = .06$; affect and perceived activation, Wilks's $\lambda = .01$, $F(4, 94) = .14$, $p = .969$, $\eta_p^2 = .01$; motivation variables (state motivation and flow), Pillai's Trace = .08, $F(4, 96) = 1.00$, $p = .411$, $\eta_p^2 = .04$; end, peak, and average heart rate, Wilks's $\lambda = .94$, $F(6, 92) = .50$, $p = .804$, $\eta_p^2 = .03$; and state attention, $F(2, 48) = 1.16$, $p = .321$, $\eta_p^2 = .05$.

Main effects

There were significant main effects for condition in time trial performance, $F(1.28, 30.85) = 5.18$, $p = .022$, $\eta_p^2 = .18$, the motivation variables, Pillai's Trace = .21, $F(4, 96) = 2.85$, $p = .028$, $\eta_p^2 = .11$, and state attention, $F(2, 48) = 4.65$, $p = .014$, $\eta_p^2 = .16$. Effects for time trial performance and state attention were large, and moderate for the motivation

variables. There were no significant main effects for gender ($p > .05$). There were no within-subject differences in the three heart rate variables (finish, peak, and average), and in each trial, participants worked close to their age-predicted maximal heart rates (see Table 2).

Bonferroni-adjusted within-subjects contrasts indicated that in terms of time trial performance, participants swam faster under the motivational music condition when compared to control, $F(1, 24) = 5.91, p = .023, \eta_p^2 = .20$, and faster under the oudeterous music condition when compared to control, $F(1, 24) = 5.24, p = .031, \eta_p^2 = .18$ (see Fig. 1). Follow-up univariate tests for the motivation variables showed that state motivation was significant, $F(2, 48) = 4.52, p = .016, \eta_p^2 = .16$. Within-subjects contrasts indicated that participants reported higher levels of motivation when exposed to the motivational music compared to control, $F(1, 24) = 6.50, p = .018, \eta_p^2 = .21$, and similarly higher levels when oudeterous music was compared to control, $F(1, 24) = 7.30, p = .012, \eta_p^2 = .23$ (see Fig. 1). Within-subjects contrasts for attention indicated that participants exhibited more dissociative thoughts relative to control when exposed to motivational music, $F(1, 24) = 7.00, p = .014, \eta_p^2 = .23$, and oudeterous music, $F(1, 24) = 4.99, p = .035, \eta_p^2 = .17$. The pattern of differences was identical across time trial, state motivation, and state attention variables: the two music conditions differed significantly from control with no differences evident between the music conditions.

Qualitative data

Semi-structured interviews were conducted with a subsample of 10 participants and the results of the subsequent analysis (see Table 3) will be explicated here in brief. The primary orientation of the present study is experimental and the qualitative data were collected as a supplement to the experimental data. Participants indicated that the use of music during the time trial performance elicited three broad categories of response that related to attentional focus, enhanced affective state, and behavioural responses.

In terms of attentional focus, seven of the participants commented that the inclusion of either of the two music tracks enabled them to focus more effectively on the task or to dissociate from the pain induced by the all-out effort. For example, a female participant commented “I didn’t notice any pain when listening to the music.” On occasion the music was so engrossing that it caused the swimmers to miss cues that were essential to their performance; a male participant revealed that “...with the music I would sometimes forget about seeing the wall.” Most commonly, however, participants passed comments such as this one from a male “The task did not seem as strenuous as it usually does.”

With reference to enhanced affective state, nine of the participants indicated that the music had a positive influence on how they felt and that it was preferable to complete the task with music than without. A female participant commented “Both tracks made me more upbeat and positive ...but more so Florence and the Machine.” Almost paradoxically the music had a relaxing effect for six of the participants as illustrated in this quote from a female “Florence and the Machine made me more relaxed so I didn’t try very hard.” Seven of the participants indicated that the music, and in particular the motivational track, had an arousing effect during the swim. A male participant revealed “I felt really pumped up to LMFAO!” while another male indicated “LMFAO made me feel more energetic.”

It transpired that the music led to behavioural responses in terms of greater effort expended and *entrainment* or synchronization to the beat. Seven of the 10 participants commented that they considered the LMFAO track to be more motivational than the Florence and the Machine track which corroborated the results of the earlier BMRI-2 rating panel. A female participant mentioned that both tracks were equally effective (as borne out in the quantitative analyses) “I thought that both tracks were good and motivational and having them playing was better than not having them on.” A male participant commented on the benefits of having a rhythmic stimulus “You almost start swimming to the tempo of the song,

so my stroke rate was faster during *Sexy And I Know It*.”

Discussion

The aim of the present study was to investigate the psychological, psychophysical, and ergogenic effects of asynchronous music on a swimming time trial task. It was hypothesized that experimental conditions involving motivational and oudeterous music would yield superior effects when compared against a no-music control. This hypothesis was only partially supported. First, an ergogenic effect was observed wherein participants swam faster under the two music conditions when compared to a no-music control (motivational 2.1% faster than control, and oudeterous 1.8% faster than control). If, for example, we compare the present results to performances in the swimming competition at the London 2012 Olympic Games, the percentage difference in time between first and fourth places in the men’s 200-m freestyle was 1.8%. Similarly, in the women’s event, the difference was 1.9%. This shows, to some degree, the meaningfulness of the present experimental effect in a real-world context. Participants appeared to derive greater benefit from music than those in the Tate et al. (2012) study; this may be due to the fact that in the latter study, participants were of a higher competitive level and thus more likely to use associative attentional strategies (see Baker, Côté, & Deakin, 2005).

The present participants also reported higher levels of state motivation during the two experimental conditions and the quantitative findings were corroborated by the results of the inductive content analysis (see Table 3). It was expected that the motivational condition would yield superior psychological effects when compared against the oudeterous condition. This hypothesis was refuted. The two music conditions were associated with significantly higher levels of dissociation than the control condition, therefore the hypothesis relating to attentional focus was accepted (see Table 2). However, the music did not influence the remaining dependent variables with the exception of perceived activation, which showed a

nonsignificant trend that mirrored the findings for time trial performance and state motivation (see Table 2). The hypothesis that the motivational condition would yield superior psychological effects when compared against the outdeterous condition was also refuted.

Across the dependent variables of time trial performance and state motivation, the two music conditions differed significantly from control, but no differences were found between the music conditions. Thus we can conclude that in a 200-m time trial, music can positively influence swimming performance and state motivation, but the motivational properties of the music appear to exert little influence over these variables. These findings can be interpreted from an information processing perspective; multiple afferent and efferent stimuli compete with each other for limited attentional processing resources. In accordance with the theoretical assertions of Rejeski (1985) and Tenenbaum (2001), there is a narrowing of the attentional bandwidth during high-intensity exercise as physiological sensations of fatigue dominate focal awareness. The competitive nature of the human information processing system means that a stronger signal may be attended to at the expense of a weaker one. Thus during high-intensity exercise, it appears that limited attention can be directed towards the motivational or aesthetic qualities of the music, as has been shown in previous studies (e.g., Terry et al., 2012). This was corroborated by the qualitative data, as participants did not differentiate between the tracks in terms of their distracting or dissociative qualities.

The modest performance benefits observed in both music conditions may be attributable to the mechanism of rhythmic entrainment (e.g., Large, 2000; Schneider et al., 2010). More specifically, if some participants were attempting to complete two strokes per musical beat, the music may have had a metronomic effect and slightly increased their stroke rate, as the music tempo (130 bpm) was set at a level that was higher than their preferred stroke rate for the 200-m freestyle task.

Although within the present protocol we could not assess the degree to which participants synchronized their movements with the rhythmical qualities of the music, they did make a number of statements during the interviews (see Table 3) that alluded to how the music either made them swim more efficiently or was used as a rhythmic stimulus (e.g., “LMFAO gave me the chance to swim to the rhythm which kept me going” [participant 2]). The benefits of both music conditions in terms of state motivation hint at the possibility of intrinsic enjoyment playing a salient role, with the presence of music rendering the maximal-effort task more pleasurable. This observation is corroborated by the affective valence results (see Table 2), which, despite being nonsignificant ($p > .05$), exhibit a strong trend towards more positive affect with music: *fairly good* with music and *neutral* without music.

Given the high intensity of the experimental task, no differences in the psychophysical measures were expected between music conditions. This hypothesis was supported as the music did not influence differentiated RPE. This concurs with previous findings indicating that music does not moderate RPE during high-intensity exercise (e.g., Boutcher & Trenks, 1990; Hutchinson et al., 2011). As expected, participants’ attentional focus was more external (dissociative) during the two music conditions; a finding that was strongly franked by the qualitative data. The subjective comments made following the time trial indicate that music distracted participants from the physical pain associated with the task. As with the time trial and state motivation results, the motivational qualities of the music did not have a significant effect on state attentional focus. Interestingly, the experimental participants’ liking scores for the two tracks revealed no significant difference between them although, as expected, the motivational track scored higher than the oudeterous track (7.50 vs. 6.96) and seven of the 10 participants who were interviewed expressed a preference for it. The attention scores show that the swimmers did not dissociate in any of the conditions but that the two music conditions led them to be less associative in their focus (see Table 2).

A noteworthy nonsignificant finding that emerged concerned the Condition x Gender interaction for state attention. Female participants appeared to associate to a greater degree than males during the no-music control ($M_{\text{diff}} = 11.92$), whereas during the motivational music condition they exhibited identical scores ($M = 50.38$). A score of 50 indicates an equal spread of associative and dissociative attention throughout the task. There was high variability in the state attention scores (see Table 2), which prevented the interaction effect from emerging as significant ($p > .05$). Previous studies have shown that females can derive greater benefit from music than males in affective terms (e.g., Karageorghis et al., 2010), but the present finding pertaining to attentional focus warrants further investigation.

Limitations of the present study

The body of knowledge pertaining to music selection in other dry land exercise modalities may not apply in equal measure to swimming. Stroke rate in swimming is generally much slower than stride rate in running or revolutions per minute in cycling. We attempted to address this by selecting a music tempo (130 bpm) that was appropriate in terms of the physiological load that the swimmers encountered (see Karageorghis et al., 2011). It is also apparent that swimmers who perform freestyle sometimes adopt a bilateral breathing pattern, so they take a breath every third stroke (Tarpinian, 1996, p. 24). Moreover, from a biomechanical perspective, there is a strong kick to every armstroke, which is followed by two softer kicks (**one** two three, **one** two three). Hence if our goal were to promote either respiratory or auditory-motor entrainment, music with a 3/4 (i.e., three quarter beats to the bar) rather than a 4/4 time signature might be more suitable, at least in rhythmic terms. Using a 3/4 time signature presents its own limitation, as it is seldom experienced by young adults owing to the predominance of four crotchets to the bar in popular music.

Given the short-duration of the time trial task, only one music track could be used. As previous studies used tasks of a longer duration (e.g., Atkinson et al., 2004; Tenenbaum et al.,

2004), it was often the case that a programme of music was used. In such instances if a participant happens to dislike one track there is a strong chance that this will be assuaged by their liking of other tracks. A limitation is that we placed a great deal of emphasis on the response to just one track in each experimental trial. Although we did adhere to published procedures in the selection of music for exercise (Karageorghis et al., 2006), it would have been advantageous to find a larger differential between the post-experimental preference ratings of the tracks used in the two experimental conditions; it was only .54. Finally, despite the fact that the research team had exclusive access to 2–3 lanes of the pool at any given time, there were other users in the remaining lanes and it is acknowledged that this is a potential source of distraction for experimental participants. It was not feasible for the research team to gain exclusive access to either of the two public pools used in the present study.

Practical implications of the present findings

The present findings are concordant with recent findings relating to the effects of motivational and neutral music on anaerobic tasks (e.g., Karageorghis et al., 2010; Terry et al., 2012) albeit that these recent findings pertain to the synchronous application of music. The commonality is that participants do not appear to be able to discriminate between musical works that have different motivational qualities. The implications of this are that music per se (of an appropriate tempo) can have a beneficial effect on high-intensity exercise and subjective ratings of motivation. This is borne out in other studies that have used asynchronous music for high-intensity tasks (e.g., Atkinson et al., 2004; Bharani et al., 2004). The implication is that when selecting music in a group scenario for high-intensity tasks such as indoor rowing ergometry or circuit training, as long as music is selected within an appropriate tempo band (125–140 bpm; Karageorghis et al., 2011), it is likely to have a beneficial effect in terms of performance output, state motivation, and promoting dissociative focus. We emphasize that the music should be consistent in its rhythmic structure without

accelerandos and *rallentandos* (speeding up and slowing down), long breaks in the rhythm, discordant harmony, or negative lyrics. The work to date has, in the main, compared motivational vs. neutral music, and if demotivational music were used rather than neutral music, this is likely to have a negative influence on athletes' and exercise participants' motivational states.

Conclusions and recommendations

The present findings support the hypothesis that the use of asynchronous music during a high-intensity task can have an ergogenic effect; this was in the order of 2% when averaged out across the two experimental conditions. The use of music, regardless of its motivational qualities, resulted in higher self-reported motivation as well as more dissociative thoughts. Qualitative findings indicated that the inclusion of music shifted participants' attentional focus, enhanced affective states, encouraged entrainment, and prompted greater intensity of effort. Taken collectively, these findings hint at the potential benefits that both competitive and recreational swimmers might derive from the use of underwater MP3 players.

There are now a number of well-controlled studies in the literature that attest to the psychological, psychophysical, and ergogenic effects of music across a wide range of physical activity modalities (e.g., Hutchinson et al., 2011; Karageorghis et al., 2009; Rendi et al., 2008). Many of the effects can be linked to existing theoretical frameworks to account for effects such as dissociation (Rejeski, 1985; Tenenbaum, 2001) or increased work output/efficiency through entrainment (Large, 2000). There are, however, phenomena evident that are not fully addressed by extant theory such as the influence of asynchronous music on performance-related variables (e.g., time trial performance) and its influence on affect during anaerobic endurance tasks (e.g., Boutcher & Trenske, 1990).

The possibility that female participants have a tendency to associate more than males during no-music conditions is worthy of further investigation; it has been suggested

elsewhere that women dissociate more than men (Antonini Philippe & Seiler, 2005). Such research would show whether targeted music interventions for females engaged in high-intensity activity would lead them to experience greater enjoyment and adherence. We intended to use attentional style as an additional independent variable in our study but this was confounded by the fact that only five participants were identified as being associators. Future research could start with a larger pool of participants in order that associators, dissociators, and switchers (those with a tendency to shift between the two attentional styles) might be compared in their use of music and other related stimuli such as video.

It appears that based on the evidence presented herein, there is an empirical basis to the application of asynchronous music use in swimming. Future studies might progress to examining the entrainment of a variety of strokes with appropriate music stimuli and, in so doing, evaluate the efficacy of both 3/4 and 4/4 time signatures.

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Table 1

Details of musical selections used in the experimental conditions

	Music Conditions	
	Motivational track	Oudeterous track
Artist	LMFAO	Florence and The Machine
Track title	Sexy And I Know It	Howl
Album	Sorry for Party Rocking	Lungs
Credit	Interscope Records (2011)	Island Records (2009)
BMRI-2 score	$M = 32.00, SD = 8.04$	$M = 12.00, SD = 3.46$

Table 2

Descriptive statistics for dependent variables

	Condition					
	Motivational Music		Oudeterous Music		No-music Control	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
Time Trial (s)	173.51 ^a	21.51	174.12 ^a	20.61	177.19	21.95
Feeling Scale	1.58	2.34	2.04	2.34	.88	1.84
Felt Arousal Scale	4.27	.78	4.42	.95	3.77	.95
Flow	33.73	3.88	35.23	3.96	33.57	3.78
Motivation	7.12 ^a	1.14	7.15 ^a	1.83	5.96	1.78
HR Finish	182.08	7.04	182.00	6.48	183.27	7.13
HR Peak	183.42	6.99	183.15	6.23	184.62	7.24
HR Average	175.96	6.93	176.96	6.74	177.35	8.10
State Attention (%)	50.38 ^a	24.12	46.73 ^a	24.01	35.96	20.10
RPE Arm	6.15	1.87	6.42	1.86	6.27	1.66
RPE Chest	5.65	1.92	5.54	2.10	6.54	1.94
RPE Overall	6.88	1.84	6.62	1.88	6.85	1.59

Note. For state attention the range of scores is 0–100 and a higher score denotes greater dissociation.

^a Different at $p < .05$ compared to the no-music control.

Table 3

Results of the inductive content analysis

Raw data themes (<i>k</i> = 39)	First-order themes (<i>k</i> = 7)	General dimensions (<i>k</i> = 3)	
Able to focus Attended to beat Concentration Clear mind Clearly focused	Enhanced Focus	Attentional focus	
Distracts from pain Focused I was singing along Not as strenuous			
Not concentrating on pain Thought about music Unaware of fatigue Would forget about wall Zoned in to task	Dissociation		
Greater enjoyment Felt positive Felt happy More positive thoughts Positive/good mood Put me in the mood	Positive mood state		
At ease Calm Chilled Florence more soothing Relaxed Soothed	Relaxing		Enhanced affective state
Energized Stimulated Pumped up	Arousing		
More motivated Music kept me going Music pushes you Helps you towards the end Felt more determined	Motivating effect		
Couldn't synch to LMFAO I tried synching my stroke I was going with rhythm My technique was better Swam to rhythm	Entrainment		

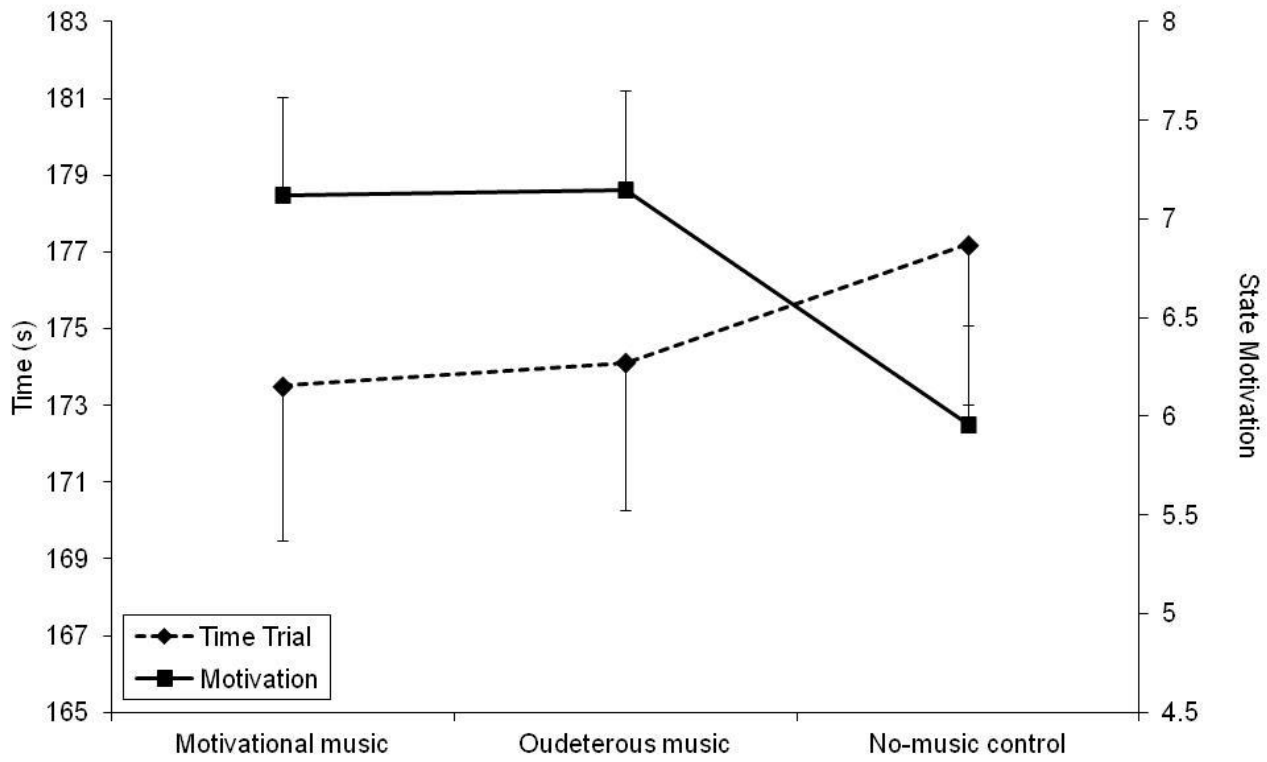


Fig.1. Means for time trial performance and state motivation across the three conditions. Error bars represent standard errors.