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Interactive Effects of Music Tempi and Intensities on Grip Strength and Subjective Affect

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Abstract

Pretask music is widely used by athletes albeit there is scant empirical evidence to support its use. The present study extended a line of work into pretask music by examining the interactive effects of music tempo and intensity (volume) on the performance of a simple motor skill and subjective affect. A 2 x 2 within-subjects factorial design was employed with an additional no-music control, the scores from which were used as a covariate. A sample of 52 male athletes (M_{age} = 26.1 $\pm$ 4.8 years) was exposed to five conditions: fast/loud (126 bpm/80 dBA), fast/quiet (126 bpm/70 dBA), slow/loud (87 bpm/80 dBA), slow/quiet (87 bpm/70 dBA) music, and a no-music control. Dependent variables were grip strength, measured with a handgrip dynamometer, and subjective affect, assessed by use of the Affect Grid. The tempo and intensity components of music had interactive effects for grip strength but only main effects for subjective affect. Fast-tempo music played at a high intensity yielded the highest grip strength, while fast-tempo music played at a low intensity resulted in much lower grip strength ($M_{diff.}$ = -1.11 Force kg). For affective valence, there were main effects of tempo and intensity, with fast and loud music yielding the highest scores. For affective arousal, there was no difference between tempi although there was between intensities, with the high-intensity condition yielding higher scores. The present findings indicate the utility of fast/loud pretask music in enhancing affective valence and arousal in preparation for a simple or gross motor task.

Key words: Activation, arousal potential, circumplex model, precompetition, strength task

Music appears to be an essential aspect of athletes' precompetition routines.[1,2] The music used by two Olympic gold medalists illustrates its potential to influence precompetition mindset. For U.S. swimming champion Michael Phelps, listening to a distinctly "rapcentric" playlist proved an effective strategy for optimizing his activation levels in the last four Olympiads.[3 (p 165)] Contrastingly, Audley Harrison, the Sydney 2000 superheavyweight boxing champion, listened to Japanese classical music to ease his precompetition anxiety approaching the final.[3 (pp 15–16)]

Only a modest number of empirical studies (*k* = 21; see Data S1 for a full list) have explored the application of music as a form of stimulant or sedative prior to a motor task. One of the early studies developed the work of Pearce[4] in examining the effects of fast, energizing music and slow, relaxing music played prior to a handgrip dynamometer test.[5] The participants, who were 16 female and 33 male undergraduates, exhibited significantly higher grip strength after listening to stimulating music compared to sedative music or a white-noise control (i.e., an auditory stimulus with constant power spectral density that is commonly used in psychomusicology studies as a matched-control condition). Also, listening to sedative music resulted in lower strength scores than white noise. These findings demonstrate how the use of a highly standardized task—in this instance, isometric handgrip contraction—can be effective in illustrating the effects of pretask music on psychomotor performance.

Bishop et al.[6] used a sample of tennis players to examine how changes to musical tempo and intensity (volume) influenced affective responses and subsequent choice-reaction task performance. A researcher-selected piece of music was modified to create six versions (3 tempi x 2 intensities) that were compared against white noise and silence. A key finding was that listening to fast, loud music produced emotional states that were more pleasant/arousing and elicited shorter choice-reaction time when compared to the same music played at moderate volume. An implication for athletes is that in situations where a high level of arousal coupled with short reaction times is desirable, the use of fast music delivered at a high intensity is potentially advantageous. As yet, it is unclear whether the findings of this study are generalizable to other psychomotor tasks (e.g., strength-related tasks).

A follow-up study examined the neurophysiological mechanisms associated with music applications in a sport context.[7] The researchers placed young tennis players (6 female and 6 male; M_{age} = 21.2 years) in an *f*MRI scanner to examine which parts of their brains were stimulated when they listened to music that varied in terms of its arousing qualities. They showed that listening to arousing music (i.e., fast/loud) stimulated parts of the primary auditory cortex and the cerebellum. These brain regions share the responsibility of processing emotion and governing motor control or movement patterns. Music's cross-stimulation of these regions may be one of the main reasons for its effectiveness as a auditory prime for motor performance.

Theoretical backdrop

The theoretical underpinnings for this line of work lie in the work of Daniel Berlyne[8,9] who was a pioneer in the field of *experimental aesthetics* – the systematic study of how we respond to works of art, such as music, and other objects of aesthetic value. Aesthetics entail how the characteristics of a stimulus impact upon value judgments such as perceived pleasantness or estimations of beauty. Berlyne[8 (pp 81–82)] postulated that the *arousal potential* of musical stimuli determines preference and their suitability for different contexts (e.g., physical activity). Arousal potential refers to the amount of activity that a piece of music induces in areas of the brain such as the *reticular activating system* – the region situated at the core of the brain stem associated with motivation and arousal. Under normal circumstances, musical selections that carry a moderate degree of arousal potential tend to be liked most and preference decreases toward the extremes of arousal potential according to an inverted-U relationship (Wundt curve). Given that the execution of a simple motor skill (e.g., grip strength) requires a relatively high level of activation to facilitate optimal muscle fiber recruitment and subsequent performance, it follows that the use of highly stimulative music would be most efficacious in this context. The maximal recruitment of muscle fibers required by the grip strength test renders stimulative music an appropriate accompaniment. The propositions of Berlyne are supported by recent work in the realm of neurophysiology that has assessed the concurrent psychological, cerebral, and neuromechanical effects of music.[10]

A number of studies have evaluated the impact of music used prior to an all-out cycle sprint on a stationary bike[2,11,12] Yamamoto et al.'s[12] participants listened to either slow or fast music for 20 minutes prior to completing the trial (no control condition was included). Music failed to influence power output during the test. However, based on assay of the neurotransmitter norepinephrine (implicated in the fight-or-flight response), the researchers reasoned that the slower music lowered arousal during the listening period, whereas the faster music elevated it. Eliakim et al.[11] administered only a stimulative music condition in apposition to a no-music control. Music exerted no ergogenic effect although it did raise heart rate prior to the task, thus indicative of an increase in arousal. Loizou and Karageorghis (2015) used a slow musical composition with strong extramusical qualities (*Chariots Of Fire* by Vangelis). They found that music positively influenced affective valence, albeit that a condition of motivational verbal primes combined with music and video had a positive effect on affective valence and arousal as well as subsequent anaerobic performance. Collectively, these studies provide some preliminary evidence that pretask music can assist in preparing the mind and body for a bout of high-intensity activity.

The Circumplex Model of Affect

Research work in the domains of mainstream psychomusicology as well as sport and exercise psychology has embraced Russell's[13] circumplex model of affect to assess the affective properties of music or how we respond to music in a physical activity context.[10] North and Hargreaves[14] played 32 pieces of pop music to participants who rated them for affective valence (pleasure/displeasure) and arousal (aroused/sleepy). A second group of participants rated the same pieces according to eight different emotions. The results provided strong support for Russell's model insomuch as the songs that were liked and considered arousing were also regarded as "exciting", songs that were disliked and not arousing were also regarded as boring, songs that were liked and not arousing were regarded as relaxing, and songs that were disliked and arousing were regarded as aggressive.

Rationale, Purpose, and Hypotheses

Music can influence arousal levels in two key ways: First, physiological processes tend to react sympathetically to its rhythmical components.[15,16] Fast, upbeat music increases heart rate, respiration rate, sweat secretion, and numerous other indicators of physical activation. Second, arousal is increased via extramusical associations.[3 (pp 80–82)] Therefore, careful attention to the selection of music is vital if one's goal is to promote thoughts that will stimulate physical activity or superior sporting performance.

The present study will extend previous work[4,5,11] through the application of a more rigorous and exacting methodological approach that holds a high degree of internal validity. (i.e., the influence of potential confounds was minimized). A closed kinetic chain task (handgrip dynamometry) was used, and two of the physical features of a single piece of music (tempo and intensity) were manipulated. This facilitated an examination of whether any changes in psychomotor performance and attendant affective responses were elicited by the music manipulations. A secondary purpose was to examine whether handgrip dynamometry performance was correlated with affective responses to the music. The findings will give sport and exercise scientists a more nuanced understanding of how to manipulate music variables such as tempo and intensity in the pretask phase. Given that several sporting organizations have banned the use of music in the sporting arena (e.g., the IAAF in 2007), its primary application in the sport context is now pretask.[3 (pp 149–198)]

Pretask music can have a potent effect on core affect, but the selection process demands sensitivity to the listener's personal preferences, the match between the characteristics of the music and the target emotion, and the associations elicited by a particular piece.[3 (pp 80–82)] It was hypothesized that the fast/loud condition would yield greater grip strength, a more positively-valenced affective state, and higher affective arousal when compared to all other conditions (H_1). It was also hypothesized that both of the fast conditions (loud and quiet) would yield greater grip strength, more positive affect, and higher activation than the control condition; and the slow/quiet condition would yield lower scores on all three dependent variables than control (H_2). Given a dearth of empirical evidence and the exploratory nature of the correlational analysis between grip strength and affective responses to music, it was hypothesized that there would not be significant correlations evident in any of the conditions (H_3). All three hypotheses were tested at an alpha level of $P < .05$.

Method

Participants

A power analysis was undertaken using G*Power[17] to establish an appropriate sample size using the "MANOVA: Repeated measures, within factors" option. Based on a small predicted effect size ($f = .10$),[6] an alpha level of .05, an estimated correlation among measures of $r = .85$, and desired power of .85, the analysis indicated that 46 participants would be required. Fifty-two participants were recruited to account for the possibility of experimental dropouts and multivariate outliers. Participants were male amateur sportsmen (cricket [$n = 2$], field hockey [$n = 4$], rugby [$n = 19$], soccer [$n = 10$], swimming [$n = 7$], tennis [$n = 3$], and track and field [$n = 7$]; $M_{\text{age}} = 26.1 \pm 4.8$ years) whose sporting experience ranged from 2 to 26 years ($M_{\text{experience}} = 14.3 \pm 4.9$ years). They all indicated that they made routine use of music both during training and to aid their psychological preparing for competition. Given that cultural background has been postulated to have a strong moderating influence on the psychophysical responses to music,[18,19] a culturally homogeneous sample was recruited. Accordingly, 50 of the participants described their ethnicity as “White British”, one as “White Irish,” and one as “White Other” (South African). Participants had spent at least the last 10 years living in the UK. It was decided to focus the present study exclusively on male participants in order to maintain experimenter–participant compatibility.

Apparatus and Measures

Auditory stimuli

Music selection was based upon popular tracks that had achieved success in the Official UK Singles Chart. Berlyne[8 (pp 168–170)] suggested that familiarity moderates preference for a musical selection, although with over-familiarity, the relationship becomes an inverted-U.[20] The track *Umbrella*, sold under The Island Def Jam Music Group label, by award-winning Barbadian singer Rihanna was chosen due to the huge UK success that it has enjoyed. It held the number 1 spot on the UK Singles Chart (Official UK Charts Company, London, UK) for 10 weeks. In order to provide a fast-tempo counterpart, a professionally-produced upbeat remix of the same track was chosen, the Jody den Broeder Destruction Remix. A 140-second excerpt of each track was used as this permitted the inclusion of the most distinctive sections, a chorus and verse[21], while excluding the intro and outro sections that were musically distinct from the remainder of the track. This duration of music exposure was deemed sufficient to influence participants' affective states and potentially cause a change in their motor performance.[22] Standardized vocal instructions were prerecorded onto the test tracks and positioned both before and after the music excerpts:

> Thank you for agreeing to take part in this piece of research. In a few seconds, I would like you to listen to a piece of music by Rihanna. When the music is finished, please perform the grip task as was previously demonstrated. Just to remind you, you need to hold the grip above your head at arm's length. Then squeeze the grip as firmly as possible whilst lowering it to your side. Please then return the dynamometer to the researcher, but do not look at your result. Now for the music...(music then plays; 140 s)... Now perform the grip task as forcefully as possible.

Music tempo for each of the tracks was calculated using bpm software (Tangerine! v.1.4; Cupertino, CA, USA). The tempo measurements were as follows: Fast conditions – Rihanna, *Umbrella* (Jody den Broeder Remix) 125 bpm; slow conditions – Rihanna, *Umbrella* (original version) 87 bpm. Hence, there was a difference of 38 bpm between the fast and slow music conditions; which is considered a large difference in tempo.[23] Initially, the two tracks of differing tempi were normalized for intensity. A decibel meter was used to check these levels (GA102 Sound Level Meter Type 1). Manipulation to produce the lower intensity tracks was undertaken using the software Live v.8.3 (Ableton, Berlin, Germany). This produced two additional test tracks, 10 dBA lower than the initial tracks.

Delivery of Music Tracks

Music was played to participants using a portable MP3 player (iPod Nano A1236) through closed-back, supra-aural earphones (K81DJ). The decibel meter was used in conjunction with the iPod volume dial to set suitable output dBA levels from the headphones.

Dependent Measures: Grip Strength and Subjective Affect

A dynamometer (TKK5101) was used to measure grip strength (Force kg). This digital apparatus automatically calibrates itself before each use. The Affect Grid,[24] which measures core affect along the two orthogonal dimensions of pleasure–displeasure (affective valence) and arousal–sleepiness (affective arousal), was used to gather subjective affective data after the administration of each condition. Participants were required to place a single cross (X) within one of the small squares on the grid. Five in total were completed by each participant (one for each condition) presented in counterbalanced order during a single session and punctuated by 10-minute breaks. A single, laminated Affect Grid with a dry marker pen was used throughout the testing procedures. The reliability and validity of the Affect Grid was established by Russell et al.[24] with reference to the original circumplex model.[13] Subsequent studies have shown that the two dimensions of affective valence and arousal are strong predictors of the emotional experiences associated with music listening.[14,25]

Procedure

With the approval of the institutional review board of the authors, potential participants were approached at public sport and leisure facilities in the southeast of England, UK. Initially, participants were asked to complete the informed consent form and a short demographic questionnaire. Participants were also reminded that their data would be kept in confidence and that they were free to withdraw from the study at any point. A brief introduction to the study followed wherein participants were informed that they would listen to a piece of music and then be tested for grip strength. In addition, following an initial pilot test, subject expectancy effects (or Hawthorn Effects) were highlighted as a potential problem. To counteract expectancy, the experimenter gave a vocal reminder prior to each test to “perform maximally.”

Participants were administered one maximal test on the dynamometer as a familiarization/warm-up trial before the administration of each condition. Following a 1-minute recovery period, the earphones were placed into position by the participant and checked by the researcher. During the music listening phase, the researcher stood out of the sightline of the participant so as not to distract him. Participants were instructed to stand and hold the dynamometer above their head using their dominant hand. It was then lowered evenly to the side of the torso with the arm extended. During this lowering, the participant squeezed the handle of the dynamometer with maximal force. The dynamometer was then handed to the researcher without the participant seeing their result, as the LCD display was facing away from them. Participants waited for 10 min in an adjacent quiet room after each trial and were instructed not to use their cell phone or any other electronic gadget.

The researcher administered the grip-strength task following each of the four experimental music conditions that were presented in a counterbalanced order: fast/loud (126 bpm/80 dBA), fast/quiet (126 bpm/70 dBA), slow/loud (87 bpm/80 dBA), slow/quiet (87 bpm/70 dBA), and a no-music control condition. Immediately after the listening/grip strength phase of each condition, the Affect Grid[24] was administered. Following the final trial, the participant was verbally debriefed and provided with the researcher's contact details in order that they could request a summary of the findings.

Data Analysis

The study employed a 2 x 2 within-subjects factorial design with an additional no-music control condition, the scores from which were used as a covariate. Data-handling software (Oracle Corp., Redwood City, CA, USA) was used initially to capture the data, which were subsequently imported into SPSS v.22.0 (IBM Corp., Armonk, NY, USA) for analysis. The analysis was preceded by a screening for univariate and multivariate outliers (the latter for Affect Grid data only) and normality checks for each cell of the analysis using standard skewness and kurtosis scores. The assumptions underlying the use of covariates were also tested.[26 (pp 203–205)] Where Mauchly's test indicated violations of the sphericity assumption, Greenhouse-Geisser adjustments were made to the relevant *F* test. Primarily a 2 (Tempo) x 2 (Intensity) repeated-measures (RM) ANCOVA was used to analyze the grip strength scores for each of the music conditions, with the no-music control scores entered as the covariate. A further one-factor RM ANOVA for grip strength was then computed to enable comparisons with each of the five music conditions individually (fast/loud, fast/quiet, slow/quiet, slow/loud, no music control).

Arousal and pleasantness scores were analyzed for the music conditions using 2 (Tempo) x 2 (Intensity) RM ANCOVAs, with either arousal or pleasantness scores for the no-music condition included as covariates. The ANCOVAs were subject to Bonferroni correction as affective valence and arousal are theoretically linked and would ideally have been analyzed using a multivariate analysis.[26 (pp 245–248)] This was done in order to avoid the complication of two covariates, each of which was relevant to only one dependent variable.[26 (pp 213–214)] As a follow-up, a one-factor RM MANOVA for condition was computed, with affective valence and arousal as dependent variables to facilitate individual comparisons among each of the five conditions. This analysis enabled a test of H_2. In the RM ANOVA and MANOVA, where the assumption of sphericity was violated, Greenhouse-Geisser adjustments were made to the relevant *F* test. Pearson product-moment correlations (two-tailed) were used to assess the relationship between psychomotor performance and affective responses in each condition. Thereafter, Fisher's *z* test was used to compare the magnitude of correlation coefficients across conditions.

Results

Checks for outliers indicated one univariate outlier ($z > 3.29$) and the case associated with it was deleted prior to further tests. The data in each cell of each analysis ($k = 27$) were normally distributed (std. skewness and kurtosis < $\pm$ 2.58; see Table 1). In the *F* tests associated with the RM ANOVA and MANOVA, Mauchly's test indicated a violation of the sphericity assumption, therefore Greenhouse-Geisser adjustments were made. Collectively, the diagnostic tests indicated that the assumptions underlying two-way, mixed-model ANCOVA and RM ANOVA/MANOVA were satisfactorily met.

Interaction Effects

The ANCOVA two-way interaction of Tempo x Intensity for grip strength was significant, $F(1.00, 49.00) = 7.01$, $P = .011$, $\eta_p^2 = .13$, and the independent variable manipulation accounted for 13% of the variance (see Figure. 1). Pairwise comparisons for the interaction using standard errors to identify reliable differences and Bonferroni adjustments to protect against experimentwise error indicated differences between fast/loud and fast/quiet music, $M = 58.22$ vs $M = 57.59$, $P = .001$, $d = 0.50$; fast/loud and slow/loud, $M = 58.22$ vs $M = 57.11$, $P < .001$, $d = 0.53$; fast/loud and slow/quiet, $M = 58.22$ vs $M = 56.81$, $P < .001$, $d = 0.63$; and slow/loud and slow/quiet $M = 57.11$ vs $M = 56.81$, $P = .034$, $d = 0.30$ (see Table 1 and Fig. 1). Fast tempo combined with high intensity yielded the highest grip strength, while the fast-tempo excerpt played at a low intensity resulted in much lower grip strength ($M_{diff.} = -0.63$ Force kg). For slow tempo, a similar pattern emerged ($M_{diff.} = -0.30$ Force kg), although not as pronounced as that of the fast-tempo conditions. The ANCOVA two-way interaction of Tempo x Intensity for valence was nonsignificant, $F(1.00, 49.00) = .408$, $P = .526$, $\eta_p^2 = .01$, as it was for arousal, $F(1.00, 49.00) = .250$, $P = .620$, $\eta_p^2 = .01$ (see Table 1).

Main Effects

The ANCOVA main effects for grip strength indicated no significant differences for tempo, $F(1.00, 49.00) = .88$, $P = .353$, $\eta_p^2 = .02$, or intensity $F(1.00, 49.00) = .29$, $P = .595$, $\eta_p^2 = .01$. Nonetheless, it is noteworthy that the pairwise comparisons did reveal significant differences for both tempo 95% C.I. = .23 - .70, $P < .001$ ($M_{diff.} = .46$), and intensity, 95% C.I. = .29 - 1.61, $P = .006$ ($M_{diff.} = .95$). This anomaly led us to rebuild the ANCOVA model to examine potential differences more closely (i.e., paired sample *t* tests, ANOVA then ANCOVA). The differences evident in the original pairwise comparisons appeared to have been masked by the inclusion of the covariate. The RM ANOVA for grip strength indicated differences among conditions, $F(2.013, 106.63) = 9.20$, $P < .001$, $\eta_p^2 = .16$, with the independent variable manipulation accounting for 16% of the variance; a large effect. Pairwise comparisons revealed differences between the fast/loud condition and all other conditions (fast/quiet: $P = .001$, $d = 0.50$; slow/ loud: $P < .001$, $d = 0.53$; slow/quiet: $P < .001$, $d = 0.63$; and no-music control: $P < .001$, $d = 0.71$) and between the fast/quiet condition and the no-music control ($P = .048$, $d = 0.41$). The Cohen's *d* effect sizes indicated medium effects with the exception of the fast/loud vs slow/quiet com- parison, which yielded a large effect.

The ANCOVA main effects for valence showed significant differences for tempo, $F(1.00, 49.00) = 6.87$, $P = .012$, $\eta_p^2 = .12$, with the independent variable manipulation accounting for 12% of explained variance. There were also significant differences for intensity, $F(1.00, 49.00) = 10.08$, $P = .003$, $\eta_p^2 = .17$, with a large effect, wherein 17% of the variance was explained; the fast-tempi conditions yielded higher scores than the slow-tempi conditions ($M_{diff} = 0.75$ Force kg). For arousal, there was no significant difference between tempi, $F(1.00, 49.00) = .68$, $P = .414$, $\eta_p^2 = .01$, although there was between intensities, $F(1.00, 49.00) = 6.36$, $P = .015$, $\eta_p^2 = .12$. Intensity accounted for 12% of the variance in arousal; the high-intensity condition yielded higher arousal scores than its low intensity counterpart ($M_{diff} = 1.01$ Force kg).

The RM MANOVA for affective valence and arousal generated significant omnibus statistics, Pillai's Trace = 0.40, $F(8.00, 398.00) = 29.23$, $P < .001$, $\eta_p^2 = .37$, with the inde- pendent variable manipulation accounting for 37% of the variance, a large effect. Follow-up univariate tests showed that there were differences for affective valence, $F(2.62, 131.18) = 50.34$, $P < .001$, $\eta_p^2 = .50$, and arousal, $F(2.88, 144.13) = 57.41$, $P < .001$, $\eta_p^2 = .53$. Pairwise comparisons for affective valence revealed differences among all conditions (fast/loud vs fast/quiet: $P < .001$, $d = 0.74$; fast/loud vs slow/loud: $P < .001$, $d = 0.85$; fast/loud vs slow/quiet: $P < .001$, $d = 1.31$; fast/loud vs no-music control: $P < .001$, $d = 1.36$; fast/quiet vs slow/loud: $P < .001$, $d = 0.55$; fast/ quiet vs slow/quiet: $P < .001$, $d = 1.19$; fast/quiet vs no-music control: $P < .001$, $d = 1.23$; slow/loud vs slow/quiet: $P < .001$, $d = 0.74$; slow/loud vs no-music control: $P < .05$, $d = 0.47$) with the exception of slow/quiet vs no-music control ($P = 1.000$, $d = 0.05$). The Cohen's *d* effect sizes indicated large effects in all but three comparisons, which were medium.

Pairwise comparisons for affective arousal revealed differences among all conditions (fast/loud vs fast/quiet: $P < .001$, $d = 0.81$; fast/loud vs slow/loud: $P < .001$, $d = 0.88$; fast/loud vs slow/quiet: $P < .001$, $d = 1.52$; fast/loud vs no-music control: $P < .001$, $d = 1.61$; fast/quiet vs slow/loud: $P < .05$, $d = 0.46$; fast/quiet vs slow/quiet: $P < .001$, $d = 1.15$; fast/quiet vs no-music control: $P < .001$, $d = 1.14$; slow/loud vs slow/quiet: $P < .001$, $d = 0.89$; slow/loud vs no-music control: $P < .001$, $d = 0.54$; slow/loud vs no-music control: $P < .01$, $d = 0.54$) with the exception of slow/quiet vs no-music control ($P = 1.000$, $d = 0.04$). The Cohen's *d* effect sizes indicated large effects in all but four comparisons, which were medium.

Correlations Between Psychomotor Performance and Subjective Affect

In the fast/loud condition, grip strength was not corre- lated with affective valence ($r = .11$, $P = .435$) or arousal ($r = .14$, $P = .302$). In the fast/quiet condition, there was a significant positive correlation between grip strength and valence ($r = .29$, $P = .041$) but no significant correlation with arousal ($r = .24$, $P = .093$). In the slow/loud condition, grip strength was not correlated with valence ($r = .12$, $P = .391$) or arousal ($r = .14$, $P = .305$). Similarly, in the slow/quiet condition, there were no significant correlations for valence ($r = -.05$, $P = .704$) or arousal ($r = -.05$, $P = .714$). The same finding emerged in the control condition for valence ($r = .26$, $P = .059$) and arousal ($r = .03$, $P = .843$). Fisher's *z* test indicated that there were no significant ($P > .05$) differences when each pair of correlation coefficients was compared. This shows that the weak relationships found between grip-strength performance and subjective affect did not differ across conditions.

Discussion

The main aim of the present study was to investigate the interactive effects of music tempo and intensity on grip strength and subjective affect. H_1 was accepted as the fast/loud condition yielded higher grip strength, affective valence, and arousal scores than the remaining conditions. Contrary to expectations, the slow/quiet condition did not yield lower scores than control.[5] Also the fast/quiet condition did not yield greater grip strength than the slow/loud condition. Accordingly, H_2 was not accepted. The significant Tempo x Intensity interaction that emerged for grip strength ($P = .011$) failed to emerge for affective valence and arousal. The correlations between psychomotor performance and subjective affect were nonsignificant, with the exception of the fast/quiet condition in which there was a weak but significant correlation, and so H_3 was accepted.

Collectively, the present results demonstrate that the tempo and intensity of music influence grip strength and the attendant psychological constructs of affective valence and arousal. Furthermore, their effects on grip strength appear to be interactive in nature. The pattern of results that emerged shows that the combination of fast-tempo and high-intensity music elicited the greatest levels of grip strength coupled with the highest scores for affective valence and arousal. Conversely, the slow/quiet condition exerted the weakest effect when compared to the remaining experimental conditions. The results follow a logical premise as the fast/loud condition that elicited the strongest effects was *doubly* stimulative, whereas the slow/quiet condition was characterized by sedative qualities (slow tempo *and* quiet volume).[7] Studies that have reported a sympathetic physiological response to musical stimuli are also franked by the present findings insofar as a heightened level of physiological arousal is required for optimal performance of a simple motoric task such as handgrip dynamometry.[15,27]

The interaction effect for grip strength ($\eta_p^2 = .13$; see Fig. 1), was not reflected in subjective affect scores. The implication of this finding is that the musical qualities of tempo and intensity have differential effects on grip strength and subjective affect. Related studies showed that pretask music did not significantly enhance performance, but did influence other dependent measures such as the neurotransmitter norepinephrine[12] and heart rate.[11]

When examined collectively, the extant findings indicate that fast, loud pretask music, selected with the task and musical background of the athlete/exerciser in mind, is highly likely to engender a state of pleasurable excitement and positively influence performance of a short-duration, motoric task such as weightlifting or sprinting.[28] As might be expected, the two conditions that were "mixed" in terms of their stimulative qualities (fast/quiet and slow/loud) produced broadly equivalent results, with the fast/quiet condition proving marginally the more potent for all dependent variables.

The present results concord with previous findings in that stimulative music has been found to improve grip-strength performance.[4,5] Both faster-tempi and louder music have been shown to elicit feelings of pleasure and arousal while improving reaction-time performance. [6] Moreover, previous findings that demonstrate the efficacy of the circumplex model of affect in predicting the hedonic response to music[2] are broadly supported by the present findings.

From a conceptual standpoint, the results of these studies are explicable with reference to the psychobiological aesthetics approach.[8,9] The preference for music (and subsequent reactivity) is thought to be a product of its *arousal potential*, which is determined by informational features such as complexity and intensity. Fast tempi contribute to this arousal potential by increasing the amount of information carried within a given time period whereas loudness increases the strength of the signal as detected by the inner ear.[29] A further implication of psychobiological theory is that there is an optimal level of arousal potential represented by a Wundt curve. Accordingly, an additional extremely fast/extremely loud condition would possibly have exerted deleterious effects.

Rejeski[30] advanced a parallel-processing model to explain the dissociative effects of music during physical activity. The model posits that the channel capacity of the nervous system that processes signals toward the brain is limited, a phenomenon that has recently been demonstrated in neurophysiological work in music and exercise.[10] Auditory input may therefore block the internal feedback relating to exercise including sensations of effort, fatigue, and tension. In the present study and that of Bishop et al.[6] such an effect would not have been accrued as the music was used in an antecedent capacity. Nevertheless, it is plausible that the faster, louder music was more able to distract participants from psychological sensations that would have impaired performance such as a sense of fatigue or self-doubt. Partial evidence for this assertion can be found in the work of North and Hargreaves[31] who showed that when compared to slow, quiet music, a fast, loud soundtrack interfered with cognitive performance during a computer driving-simulation thereby increasing lap times (i.e., worsening performance).

North and Hargreaves[19] proposed that music is selected with stimulative or sedative properties as required by the particular context in which the piece is heard. For example, exercisers are apt to select faster, more stimulative music as a means to increase affective arousal because this is a functional state for most forms of exercise. This principle was underlined by a series of studies led by Karageorghis and Jones, who determined that participants expressed a preference for musical selections with tempi that contoured the intensity levels of the cardiovascular exercise they undertook.[23,32] A relatively high state of psychomotor arousal was appropriate to the motoric task selected for the present experiment.

As expected, nonsignificant correlations emerged between grip-strength performance and subjective affect (H_3). These weak and nonsignificant relationships indicate that although the music manipulation had an independent effect on task performance and subjective arousal, there are unknown factors influencing the relationship between performance and affect. Such factors might be psychological (e.g., motivation),[32] psychophysical (e.g., perceived exertion),[27] or psychophysiological (e.g., neuro-activation)[10] in nature. It is also noteworthy that the temporal resolution of the subjective affect measures is different to real-time changes in activation, which could have been tracked using psychophysiological measures such as heart rate variability, electroencephalography, or electrodermal activity.[2,10]

The present findings offer a partial validation of the theoretical model advanced by Karageorghis.[33] This theory posits that music high in energizing qualities (e.g., tempo, melody, lyrical content), if appropriate in terms of a range of personal and situational moderator factors, will serve to increase arousal, enhance affect, and lead to small gains in motor performance. The grip strength improvements in the present study were accompanied by improved affective valence and heightened arousal. Notably, the pattern of responsiveness in affective valence and arousal was almost identical (see Table 1). The findings are also significant in that they offer a possible explanation for the reported ergogenic effect in terms of underlying psychological processes. Although the results are not a direct proof that heightened positive affective valence and arousal *caused* the improvements in performance, they do provide a probable pathway to explain this effect. Further research that accounts for indices of physiological arousal (e.g., heart rate variability) may substantiate this link.

Limitations of the Present Study

The grip-strength task that we employed enabled the researcher to standardize the test protocol across experimental participants. Nonetheless, generalization to more complex motor tasks is restricted. A further limitation is that participants' pretask affective state was not assessed or standardized. However, the long preparation period prior to the task was intended to fulfil such a standardization function. During the experimental task, psychophysiological markers such as heart rate variability were not assayed; these measures would have provided a cross-reference among physical performance, psychological, and physiological indices.[10]

The researchers selected the music used so as to maintain standardization in the protocol with a fast and slow version of the same track. Nonetheless, it is acknowledged that in most instances, pretask music is self-selected. Allowing participants to select their own music would have threatened the internal validity of the study[34] and given that this line of research remains at a nascent stage, the protection of internal validity was deemed paramount. Related to the maintenance of internal validity, an all-male, culturally homogenous sample was used.[18,19] This limits the degree to which the findings can be generalized to females, non-Caucasians, and cultures beyond those of the British Isles. Despite this, in terms of generalizability to females, extant research indicates that with a simple motor task as grip strength, the present findings are likely to generalize well.[5, 22, 32]

Based on the ANCOVA main effects for tempo and intensity, it was apparent that relatively large differences in grip strength were masked by the inclusion of the no-music grip-strength score as a covariate. The inclusion of a covariate removes a degree of freedom from the error term while not removing commensurate sums of squares for error and thus increases the likelihood of a type II error.[26 (pp 213–214)] A related point is that using a covariate measure that was not a baseline or pretask measure might be considered a statistical limitation.[26 (pp 202–203)] The control scores were taken within the counterbalanced design in order to facilitate two types of analysis (M)ANCOVA *and* (M)ANOVA. We were thus able to isolate the effects of the two independent variables (music tempo and intensity) using (M)ANCOVA but also able to conduct a comparison across all conditions by use of

(M)ANOVA.

Practical Implications of the Present Findings

It appears that the tempo of music and the intensity at which it is delivered have a strong bearing on subsequent motor performance and affective states. Practitioners might capitalize upon the present findings by using pretask fast/loud music to prime exercisers, particularly given that “not being in the mood” is an oft-cited reason for not attending exercise facilities.[35] The repeated use of a particularly apposite piece of music can also function as a conditioned stimulus and thus engender a positive mindset for a bout of exercise or training session.[3 (p 30)]

Sport scientists might apply the present findings to sporting endeavors that require gross motor skills, such as throwing events, weightlifting, or sprinting.[28] The influence of pretask music in sports that require fine motor skills, such as golf or darts, is uncertain and thus there is scope for more empirical research in this regard. Music can also be integrated into the pre-event routine of athletes so as to enhance their affective states and give them a sense of control over their immediate environment. Clearly, the selection of music needs to be sensitive to their needs and preferences.[19] There will also be contextual differences insofar as activities that require a relatively low level of psychomotor arousal, such as yoga or snooker, are likely to be adversely affected by fast/loud music. Moreover, the use of very loud music during exercise (e.g., > 85 dBA) is contraindicated as it can cause damage to the inner ear and, over time, result in conditions such as tinnitus.[36]

Perspectives

The present findings indicate a Tempo x Intensity interaction for grip strength but not the valence and arousal dimensions of affect, which were influenced by each of these musical qualities in a main effect. Fast/loud music may prove most efficacious in terms of enhancing performance in a simple motor task and engendering more positive affect, whereas slow/quiet music appears to have no effect when compared with a no-music control. There is now a need to assess the etiology of ergogenic effects in a more nuanced manner to discover precisely how they manifest. Qualitative work may provide one avenue for such learning.[37] A further vector for research efforts would be the selection of more complex motor tasks that present a greater cognitive load and therefore more closely resemble the movements undertaken by exercisers and sportspersons as part of their training regimens.[38] Finally, research that addresses the effects of music across an entire bout of exercise would be of considerable value, as this would lead to a fuller understanding of the impact that musical interventions might have on the realization of long-term physical performance and health-related goals.

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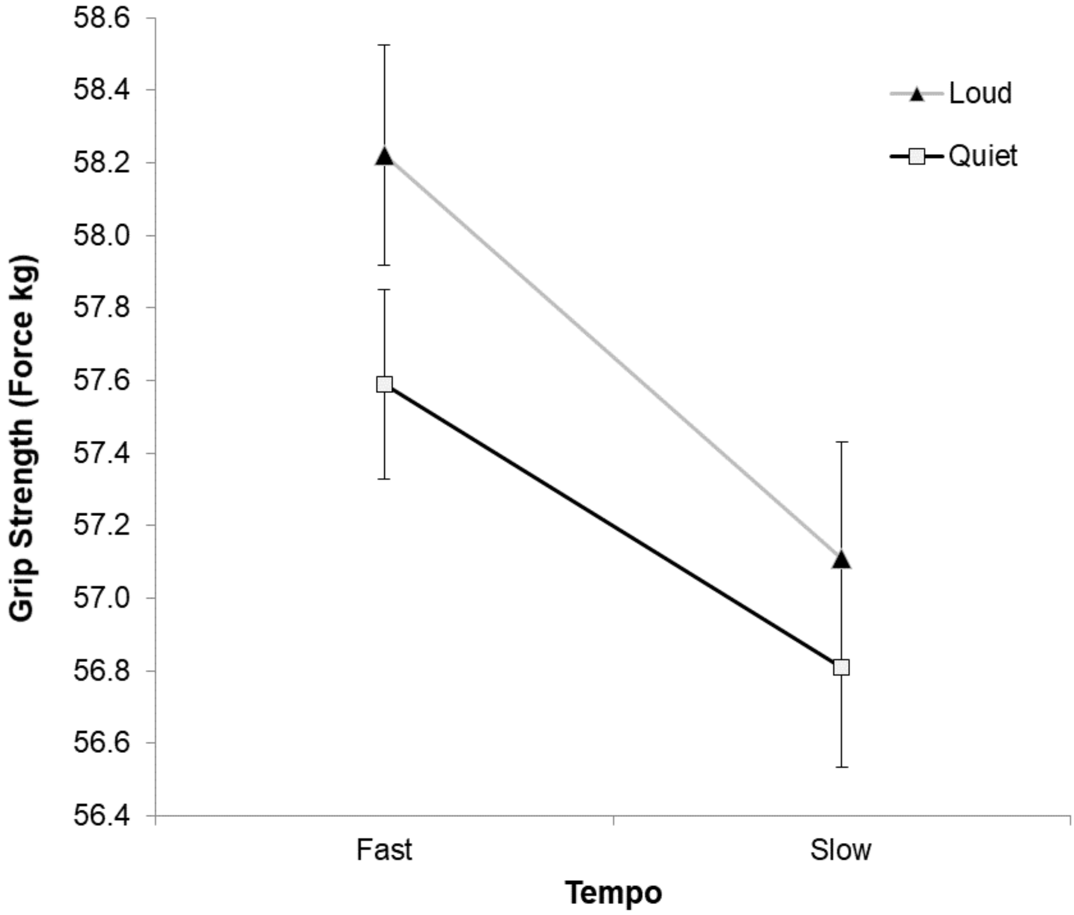

Fig. 1. Significant Tempo x Intensity interaction effect for grip strength (*P* = .011; $\eta_p^2 = .13$).

Note. The T-bars denote standard error.

Table 1. Descriptive statistics for dependent variables under each condition

Variable/Condition	*M*	*SD*	Std. Skew	Std. Kurt.
Grip strength				
Fast/Loud	58.22	5.38	-1.44	-0.57
Fast/Quiet	57.59	5.52	-1.84	-0.58
Slow/Loud	57.11	5.25	-0.96	-0.92
Slow/Quiet	56.81	4.91	-0.98	-0.64
No-music Control	56.64	5.47	-2.16*	-0.06
Affective valence				
Fast/Loud	7.10	1.22	-1.61	-0.32
Fast/Quiet	6.29	0.78	-0.95	-1.25
Slow/Loud	5.61	1.13	1.75	1.47
Slow/Quiet	4.92	1.03	1.84	0.57
No-music Control	4.98	0.86	1.29	0.54
Perceived activation				
Fast/Loud	7.18	1.37	-2.02*	-0.10
Fast/Quiet	6.06	0.93	-1.31	-0.46
Slow/Loud	5.47	1.12	-0.44	0.53
Slow/Quiet	4.57	0.94	0.72	-0.38
No-music Control	4.63	0.98	0.88	-0.01

*$p < .05$.

Supplementary File 1

Empirical Studies that Explored the Application of Music as a Form of Stimulant or Sedative Prior to a Motor Task

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