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Judy Edworthy^a & Hannah Waring^a

^a School of Psychology, University of Plymouth, Drake Circus, Plymouth, PL4 8AA, Devon, UK

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The effects of music tempo and loudness level on treadmill exercise

JUDY EDWORTHY* and HANNAH WARING

School of Psychology, University of Plymouth, Drake Circus,
Plymouth PL4 8AA, Devon, UK

This study examined the effects of loudness and tempo of background music on exercise performance. A total of 30 volunteers performed five 10-min exercise sessions on a treadmill. The music listened to whilst exercising was either fast/loud, fast/quiet, slow/loud, slow/quiet or absent. Measures of running speed, heart rate, perceived exertion and affect were taken. Significant effects and interactions were found for running speed and heart rate across the different music tempo and loudness levels. More positive affect was observed during the music condition in comparison to the 'no music' condition. No significant differences for perceived exertion were found across conditions. These results confirm that fast, loud music might be played to enhance optimal exercising, and show how loudness and tempo interact.

Keywords: Music; Exercise; Heart rate; Affect; Perceived exertion

1. Introduction

The beneficial effects of listening to music have been reported in a variety of applied settings. At the same time potential physiological and psychological properties of music has become an area of increased interest among sport and exercise enthusiasts. From an empirical point of view there are two main questions that need to be addressed. The first is the question as to whether music has any effect per se, that is, whether dependent measures (such as actual performance, heart rate, perceived exertion and other more subjective and affective dimensions) differ depending on whether participants perform exercise tasks in the presence of music or silence (or some other auditory stimulation such as noise). The second is a more specific question about the nature of the music itself. In this sphere, one of the key questions is that of whether fast (and usually loud) music has different effects than slow (usually quiet) music on either or both objective and subjective measures. When people exercise to music they typically select the former rather than the latter and this may in turn suggest something about the relationship between music and exercise performance, which can be explored empirically.

*Corresponding author. Email: jedworthy@plymouth.ac.uk

The research evidence suggests that the use of music affects a range of dependent variables during exercise. For example, a study by Szmedra and Bacharach (1998) showed that exercising while listening to music differed on several measures when compared to exercising in silence. They found that haemodynamic and lactate measures were higher in the no music than in the music condition, although there was no difference in oxygen consumption. Perceived exertion measures were also higher in the no music condition. They interpret their results as suggesting that music might allow participants to reduce muscle tension, thus increasing blood flow and consequently having a psychobiological impact on exercise. Thornby *et al.* (1995) tested exercising participants in the presence of music, no music and noise. They found that the time spent exercising, the amount of work done and heart rate were all significantly higher in the presence of music than in the other two conditions. By contrast, perceived exertion was lower in the music than in the other conditions. Perceived exertion was also greater in the no music than in the noise condition. Another study, where participants performed in a variety of conditions, (Nethery *et al.* 1991) found that perceived exertion while exercising in music was lower than for other attention distracters and for the no distraction condition. A more recent study by Nethery (2002) again showed that perceived exertion was lower in a music condition in comparison to exercising to no music, a video or in conditions of sensory deprivation. The most consistent finding seems to be that perceived exertion appears to be lower when participants exercise to music, which has been typically interpreted within an information-processing framework. The information-processing approach assumes that the exerciser has a limited attentional capacity; thus, by turning their attention away from exercise through some distracter (such as music), they are less able to attend to other influences (such as perceived exertion). Music, therefore, seems to be particularly effective in distracting the exerciser away from his or her perceived exertion. Its effect on actual performance and other physiological measures is perhaps less clear. An alternative explanation for this is that performance is aesthetically mediated, so that people's level of arousal and subsequent enjoyment of the task could be optimized by the use of music (Berlyne 1971).

Many of the studies that have compared music with no music control conditions have included more than one music condition on the basis that different types of music are likely to produce different effects. The main focus of interest here has tended to be the pace of the music, or the aesthetic preferences of the exerciser. There are a number of reasons why the pace (tempo or speed) of the music might be important in exercise. First, fast (and usually loud) music is typically chosen for use in aerobics classes (Karageorghis *et al.* 1999). This may suggest an aesthetic preference (fast music is typically more upbeat and positive in affect than slow music, thus inducing an appropriate mood). However, a second possibility is that fast music is more arousing and may therefore produce higher levels of performance. Third, it may be that the pace of the music influences the pace of exercise, meaning that fast music will produce (for example) faster running and cycling speeds (and other objective measures of exercise performance). All of these factors are possible explanations for any differential effects caused by music with different tempos. For perceived exertion measures, the effects across different types of music appear to be less clear cut than the contrast between the use of music and no music, as described above.

Szabo *et al.* (1999) subjected their participants to five conditions, including a control (no music) condition. They exercised while listening to fast or slow music, but also fast to slow and slow to fast interventions, where the pace of the music was slowed down or speeded up during the course of the exercise. The slow to fast condition produced

significantly higher workload, as well as better efficiency in terms of the workload/heart rate reserve ratio. The participants also preferred the fast, and slow to fast, conditions. Brownley *et al.* (1995) also compared performance in fast and slow music conditions, as well as a control condition. Their results showed an increased respiratory frequency during fast when compared to slow or no music. Their results also showed that under high workload conditions plasma cortisol levels were found for the fast music condition. They also found that untrained exercisers reported more positive affect when listening to fast music during both low and high intensity exercise. Becker *et al.* (1994) found that fast music produced a higher mileage on an exercise bicycle, whereas a further study (Becker *et al.* 1995) found that slow ('mellow') music produced a decrement in walking distance. Copeland and Franks (1991) measured heart rate, rating of perceived exertion (RPE) and time to exhaustion on a group of exercising participants who ran on a treadmill in three different music conditions: soft slow easy-listening music; loud fast popular music; and no music. They found that heart rate, time to exhaustion and rated perceived exhaustion were all lower for the slow, soft music than for the loud, fast music. This suggests that the loud, fast music was more arousing than the slow soft music and that the rate of exercise was influenced accordingly.

Anshel and Marisi (1979) also supported the supposition that music improved exercise performance, claiming in particular that synchronized movement to music increased bicycle endurance when compared to asynchronized movement to music or the absence of music. Karageorghis *et al.* (1999) also showed that aerobics instructors strongly favour synchronous music in classes. Thus, either directly or indirectly, faster music may improve performance, particularly for synchronized tasks or where athletes are not expected to perform maximally.

The few studies that have compared slow and fast music, however, have not typically explored another important acoustic parameter, loudness. Copeland and Franks (1991) compared loud, fast music with slow, quiet music as contrasting genres. Other studies have looked at fast and slow music at similar loudness levels (e.g. Becker *et al.* 1994, Brownley *et al.* 1995) and others have compared music with other auditory stimulants at the same loudness level, such as noise (e.g. Thornby *et al.* 1995). While the loudness of the stimuli is typically controlled (except in Copeland and Franks 1991) it might be expected that the loudness level of the music will have some effect on measures typically taken during exercise, as it is an additional source of arousal. Fast, loud music might, for example, produce higher levels of exercise performance (and associated measures) than fast, quiet music. Indeed, slow, loud music might have the same effect as fast, quiet music or the two might interact. In any case, it is important to dissociate the potential effects of loudness from the effects of speed and this has, by and large, not been done empirically. It is important from an applied point of view to look at both of these important acoustic variables.

There is evidence to suggest that louder sounds produce quicker movements. For example, in the area of auditory warning design, it is well known that louder auditory warnings produce faster reaction times and to some extent have physiological correlates (Burt *et al.* 1995, Haas and Casali 1995, Haas and Edworthy 1996). More generally, it is well established that increases in noise increase arousal levels (Jones and Broadbent 1987). Thus, it might be expected that loud music will also have an effect on increased heart rate and possibly exercise performance.

In terms of subjective measures, it is also known that both increased tempo and increased loudness increase perceived urgency of auditory stimuli, a finding that has been replicated over many studies (Momtahan 1990, Edworthy *et al.* 1991, Hellier *et al.* 1993). Perceived urgency is a subjective sound quality measure centrally important in auditory warning design. In exercise performance, the tempo of music might therefore be expected

to have an indirect effect on heart rate; faster tempos might induce faster movement, which in turn might induce faster exercise rates as well as higher physiological measures, such as heart rate. Louder stimuli might also be expected to produce higher objective measures because it is an arouser. Thus, whereas loudness might be expected to have a direct effect on exercise rate and heart rate, tempo might be expected to have indirect effects because it influences exercise speed.

The work of Berlyne (1960, 1971) also provides a useful backdrop for these studies as there are aesthetic issues about music choice, optimal arousal levels and preference, which could also underpin performance whilst exercising. Berlyne (1971) argued that pleasure can be evoked by a range of artistic stimuli, including music, and that the listener seeks an optimal level of arousal that is determined both by characteristics of the listener and of the stimulus. The relationship between arousal and pleasure is an inverted 'U', with very low or high values of arousal leading to low hedonic tone and values towards the middle having the greatest hedonic tone. This provides a theoretical backdrop in terms of explaining both why people might prefer to listen to music rather than to have silence and also why people have preferences for the use of different types of music whilst exercising. Berlyne argued that the most pleasurable stimuli, those with the greatest hedonic tone, represent some optimal level of arousal in the individual and that the optimal level is determined by the complexity and other 'collative' variables (Berlyne 1960) of the stimulus. For different listeners, the perceived complexity of a stimulus will differ depending on their experience or exposure to similar stimuli but the stimulus properties themselves have arousal potential, which may also follow an inverted-'U' function. For example, Berlyne (1971) cites evidence of an inverted-'U' function for the pleasurability of tones varying in loudness and pitch. Thus, a loud, high-pitched sound and a quiet, low-pitched sound may not be very pleasurable, but tones in between these two extremes may be more pleasurable. Although the study presented here does not look directly at preference, it does compare exercising with music to exercising in silence and it also uses two very different pieces of music, one of which can be confidently considered to be of lower arousal than the other.

In the current study a treadmill was utilized, whereby each participant was tested for a consistent 10-min period for each of five music conditions (loud/fast; loud/slow; quiet/fast; quiet/slow; and no music). A period of 10 min was selected as the exercise period so that the majority of participants could reach their peak and the music would have time to have an influence. Participants were also required to set the treadmill speeds to their own comfort zone. The musical selection consisted of two jazz pieces, one fast and one slow, each played at two levels of loudness. The pieces were by the same artist and were selected from music expected to be unfamiliar to the participants. The fast piece selected represented generally higher levels of Berlyne's 'collative' variables (surprisingness, novelty, complexity, ambiguity and puzzlingness) (Berlyne 1960) and could therefore be considered as more arousing.

The objectives of this study were to investigate the effects of the loudness and tempo of music on exercise performance, rated perceived exertion and affect responses in physically untrained male and female participants.

2. Method

2.1. Participants

A total of 30 volunteers (15 women, 15 men) between the ages of 18 and 63 years participated in this study. Participants were recruited using a sign-up sheet. They were

either Young Men's Christian Association (YMCA) gym members or undergraduate students at the University of Plymouth. Previous exercise experience was not recorded.

2.2. Materials

The music was played from recorded cassette tapes through personal headphones in four of the experimental treatments, with the other treatment being a no music condition where headphones were worn but nothing was played. One fast and one slow piece of music were selected from a CD of 'The Beiderbecke Connection' played by the Frank Ricotti Allstars (CD no. DN20CD; Dormouse DM20). The fast music stimulus was derived from 'Viva La Van' (measured at 200 beats per min (bpm)) and the slow music stimulus was from 'First Born's Lullaby' (measured at 70 bpm). Both selections were played at two different levels, the higher at approximately 80 dB at the ear and the other at approximately 60 dB at the ear. Both selections were approximately 2.5 min long, chosen as the shortest period for which no significant tempo change occurred in either of the pieces. This was then looped on to a tape several times, in order that it could play throughout each of the exercise periods.

All running trials were performed on a Life Fitness Treadmill 9/00 Flexdeck (Life Fitness UK Ltd., Ely Cambs., UK). Heart rate was monitored with a Polar (beat) heart rate monitor (Polar Electro Oy, Kempele, Finland). A stopwatch was used to record the timing of conditions to ensure that each lasted exactly 10 min. Two subjective scales, the feeling scale (Hardy and Rejeski 1989) and the RPE scale (Borg 1962) were displayed throughout each trial and participants' verbal ratings were recorded at 5-min intervals, beginning at the 5th min. The feelings scale assesses the affective dimension of the exercise experience ranging from 'very bad' to 'very good' (-5 to +5) and RPE summarizes exertion levels between rest and maximum effort (6 to 20). Numerous studies have demonstrated the suitability of these measures for assessing perceived effort during physical work (Hardy and Rejeski 1989).

Music was introduced in a manner intended to be inconspicuous, by waiting until the participants appeared to be engrossed in the running task during the warm-up stage before the music was started. The volume of the music started quietly on introduction and then built up to the required level over the period of a few seconds after introducing the music. This was done by setting the level of the music using a pre-marked visual indicator operated by the experimenter. The music was switched off after the 10-min period. The length of the test period was 10 min, excluding warm-up time.

2.3. Design

The experiment was a 2×2 within-subjects factorial design with an additional control condition. Participants carried out the exercise to each of the five experimental music conditions: loud/fast (80 dB/200 bpm); loud/slow (80 dB/70 bpm); quiet/fast (60 dB/200 bpm); and quiet/slow (60 dB/70 bpm); in the absence of music.

2.4. Procedure

The experiment took place in the YMCA gym. Participants took part in the study one at a time. A brief was handed to participants on a sheet of A4 paper. The brief included that the participants were free to withdraw from the study at any time, assured confidentiality and informed that an ethical committee had approved the study. All participants gave

their consent and signed the consent form. Concise instructions were read to participants, they were informed of the experimental procedure, the equipment and its function were described and any further questions were answered. The written instructions were as follows:

'The experiment consists of five separate conditions that will be run on different days at times arranged. For each condition you are required to run/walk on the machine at a pace at which you feel comfortable for a consistent ten minutes. You are required to wear the headphones throughout the experimental procedure, for each of the conditions the music might vary. There is also a control condition in which there is no music. You are required to wear a heart rate monitor that is placed around your middle, but before placing on your body the sensors need to be wet. The running machine will start working once you press the quick start button. I suggest that you have a warm-up period (of a few minutes) to get used to the machine and get to a pace at which you feel comfortable to perform the ten-minute run. I will start the stopwatch when you feel ready to begin the experimental procedure. The display of the running machine will be covered up. The adjustment of the speed of the treadmill is here [*experimenter points to control*] and you can increase or decrease the speed freely throughout the experiment.

Additionally, you will be required to respond to two scales after five minutes into the experiment and again just before the end. This will be completed whilst you continue to perform the experiment. Here are the instructions for the scales:

Ratings of perceived exertion (RPE) scale:

The RPE scale measures how hard you feel you are working. You are required to consider the total amount of exertion you feel, taking into account all sensations of physical stress, effort and fatigue in your whole body [*experimenter shows scale*]. The scale presents a 15-point scale ranging from very very light to very very hard. At five-minute intervals you are required to select the point that best represents how hard you are working.

Feeling scale:

While participating in exercise it is quite common to experience changes in mood. Some individuals find the physiological changes that take place during exercise as pleasurable, whereas others find it not pleasurable. Additionally, your feelings may fluctuate across time. A scale has been designed to measure such responses [*experimenter presents scale*]. The scale is presented as an 11-point bipolar good/bad format, ranging from +5 to -5. At five-minute intervals you are required to select the figure that best represents your feelings. I will tell you when you need to respond to this scale.'

Before each trial the heart rate monitor was attached around the participants' chest and after a 5-min rest period the heart rate measure was recorded by the experimenter (on a score sheet) as a baseline measure. At the beginning of the test sessions, participants were allowed a warm-up period on the treadmill to familiarize themselves with the equipment and the test environment. Participants were then exposed to each of the five

experimental conditions with an interpolated rest interval (ranging from 1 to 3 d) between each condition. The order of the conditions was counterbalanced across the participants. For each condition, participants were required to run/walk at a rate they felt comfortable with for a consistent 10-min period. Participants were informed they could adjust the speed of the treadmill throughout the experiment but there was no verbal encouragement given to increase or decrease their performance.

Participants were prevented from knowing the time during the run, how fast they were going or the end score of their run. During the final minute of each 5-min stage, heart rate and speed of the treadmill were recorded on a score sheet by the experimenter, who read the heart rate from the Polar heart rate monitor. Additionally, participants' verbal responses to the RPE scale and feeling scale were obtained whilst they continued to perform the experiment. The numbers were reported on paper as spoken by the participants.

3. Results

The results are divided into four sections: speed of the treadmill; heart rate; RPE; affect. The results of the 2(3) (time: start/5 min/end) \times 2 (music speed: fast/slow) \times 2 (music volume: quiet/loud) ANOVA is given for each of the four measures. This is followed by one-way repeated measures ANOVA, which include the control (no music) condition. The first of these shows the contrasting and interacting effects of the music variables while the second makes a direct comparison with the various music conditions and no music.

Mean and standard deviation values for these four measures, by experimental conditions, are summarized in table 1. The only measure for which there was a value before the experiment began was heart rate, and the means for these were recorded as 79.7 bpm (control), 81.4 bpm (slow/quiet), 79.1 bpm (slow/loud), 79.4 bpm (fast, quiet) and 82.8 bpm (fast, loud).

3.1. Speed of treadmill

A 2 \times 2 \times 2 (time: 5 min, 10 min; volume: loud, quiet; tempo: fast, slow) within subjects ANOVA was carried out. The analysis revealed a significant main effect of tempo

Table 1. Effects of music tempo and loudness on physiological and psychological responses (means and standard deviations) to treadmill exercise at 5 and 10 min.

Conditions		Fast/Loud		Fast/Quiet		Slow/Loud		Slow/Quiet		No music	
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Heart rate	5 min	162.8	21.87	159.1	18.98	155.97	20.55	157.87	16.19	157.83	18.54
	10 min	169.23	17.54	163.13	22.39	161.1	20.48	160.13	20.80	164.47	20.42
Speed	5 min	9.47	1.99	9.32	1.88	9.06	2.18	8.62	2.12	8.96	2.24
	10 min	9.69	2.09	9.37	1.99	9.03	2.07	8.98	2.20	9.04	2.35
Feeling	5 min	1.83	1.42	1.63	1.52	1.43	1.48	1.40	1.54	0.60	1.73
	10 min	1.17	2.0	1.17	1.88	0.77	1.43	0.73	1.53	0.20	1.63
RPE	5 min	12.23	1.3	11.9	1.77	11.67	1.65	11.67	1.69	12.43	2.14
	10 min	13.37	1.97	12.83	2.05	12.33	1.95	12.50	1.76	12.97	2.11

RPE=rating of perceived exertion.

($F_{1,29} = 5.66$, $p < 0.05$). Participants produced higher treadmill speeds when the music was fast (means were 9.46 km/h for fast speeds and 8.92 km/h for slow speeds). The effects of time and volume were not significant, although both approached significance.

A significant time \times volume \times tempo interaction emerged ($F_{1,29} = 6.57$, $p < 0.05$; figure 1). The results indicate that treadmill speed is faster with fast music than with slow music. However, the fast tempo music has little effect on treadmill speed over time when played quietly, whilst treadmill speed increased over time in the fast/loud condition. The slow tempo music increased speed over time if played quietly whilst there is little difference over time in the loud music condition. Further simple effects analysis examined the interaction between volume and tempo over time. The analysis revealed significant main effects showing that fast, loud music and slow, quiet music increased treadmill speed over time ($p < 0.05$). No other significant effects were revealed.

A one-way (repeated measures) ANOVA was run on treadmill speed at the 5 min measure. This tested the differences between the five conditions at the exercise midpoint and, in particular, tested the differences between the control and the music conditions. A significant difference between the conditions was found ($F_{4,116} = 3.194$, $p = 0.05$). Post hoc analysis revealed a significant difference between the fast/loud condition (9.47 km/h) and slow/quiet condition (8.62 km/h, $p < 0.05$; table 1). No other effects or interactions were significant.

3.2. Heart rate

A $3 \times 2 \times 2$ (time: 0 min, 5 min, 10 min \times volume: loud, quiet \times tempo: fast, slow) within subjects ANOVA revealed a significant main effect of tempo ($F_{1,29} = 7.27$, $p < 0.05$). Participants' heart rate was higher in the fast music conditions than in the slow

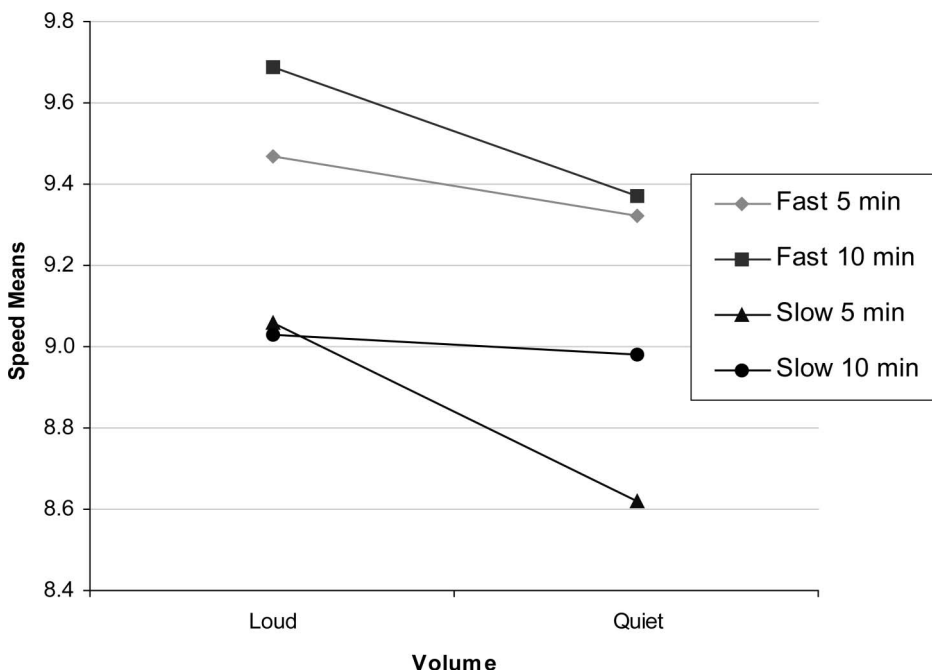


Figure 1. Time \times volume \times tempo interaction, treadmill speed data.

music conditions (table 1). Means for the two conditions were 163.57 bpm for the fast conditions and 158.76 bpm for the slow conditions. A main effect of time was also found ($F_{2,29} = 700.1$, $p < 0.001$). Participants' heart rate increased over time, giving means of 158.71 bpm after 5 min and 163.61 bpm after 10 min. No main effect was found for volume (means were 162.28 bpm for loud music and 160.06 bpm for quiet music).

A significant volume and tempo interaction emerged ($F_{1,29} = 4.71$, $p < 0.05$), as shown in figure 2. The results indicate that the effect of volume is dependent on the tempo of the music. There is a large effect of volume in the fast music conditions but not for the slow music conditions. A simple effects analysis showed that volume had a significant main effect in the fast music conditions ($F_{1,29} = 5.345$, $p < 0.05$). The effects of volume are non-significant in the slow music conditions ($F_{1,29} = 1.095$, $p = 0.304$).

The one way repeated measures ANOVA (including the control condition) was run on the heart rate after the 10 min measure (at the point when participants stopped the task). A significant difference between the conditions was found ($F_{4,116} = 3.22$, $p < 0.05$). Bonferroni *t* statistics were used to examine the mean comparisons between the five conditions and, in particular, tested the differences between the control and the music conditions. Post hoc analysis showed that heart rate levels were significantly higher ($p < 0.05$) when participants were listening to fast/loud music (169.2) when compared to slow/loud music (161.1) or slow/quiet music (160.1). No other significant differences were found.

3.3. Rating of perceived exertion

A $2 \times 2 \times 2$ (time: 5 min, 10 min, volume: loud, quiet, tempo: fast, slow) ANOVA revealed a significant main effect of time ($F_{1,29} = 35.32$, $p < 0.001$). Overall, RPE scores

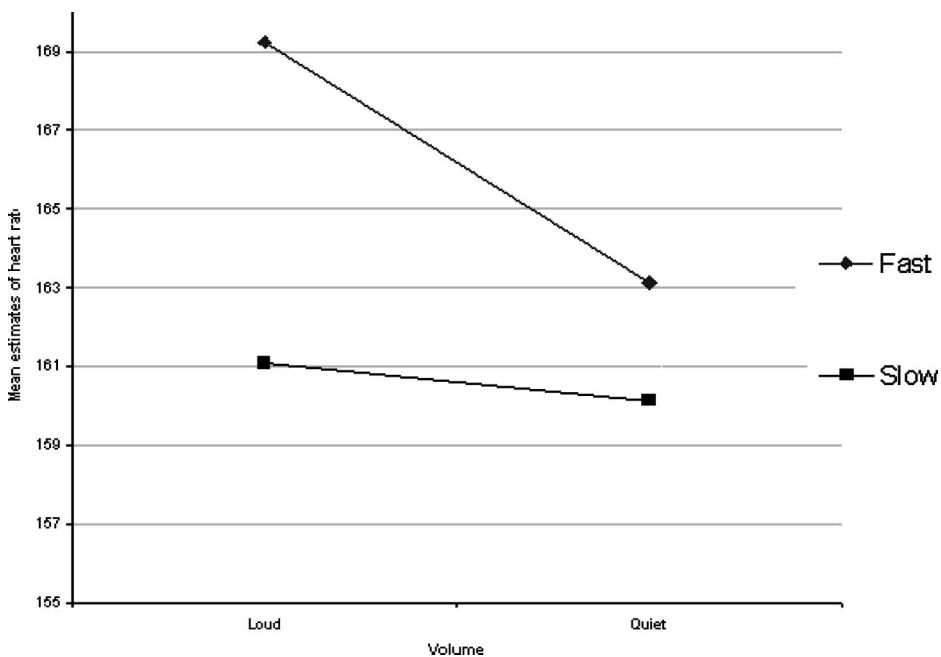


Figure 2. Volume \times tempo interaction, heart rate data.

increased between the readings taken at 5 and at 10 min. The mean RPE scores were 11.98 at the 5-min point and 12.8 at the 10 min point. There were no other significant effects.

The repeated measures one-way ANOVA (including the control condition) revealed no overall significant difference between the five conditions, although there is a pattern here whereby participants' RPE were highest in the fast music and no music condition and lowest in the slow music conditions (table 1).

3.4. *Feeling scale*

A $2 \times 2 \times 2$ (time: 5 min, 10 min, volume: loud, quiet, tempo: fast, slow) within subjects ANOVA on the experimental conditions revealed only a significant main effect of time ($F_{1,29} = 19.94$, $p < 0.001$). Mean feeling scores were higher after 5 min (mean 1.38) than after 10 min (mean 0.81). No other significant effects or interactions were found.

One-way repeated measures ANOVA on all five conditions (including the control) revealed an overall effect of feeling ($F_{4,116} = 3.1$, $p < 0.05$). Follow-up analysis showed that the control condition had a significantly lower mean score (mean 0.4) than any of the four music conditions ($p < 0.05$; table 1). Participants reported a more positive affect during all of the music conditions than they did during the 'no music' condition.

4. Discussion

The results of this study show that both the volume and the tempo of music, as well as the use of music per se, has effects on performance itself, heart rate and some subjective parameters. It also shows that volume and tempo of music interact in interesting ways. Looking at task performance first, the study shows that more than anything else the speed of the music affects the speed at which the participant runs: faster music produces faster speeds. Louder volumes do not produce faster speeds, although there is an interaction between treadmill speed, music volume and music tempo in that fast, loud music is particularly effective in increasing speed of running during the test period. Further analysis of the mid-trial condition (at 5 min) also indicated that performance was significantly better in the fast, loud condition in comparison to the slow, quiet condition. Thus, the speed, and to a lesser extent the loudness, of music increases the speed at which exercisers run. This would be expected to be mirrored in the heart rate data, which it is.

The heart rate data again revealed a significant effect for tempo. Faster music resulted in faster heart rates, as would be expected from the fact that people appeared to be exercising faster in those same conditions. The increase in heart rate can therefore be attributed to the greater treadmill speeds achieved during exercising to (in particular) fast, loud music. The results were again qualified by an interaction, this time between the two acoustic dimensions: volume and tempo. Volume has an effect in the fast music conditions but not in the slow music conditions. Thus, heart rate increases if the volume of fast music is increased, but not if the volume of slow music is increased. This, together with the main effect found for tempo, suggests that tempo is more important than loudness in increasing heart rate, but that at the higher levels of heart rate (fast music) increasing the volume can add a little more to heart rate. The effect for fast, loud music is mirrored in the treadmill speed measurements so it can be assumed that the increases in heart rate have come about because the participants were exercising more energetically. This in turn was a result of the music, and of the tempo of the music in particular.

Thus, it has been shown that the speed of music directly affects performance and heart rate. The added benefit of playing music loudly only appears to apply when music is played fast.

As far as the subjective measures are concerned, only time was found to be significant for perceived exertion. However, the ratings were highest for the fast, loud condition and the no music condition. The ratings for fast, loud music would be expected to be highest because this was the condition where participants did exert themselves most; however, they did not particularly exert themselves in the control condition, so this suggests that, in the absence of external stimulation, participants may focus more strongly on their own efforts and perceive them to be higher. Thus, in the no music condition they did not work harder, but perceived themselves to be working harder. Although the current results are not significant, they are to some extent in line with other findings and can be explained by two different mechanisms. In the loud, fast music condition the participants were running at faster speeds and produced higher heart rates. They thus correctly perceived themselves to be at higher levels of perceived exertion. In the no music condition, their rate of perceived exertion was relatively high given their exercise rate, which is in line with earlier findings. In loud, fast music conditions arousal levels may underpin performance, whereas in no music conditions an information-processing model may underpin performance on subjective measures, such as perceived exertion.

The present results also show some effects for affect. Analysis of the feeling scales showed that there was a significant effect of music vs. no music; in other words, participants enjoyed what they were doing more when they were listening to music of any sort when compared to when they were not. There was a trend towards reporting fast music in a more positive light than slow music, although this was not significant.

As the task that was set to the participants was potentially of a synchronous nature, speed might be expected to affect their performance rather more than loudness, as they will try to find a pace of running that fits with the music. This pace is likely to be faster with fast music than with slow music. With asynchronous tasks, the effect of loudness may be greater than that shown here. It is well known that increasing levels of loudness lead to increasing levels of arousal, which may be important for some sports but not particularly so for running, which depends more on the participant setting a pace with which they feel comfortable. While faster music can be used to manipulate this pace, it is hard to see how simple changes in loudness could have such effects. Indeed, the important factor with loudness may be audibility; if music is loud enough, increasing its loudness might not be of any great value, whereas if it is hard to hear, increasing its level will have a positive influence on performance. This is a topic worthy of further investigation.

The present results are consistent with those of the Copeland and Franks (1991) study, in which there was a lower heart rate for slow music than for fast music. However, Copeland and Franks failed to identify an increase in physiological responses in the fast, loud condition, which has been shown in the present study to have an effect in certain conditions. Moreover, this study looked at the effects of volume and tempo separately and has shown the extent to which they are independent and interact. The present results are also in accordance with Brownley *et al.* (1995), who found that fast music, compared with no or slow music conditions, increased physiological responses. This work also suggests that acoustic factors important in perceived urgency (e.g. Edworthy *et al.* 1991) can have physiological correlates, especially in synchronous tasks. Future work could look at the disentanglement of volume and speed in more detail for a range of sports activities and other tasks. Other acoustic dimensions, such as pitch, might be expected to also affect some aspects of the tasks.

The present data also support the proposed dichotomous effect of slow and fast music on exercise affect in participants. Results revealed responses were higher (more positive) for affect during fast music conditions than in the slow music conditions. The positive effects of music on affect support prior research that has demonstrated that music is effective in producing positive feelings during exercise (Boutcher and Trenske 1990). However, the issue as to whether or not to listen to music at all may be a different one from that as to which type of music to listen to: listening to music appears to improve people's enjoyment of the task, but certain types of music appear to aid performance better than others. Thus, there may be separable issues concerning aesthetics and pace-setting, which could be explored in future research.

The present study failed to replicate significant differences of perceived exertion in the different music conditions. However, variations in participants' exercise experience may have been a mediating factor on RPE and affect responses. Brownley *et al.* (1995) suggest that trained and untrained participants respond differently to music stimuli. It has been reported that untrained participants derive greater psychophysical benefits from music, whilst trained participants experienced a disruption of their internal focus in the presence of music. In the current study, participants' physical fitness and exercise was generally that of an untrained athlete and so they might be expected to be influenced by music.

As well as being interpretable within an information-processing framework, the data can to some extent be interpreted within an aesthetically mediated framework. Although the stimuli in the present study represented different levels of complexity in terms of Berlyne's (1971) theories, there is no way of knowing what levels of arousal (and corresponding hedonic tone) that the specific stimuli used in this study represent, as the inverted 'U' is determined by absolute stimulus values rather than relative stimulus values. Because it would be impossible to determine average values of, for example, pitch and loudness, in these stimuli it was not possible to make specific predictions in this area. However, it is certain that the slow music and the quiet music would be less arousing than the fast and the loud music, and that the loud, fast music was the most arousing and the slow, quiet music the least. It might therefore be expected that there would be some effects over the 10-min duration of the study as the lowest arousing music might slowly creep up the inverted 'U', whereas the most arousing music might quickly fall from optimal to a level of over-arousal. There is some indication in the data that this did indeed occur. For example, the interaction between time, volume and treadmill speed showed (among other things) that treadmill speed slowly increased over time in the quiet, but not in the loud, condition. This suggests that levels of arousal were slowly reaching optimal level over the duration of the study. However, there are some other more compelling effects that suggest that aesthetic preference had an impact in this experiment. The treadmill data also show that speed increased over time in the loud conditions (which goes against a straightforward explanation that it is simply the arousing qualities in the music that are determining performance). Heart rate also was highest in the loud, fast condition and lowest in the slow, quiet condition. In terms of the aesthetics of music, loud is more compatible with fast than it is with slow music, and quiet music is more compatible with slow than with fast music. Indeed, in the original performances the fast music was much louder than the slow, which was originally played quietly. So in terms of aesthetics alone, the loud/fast and the quiet/slow versions of the stimuli were the most aesthetically 'correct' and, it can therefore be assumed, more pleasing. According to Berlyne, stimuli with the greatest hedonic value tend towards an optimal level of complexity and novelty and should therefore lead to the greatest pleasure ratings. If it is assumed that the participants adjusted their pace to fit with the music, and that this pace was the most

appropriate pace, then this was done more successfully when the music was aesthetically satisfying rather than sounding unusual in some way. However, this is a matter of some speculation and would benefit from further study.

In terms of more simple relationships between arousal, performance and music, no differences between the control condition and the music conditions were found for the speed and heart rate data. However, the subjective data show some interesting findings. The RPE was highest for the fast, loud and the control conditions. Whereas exertion was actually higher in the fast, loud condition (so perceived exertion would be expected to be higher), it was not for the control condition. The feeling data also showed that the control condition produced the lowest score. Both of these subjective measures suggest that the least arousing condition was the least enjoyable. One assumption that can be made is that the participants in this condition were at a low, suboptimal level of arousal (Berlyne 1971).

One issue that was not considered in this study was that of preference. As the music selection was made by the experimenters on the basis of music speed, it is quite possible that some of the participants did not like the music being played and would have picked something quite different if left to make their own choice. This is important as individual and preference factors are also known to be important in exercise performance (e.g. Dwyer 1995, Karageorghis *et al.* 1999, North and Hargreaves 2000), which in turn may have led to some of the participants exercising less optimally than others. Individual preferences may also have affected the overall feeling measure, which although likely to be due mostly to the exercising itself could also have been partially attributed to the music used. The data collected in this study do not allow any detailed investigation of the potential effects of preference on performance, but it is quite possible that preference would have had some effect, particularly if the findings presented here are to any extent aesthetically mediated, which they appear to be.

A final further issue that requires some consideration is that in this study participants were allowed to set their own treadmill speed and were requested to run at a speed with which they felt comfortable. It was assumed that participants would interpret this instruction as meaning that they should run at a pace that was commensurate with their current level of fitness. The main reason for allowing this is that participants inevitably would have had different levels of fitness and so to set a fixed speed for the treadmill would not have been acceptable from an ethical viewpoint and would be unsatisfactory from an experimental viewpoint, as the effects of the different stimuli on running speed and the related variables tested here was the main focus of the study. However, allowing participants to set their own speed, while being preferable to having fixed speeds, is not without its own problems. For example, allowing participants to set their own speeds leads to the potential for participants to have different workloads, which in turn might have affected their reactions to the stimuli tested. For example, participants exercising sub-optimally may have reacted differently to loud, fast music than those who were already working at full capacity (North and Hargreaves 2000). As there is no way of knowing the participants' relative workload in this study, it is not possible to address this issue. However, it is an issue that requires attention experimentally as well as the development of experimental paradigms that are able to get round this potential source of confounding.

Being able to manipulate physiological and psychological elements of how exercise is conducted may affect how the novice exerciser succeeds in the long term. Including fast, loud music in the exercise programme of untrained individuals should produce a corresponding increase in physiological responses. The inclusion of slow, quiet music should be considered for individuals if they wish to reduce physiological responses, which may help individuals prolong exercise endurance. Additionally, slow, quiet music could

be utilized by individuals who need to maintain a lower heart rate due to medical conditions or have been advised to exercise at a moderate pace. Music offers individuals a way to improve their exercise programmes and eventually their quality of life.

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