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Effect of Background Music on Maximum Acceptable Weight of Manual Lifting Tasks

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This study used the psychophysical approach to investigate the impact of tempo and volume of background music on the maximum acceptable weight of lift (MAWL), heart rate (HR) and rating of perceived exertion (RPE) of participants engaged in lifting. Ten male college students participated in this study. They lifted a box from the floor, walked 1–2 steps as required, placed the box on a table and walked back twice per minute. The results showed that the tempo of music had a significant effect on both MAWL and HR. Fast tempo background music resulted in higher MAWL and HR values than those resulting from slow tempo music. The effects of both the tempo and volume on the RPE were insignificant. The results of this study suggest fast tempo background music may be used in manual materials handling tasks to increase performance without increasing perceived exertion because of its ergogenic effect on human psychology and physiology.

background music   manual materials handling   psychophysics
maximum acceptable weight of lift   tempo

1. INTRODUCTION

With the increase in automation in industry, many strenuously physical workloads have been eliminated. However, manual materials handling (MMH) tasks are still very common and important in workplaces. It has been shown that physical and mental stress imposed by MMH results in occupational musculoskeletal disorders and injuries [1, 2, 3, 4]. To ensure MMH tasks do not exceed the capabilities of workers, many studies provide guidelines and criteria based on biomechanics, physiology and psychophysics [5, 6, 7, 8]. The maximum acceptable weight of lift (MAWL) is widely accepted as an index for safe loads. Factors affecting the MAWL of material handlers have also been investigated [9, 10, 11, 12, 13, 14, 15, 16].

Background music has a good regulating effect on human psychology and physiology. However, very few studies have examined its influence on MMH tasks. Music has widely been applied to enhance performance in precompetition preparations, postexercise recovery and during submaximal and maximal exercise in the field of exercise and sports. Considerable studies have shown an ergogenic effect of music on the intensity of exercise [17, 18, 19]. Szmedra and Bacharach found that exercising in the music condition was conducive to a person's haemodynamic and lactate measure in contrast to no music [20]. They concluded that music had a beneficially psychobiological impact on exercise since it could relax the participants and reduce muscle tension thereby increasing blood flow and lactate clearance in the working muscles. On the other hand, some studies have compared the ratings of perceived exertion (RPE) in the music condition to that of no music or noise control conditions and found that the RPE was lower in the music condition than in the other ones [21, 22, 23]. Music may be regarded as an external stimulus which requires attention resource and is processed in our information-processing system. Human attention capability is limited. During exercise and sports, music as a useful distracter can switch the attention away from physiological cues (perceived exertion) to external musical cues. Thus,

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perceived exertion could be reduced when there is music. Based on this rationale, Barwood, Thelwell and Tipton used the intervention of psychological skills training (mental imagery and positive self-talk) to enhance exercise performance [23]. In their study, the participants ran in hot and humid conditions. The psychological skills successfully facilitated performance by distracting the participants from unpleasant sensations elicited by the poor atmosphere environment.

In addition to the presence of music, many studies identified the impact of music tempo on exercise performance, physiological and subjective responses [22, 24, 25, 26]. For example, Waterhouse, Hudson and Edwards requested the participants to cycle at self-chosen rate while listening to a program consisting of six popular music tracks of different tempos [26]. They found that high tempo music made the participants cycle harder and enjoy cycling more. In Edworthy and Waring, fast music was associated with fast treadmill exercise speed [22]. Their conclusion was that, in comparison with slow music, fast music with intrinsic and artificial tempos enhanced the rate of exercise, and physiological and subjective responses.

Most studies on the relationship between music and exercise performance were conducted under the condition that the volume of the music stimuli was controlled. Boutcher and Trenske found that positive effects of music on the RPE of physical activity might decrease during high intensity exercise above the anaerobic threshold [27]. Their explanation was that the effects of music on the RPE depended on the relative strength between music acting as an external distracter and physiological cues. When physiological cues were more salient than music cues, the effects of music were not significant. However, the influence of music could take effect when the strength of external music cues was strong enough to exceed that of physiological cues. Hence, as an important factor, music volume was investigated based on the fact that an increase in noise volume increases arousal levels [28]. It is possible that the strength of external music cues can be increased by increasing the volume of the music. Recent evidence has shown that volume level and its interaction with music tempos have significant effects on running speed and heart rate (HR) [22].

Up to now, research on the effect of background music tempo and volume level on MMH and associated physiological responses was rare. If a specific music tempo and volume combination is conducive to physiological parameters of a person performing an MMH task, it can be applied at workstations with MMH tasks. Thus, materials handlers could accept more workload without an increased sense of effort, fatigue and discomfort. Therefore, the aim of this study was to investigate the effects of the tempo of background music and volume level on the MAWL, HR and RPE of MMH tasks.

2. METHODS

2.1. Participants

Ten male college students participated in this study. They did not have any musculoskeletal disorders. Their mean (*SD*) age, height, weight, knee height, elbow height and knuckle height were 21.6 (0.7) years, 171.1 (7.1) cm, 65.2 (5.2) kg, 50.3 (1.8) cm, 110.3 (5.8) cm and 69.6 (3.3) cm, respectively. All the participants signed an informed consent before joining the experiment.

2.2. Apparatus and Material

A 35 cm (length, frontal plane) × 25 cm (width, sagittal plane) × 23 cm (depth) plastic box with a false bottom and two cutout handles 6 cm from the top was used for this experiment. The cutouts were oval with a semicircular end; they were 11.5 cm long. During the experiment, the weight of the box was adjusted with metal weights and plastic bottles filled with water. The metal weights were either 1.00 or 0.75 kg. Eight different bottle weights (0.1, 0.2, 0.3, 0.4, 0.5, 1.0, 1.5 and 2.0 kg) were prepared prior to the experiment. The participants were allowed to add or remove different weights for rough and fine adjustment of the weight of the box. The total weight of the box and the weights placed inside the box were measured after each trial and the total weight at the end of the trial was recorded as the MAWL. The participants' HR was monitored with a POLAR® Vantage XL (Finland) HR monitor.

Music of two different tempos was used as background music in this experiment. The music was selected from the album "I'm not dead" produced by the American singer Pink. The music selected was of the pop genre. The song "Leave me alone" (measured at 150 beats per minute, bpm) was chosen to be the fast tempo piece in the experiment and the song "Nobody knows" (measured at 70 bpm) was chosen to be the slow tempo piece. Background music was played in a single laboratory room on an iPod Touch connected to speakers. The volume of background music was measured with an AZ8928 sound level meter (AZ Instrument, China) and was fixed at either 60 or 80 dB. Both pieces were ~2.5 min long to ensure that there was no significant variation in tempo for the duration of a piece. The selection for each piece of music was then looped to ensure that it would play continuously throughout the duration of the experiment.

2.3. Experimental Design

A 2 × 2 within-subject factorial design with an additional control condition was used for this experiment. The independent variables were the volume and the tempo of background music. Each independent variable had two levels: high (80 dB) and low volume (60 dB), and fast (150 bpm) and slow tempo (70 bpm). The dependent variables were the participants' MAWL, HR and RPE. In addition, a no background music condition was included as a control condition. Therefore, all participants performed manual lifting tasks under five different experimental conditions: fast tempo/high volume, fast tempo/low volume, slow tempo/high volume, slow tempo/low volume and no music. The order in which the participants experienced the different conditions was randomized. On any given day, each participant joined only one experimental condition to prevent the effects of muscular fatigue. The total duration of the experiment was one week. During the experiment, the participants were required to wear comfortable shoes and clothing. The ranges of the relative humidity and temperature in the laboratory were 45%–56% and 23–27 °C, respectively.

2.4. Experimental Tasks

The participants were first instructed to stand on a starting spot on the floor and lift a box on the floor to approximately knuckle height (70 cm above floor level) using both hands. The box was placed in front of the participant; the horizontal distance from the center of the box to the ankles was ~50 cm. When lifting, the participant was encouraged to use whatever body posture he felt comfortable in. The participant was required to grip the handles on the box while lifting to achieve good coupling quality. Then he walked one or two steps as necessary and placed the box on a 70-cm-high table in front of him. The horizontal distance from the table to the starting position of the ankles was ~85 cm. A lab assistant then returned the box to its original location after the lift. The lifting frequency was two per minute.

2.5. Experimental Procedure

Before the experiment, the participants' resting HR was measured. A training session was arranged for the participants so that they were familiar with the lifting procedure and learned to use psychophysical methods to determine the MAWL [29]. The participants were also asked to balance the remaining weights in the box when adding or removing weights, to avoid a change in the gravity center of the box and the movement of the weights in the box.

For every lifting task, the initial weight in the box was randomly determined, and the weights were placed in the false bottom of the box to eliminate visual cues that might affect the participant's determination of the MAWL. During the trial, the experimenter looped a particular selection of music corresponding to one of the five experimental conditions. There was no music in the control condition. At the beginning of the task, the participant engaged in warm-up exercises for 5 min. Then, he was free to adjust the weight of the box to arrive at the maximum weight that he could handle for a relatively long period of time without feeling excessively tired, overheated, weakened or out of breath. The participant's physical condition slowly reached a stable state during this period. This session lasted ~20 min. Immediately after this session, the participant conducted a lifting task handling the MAWL that had just been determined for 10 min. His HR was monitored using a HR monitor during this period. The HR monitor recorded HR every 5 s. The mean HR over this period was used for further analysis. At the end of this session, background music stopped and the participant immediately rated perceived exertion on his leg, arm, wrist, low back and whole body using Borg's RPE scale [30].

3. RESULTS AND DISCUSSION

Table 1 summarizes the mean (*SD*) for the MAWL, HR and RPE for the five experimental conditions. The means of resting HR for no music, high volume/fast tempo, high volume/slow tempo, low volume/fast tempo and low volume/slow tempo conditions were 68.9, 67.7, 68.3, 67.7 and 68.6 bpm, respectively. The data was analyzed using a 2 (tempo) × 2 (volume) analysis of variance (ANOVA) for the MAWL, HR and overall RPE to study the effects of tempo and volume on each indicator.

3.1. MAWL

The one-way ANOVA results revealed that the mean MAWL varied significantly (F = 2.63, $p < .05$) for the five music conditions. Post hoc analyses showed that the MAWL in the fast tempo/high volume condition (15.08) was significantly ($p < .05$) higher than in the slow tempo/high volume (12.17), slow tempo/low volume (12.00) and no music (12.18) conditions. However, the difference in the MAWL between fast tempo/high volume and fast tempo/low volume conditions was not statistically significant. A 2 (tempo) × 2 (volume) within-subject ANOVA was carried out on the MAWL. The results showed that the main effect of tempo was significant (F = 7.62, $p < .05$). The MAWL for participants exposed to fast tempo music was higher than that of participants exposed to slow tempo music (M_{fast} = 14.35, M_{slow} = 12.09; $t(38)$ = 2.86, $p < .05$). This implies that the participants could lift more weight in fast tempo music conditions than in slow tempo music conditions. As expected, the fast music tempo was more conducive to the performance of MMH tasks than slow tempo, which is consistent with the results in the literature [22, 26].

Table 1 shows that the mean MAWL for both slow and fast tempos in the low volume condition was lower than that in the high volume condition (M_{slow} = 12.00 versus 12.17; M_{fast} = 13.61 versus 15.08). Even though the level of volume positively enhanced the participants' MAWL, the difference between low and high volume was not significant. The possible reason may be that low volume music was salient enough to distract the participants' attention since it was revealed in

TABLE 1. Means and Standard Deviations of Dependent Variables Under Experimental Conditions

	Fast Tempo/ High Volume		Fast Tempo/ Low Volume		Slow Tempo/ High Volume		Slow Tempo/ Low Volume		No Music	
Variable	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
MAWL (kg)	15.08	2.40	13.61	2.53	12.17	2.48	12.00	2.60	12.18	2.90
HR (bmp)	111.40	9.48	108.50	9.61	90.80	9.31	90.60	9.03	93.40	12.69
Overall RPE	10.58	1.73	10.40	2.00	9.87	0.96	9.88	1.28	10.63	1.15
Whole body RPE	10.80	1.69	10.50	1.84	9.90	1.10	10.20	1.48	10.90	1.85
Wrist RPE	10.20	1.69	10.00	2.49	9.50	1.51	9.70	1.89	10.60	1.78
Arm RPE	10.40	2.68	10.40	2.72	9.50	1.90	9.30	1.42	9.90	1.45
Shoulder RPE	10.50	2.27	10.10	2.23	9.50	1.58	9.40	1.35	9.80	1.40
Leg RPE	10.20	1.87	10.00	2.00	9.30	1.16	9.70	1.42	10.40	1.58
Low back RPE	11.40	1.58	11.40	2.12	11.5	1.18	11.00	1.41	12.20	1.62

Notes. MAWL = maximum acceptable weight of lift, HR = heart rate, bmp = beats per minute, RPE = rating of perceived exertion.

most trials that the RPE was under or equal to a light workload level (13.00).

The interaction between volume and tempo on the MAWL was not significant (Figure 1). Noticeably, it indicated that the effect of tempo on the MAWL depended on the volume of the music. Tempo significantly affected the MAWL in the high volume conditions (M_{fast} = 15.08, M_{slow} = 12.17; $t(18) = 2.66$, $p < .05$) but not in the low volume conditions (M_{fast} = 13.61, M_{slow} = 12.00; $t(18) = 1.40$, $p > .05$). Therefore, fast music tempo positively enhanced the MAWL. This was especially prominent when music volume was high.

3.2. HR

Table 1 shows that the mean HR for conditions of fast tempo/high volume, fast tempo/low volume, slow tempo/high volume, slow tempo/low volume and no music were 111.4, 108.5, 90.8, 90.6, 93.4 bmp, respectively. Comparing with resting HR, these values have an increase of 64.55%, 60.27%, 32.94%, 32.07% and 35.56%. The one-way ANOVA revealed that the mean HR varied significantly for the five different music conditions ($F = 10.10$, $p < .05$). Figure 2 illustrates the comparisons in mean HR between the four experimental conditions (different combinations of tempo and volume) and the control condition (no music). Post hoc analyses showed that the mean HR for the fast tempo/high volume condition (111.40 bmp) and fast tempo/low volume condition (108.50 bmp) was significantly ($p < .05$) higher than the mean HR for the slow tempo/high volume (90.80 bmp), slow tempo/low volume (90.60 bmp) and the no music condition (93.40 bmp). However, the difference between the fast tempo/high volume and fast tempo/low volume conditions was not significant.

A 2 (tempo) × 2 (volume) within-subject ANOVA was carried out on HR. The results showed that tempo had a statistically significant ($F = 36.22$, $p < .05$) effect on HR, while the effects of volume and the interaction between tempo and volume were not statistically significant. The HR for the participants exposed to fast tempo music was higher than for those exposed to slow tempo music (M_{fast} = 109.95, M_{slow} = 90.70; $t(38) = 6.64$, $p < .05$). Based on these HR results, we can infer that the participants' HR was higher in the fast tempo music condition due to the fact that a higher MAWL was obtained for this condition, thus requiring a higher expenditure of energy during the lifting process. It is concluded that

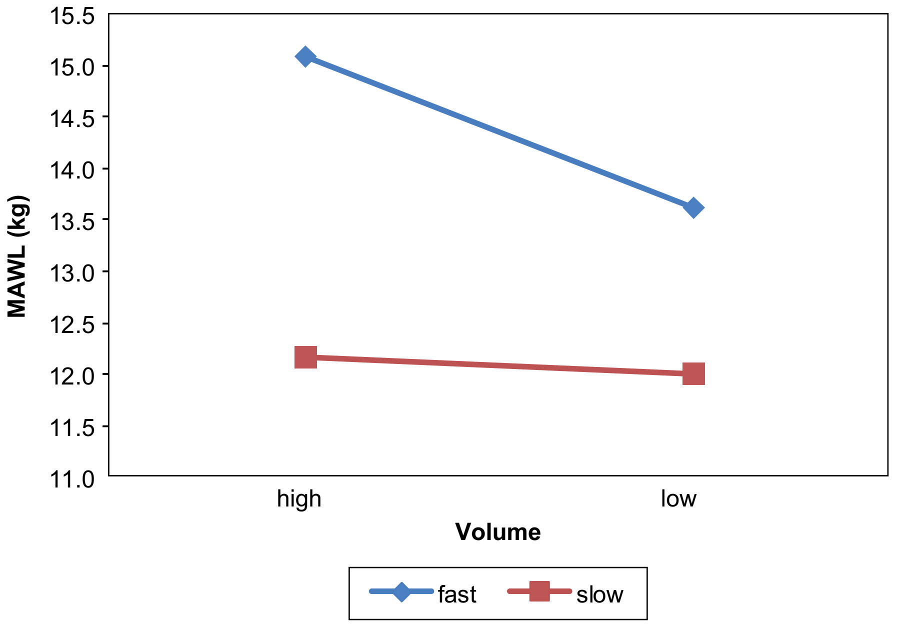

Figure 1. Maximum acceptable weight of lift (MAWL) as a function of tempo and volume.

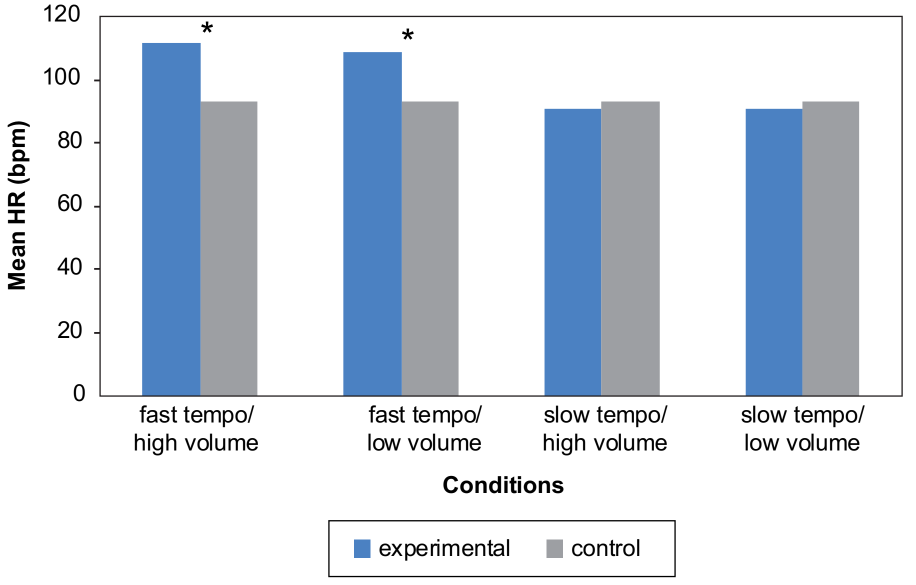

Figure 2. Comparisons in mean heart rates (HRs) between experimental and control conditions.
Notes. * = significantly different values at α = .05.

music tempo had a direct effect on the participants' MAWL and HR.

3.3. RPE

Table 1 shows that the RPE values of the low back for the participants were the highest in all body parts under the five music conditions. The possible reason was that significant stress was imposed in the low back during the lifting tasks and considerable compressive forces could be generated on the vertebral bodies in the low back region during the lifting tasks. However, the ANOVA results showed that the RPE for all body parts did not vary significantly under the five music conditions ($p > .05$). The low back RPE values under the five music conditions ranged from 9 (*very light*) to 16 (between *hard* and *very hard*), and the mean (*SD*) was 11.50 (1.59). These results indicate that the workload imposed on the participants was not the same, which is consistent with the results in the literature [31, 32]. In addition, the RPE values in most trials were under or equal to 13, indicating that most participants preferred to select light workload for MMH tasks in an 8-h work shift. This result is consistent with Wu and Chen's [33].

By averaging the values of the RPE for all body parts, an overall RPE value for the five music conditions was obtained. A 2 (tempo) × 2 (volume) within-subject ANOVA was carried out on the overall RPE. The results did not reach the .05 significance level. Those results indicate that tempo has a positive influence on the MAWL and HR but not on the whole-body RPE. Under the fast tempo/high volume music condition, the increased arousal level could have enhanced the actual work performance and so the participants could lift heavier loads than those under the no music condition. The participants under the fast tempo/high volume music condition should experience a relatively high RPE resulting from the heavier loads handled. However, perceived exertion rated by the participants under the fast tempo/high volume condition was not higher than that under the no music condition. This is consistent with Edworthy and Waring [22]. The probable reason lies in music distracting the limited attention capability of a person away from physiological cues (perceived exertion) to external musical cues. Thus, the material handler's perceived exertion was lower.

4. GENERAL DISCUSSION

The obtained results showed the participants' higher capabilities for the MAWL when fast tempo music was present. However, in step with higher MAWL, HR was also higher. Theoretically, higher

MAWL means higher exertion of a participant while higher HR reflects higher energy consumption. Thus, the RPE, as the subjective measure of exertion, should increase with an increase in the MAWL and HR. However, the obtained RPE values did not increase with an increase in the MAWL and HR. This phenomenon was also found in some other similar studies [21, 22, 23]. This means that the presence of the music decreases the feeling of fatigue but not fatigue itself.

Although the presence of music was to some degree able to increase blood flow and lactate clearance in the working muscles [20], the obtained results that higher MAWL led to higher HR in this study revealed that the presence of music did not reduce the workload of a participant. Music as a useful distracter only could attract part of a participant's attention from perceived physiological exertion. Therefore, by applying music adjustment in MMH tasks, the decrease in workload and fatigue levels merely occurs in spirit and there is no dramatic decrease in physiological workload or fatigue. If the workload is within a worker's capability, it is a good means to use music adjustment in MMH tasks. On the one hand, a worker's performance will be enhanced because of the worker's higher capability for the MAWL. On the other hand, the feeling of fatigue will decrease. However, if the workload exceeds a worker's capability, the worker will still be at risk for occupational musculoskeletal disorders. In short, whether or not music adjustment is used, to prevent workers involved in MMH tasks from suffering any occupational injuries, the workload in those tasks must meet the guidelines and criteria based on workers' biomechanics, physiology and psychophysics.

The obtained results also revealed that the values of HR and RPE were lower in the conditions of slow tempo music than that in the no music condition when the workload (MAWL) was almost same. This implies that slow tempo music might help a worker prolong MMH endurance by reducing physiological responses.

One factor that was not considered in this experiment was the participants' personal aesthetic preferences. As the music used in this experiment was chosen beforehand according to the tempo requirements, it is possible that some participants did not like that music and would probably chose a different genre of music if they had the opportunity. A few studies pointed out that participants' music preference had an important influence on their exercise performance [34, 35, 36]. It is possible that some participants exhibited poor exercise performance because they did not like the music. From the experimental data, the presence of background music does increase the MAWL or reduce the participants' RPE, but we can also postulate that certain music genres will produce a more positive effect and greater improvement in the participants' mood as compared to other genres. This will be a topic of a future study.

5. CONCLUSION

This study used the psychophysical approach to investigate the effects of tempo, volume and presence of background music on the MAWL, HR and RPE of participants engaged in manual lifting. The results indicate that tempo has a significant effect on both the MAWL and HR. Fast tempo music resulted in a higher MAWL and HR than the slow tempo and no music conditions. Volume and the interaction between tempo and volume did not have a significant effect on the MAWL and HR. For the different conditions, the MAWL and HR for the fast tempo/high volume condition were highest. An increase of 23.81% in the MAWL and 19.27% in HR were found for the fast tempo/high volume condition as compared to those in the no music condition. Regarding the RPE, no main effects were found for tempo, volume or their interaction. In short, the results of this study show materials handlers could accept more workload without an increased sense of effort, fatigue and discomfort in the music conditions.

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