Listening to Music in the First, but not the Last 1.5 km of a 5-km Running Trial Alters Pacing Strategy and Improves Performance

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Abstract

We examined the effects of listening to music on attentional focus, rating of perceived exertion (RPE), pacing strategy and performance during a simulated 5-km running race. Fifteen participants performed two controlled trials to establish their best baseline time, followed by two counterbalanced experimental trials during which they listened to music during the first (M_{start}) or the last (M_{finish}) 1.5 km. The mean running velocity during the first 1.5-km was significantly higher in M_{start} than in the fastest control condition ($p < 0.05$), but there was no difference in velocity between conditions during the last 1.5 km ($p > 0.05$). The faster first 1.5 m in M_{start} was accompanied by a reduction in associative thoughts compared with the fastest control condition. There were no significant differences in RPE between conditions ($p > 0.05$). These results suggest that listening to music at the beginning of a trial may draw the attentional focus away from internal sensations of fatigue to thoughts about the external environment. However, along with the reduction in associative thoughts and the increase in running velocity while listening to music, the RPE increased linearly and similarly under all conditions, suggesting that the change in velocity throughout the race may be to maintain a same rate of RPE increase.

Keywords: Perceived Exertion; Attentional Focus; Fatigue; Sports Performance.

Introduction

During 5-km running races, athletes naturally choose a pacing strategy that can be described as a fast start, followed by a gradual decline in velocity and an "end spurt" during the last meters of the race [14]. Previous studies have hypothesised that pacing strategy might be based on the rating of perceived exertion (RPE), so as to ensure that a maximal RPE is not reached before the end of exercise [32]. This assumption is based on the supposition that RPE is part of a regulatory motor program that integrates several psycho-physiological parameters and external cues [29]. Consequently, if the manipulation of external cues is able to modify RPE during any part of the trial, this should influence the adopted pacing strategy and affect subsequent performance.

Listening to music is one such strategy that seems to reduce the RPE during moderate- to high-intensity exercise [14]. For example, Nethery [23] has shown that listening to music during exercise at 50% of VO_2max reduced the RPE, when compared with a sensory-deprived condition. Similarly, Potteiger et al. [26] showed that listening to fast upbeat music, classical music or self-selected music results in a reduced peripheral, central, and overall RPE during 20 minutes of exercise at 70% of VO_{2peak}, when compared with a no-music condition. Tenenbaum et al. [31] also reported that music helped participants at the beginning of a run performed at 90% of $VO_{2max,}$ and seemed to direct their attention to the music, suggesting that may be a consequence of a change in attentional focus.

It has been suggested that athletes direct attentional focus in two pathways during a race: association, by which athletes focus on bodily signals, and dissociation, which distracts the runners from bodily sensations by directing attention to the environment and external cues [4,22]. Baden et al. [4] demonstrated that runners change their attentional focus from an associative to a dissociative strategy when they are performing a longer race, in order to distract themselves from fatigue and to reduce RPE. While a cause and effect relationship between attentional focus and RPE has not yet been established, it has been suggested that when exercise intensity is high, in terms of perceived effort, thoughts naturally become more associative [30]. Conversely, dissociative thoughts would occupy more attentional space if any distractive resource is applied, leaving less room for physical sensations to be processed and consequently reducing RPE [4]. This explanation is known as the parallel processing model of pain, and predicts that while all external and internal sensory stimuli are unconsciously perceived, only some of the information will be consciously perceived due a limited attentional focus capacity [28]. A possible prediction arising from this concept is that pleasurable external cues, such as music, may be able to compete with cues arising from physical exercise, thereby occupying attentional focus and reducing the RPE [31]. Although the effects of music on attentional focus during self-paced exercise have not been fully investigated, it could be expected that listening to music during exercise may draw attentional focus away from internal sensations of fatigue and towards the external environment [23].

To date, the few studies that have used self-paced exercise to investigate the effects of music on performance and RPE have produced conflicting results [3,21]. Atkinson et al. [3] reported that athletes finished a 10-km cycling time trial more quickly when listening to music than when listening to a non-auditory stimulus, and that the greatest difference between conditions was found during the first 3 km of the trial. The RPE was consistently greater throughout the whole the time trial with music. In contrast, Lim et al. [21] showed that there were no differences in RPE or time required to complete a 10-km cycling time trial when a no-music condition was compared with music introduced during the first or second half of the time trial. It is interesting to note, however, that cycling velocity was increased prior to the introduction of music, probably because participants were aware of the time at which the music would be introduced. It is also noteworthy that attentional focus has not been measured in any of these studies. Since music can moderate RPE during moderate- but not high-intensity exercise [23], and the strength of bodily signals probably are stronger at the end of the race when fatigue is more intense than at the beginning, the effectiveness of music to alter attentional focus is likely to be higher when music is introduced at the beginning rather than at the end of a time-trial.

Therefore, the aim of the present study was to examine the extent to which music introduced during the first or last 1.5 km of a running time trial could influence attentional focus, RPE, chosen pacing strategy and performance. We chose to manipulate music during the first 1.5 km because it has been suggested that small variations in an athlete's pace in the first quarter of the race are able to meaningfully influence finishing time [2], and because any potential effect of music on pacing may only be detectable in the first 30% of the race [3]. In order to compare the effects of introducing music at the start or the end of the race, we also chose to introduce music in the last 1.5 km. We hypothesised that listening to music at the beginning but not at the end would modify attentional focus, and consequently the RPE, thus altering the chosen pacing strategy and ultimately improving performance.

Methods

Subjects

Fifteen male recreational runners (mean ± SD: age: 22.5 ± 3.5 years; mass: 76.0 ± 7.0 kg; height: 177.7 ± 6.0 cm), familiarised with running on a treadmill, volunteered to participate in this study. The sample size required was derived from the equation $n = 8e^2/d^2$, where n, e, and d denote predicted sample size, coefficient of variation, and the magnitude of the treatment effect, respectively [2,17]. Coefficient of variation was assumed to be 2.0% [20]. Expecting a magnitude of effect for the treatment from 1.5 to 2.5% [14], detection of a conservative 1.5% difference as statistically significant would require at least 14 participants. The subjects were recruited from a local running club and were included if they had performed at least four 5-km running race in the last 2 years, their best time in at least one of these races had been under 30 min, and if they had been training in the last 3 years without interruption. The participants were informed of the experimental procedures and signed an informed consent form. The study was conducted in accordance with the ethical standards of the IJSM [15] and was approved by the Ethics and Research Committee of the Federal University of Alagoas.

Experimental design

The participants visited the laboratory at the same time of the day on four occasions. During the first two visits, participants performed a 5-km time trial on a treadmill (Imbrasport ATL, Imbrasport, Brazil) to establish their best 5-km baseline time (control trial). Subsequently, the participants completed two single-blinded, experimental 5-km time trials in a counterbalanced order. Music was played during the initial (M_{start}) or final (M_{finish}) 1.5 km of the 5-km trial. The participants were not informed whether or when music would be played, maintained, introduced or removed. The tests were separated by 48 to 96 h.

Experimental procedure

Before each test, the participants performed a standard warm-up (10 min) that included walking, running and stretching. Afterwards, the participants rested for three minutes in an upright position before returning to the treadmill to perform the 5-km time trial. During the trials, the participants were free to change their running speed. Constant feedback regarding the current distance and velocity was provided on the computer screen; otherwise, no information about time was provided. The participants were instructed to complete the 5-km race "as fast as possible". Velocity was measured continually and then averaged for each 0.5 km.

A specialised disc jockey (DJ) selected pop and rock music tracks based on the recommendations of Karageorghis et al. [18]. The participants listened to upbeat, fast music (>120 to 140 bpm) through headphones connected to a portable MP3 machine set at approximately 80 decibels [10]. Each track lasted approximately four minutes and the same tracks and track sequence was applied during M_{start} and M_{finish}. The song title, artist and track duration used were, respectively: 1) Destination Calabria: Alex Gaudino 3:02 min; 2) Dreams: Van Halen 5:01 min; 3) Voyage Voyage: Desireless 4:10 min; 4) Bound for Glory: Angry Anderson 4:13 min; 5) Rise up - Yves Larock 2:53 min; 6) Lay Down Your Guns:

Jimmy Barnes 03:56 min. In the M_{start} trial, the MP3 was turned on after the 3-min upright period and turned off immediately after the participants had completed 1.5 km. In the M_{finish} trial, the portable MP3 was turned on immediately after participants had run 3.5 km and was kept on until the trial was completed. In the control condition, headphones were connected, but the portable MP3 was kept off during the entire test [6].

RPE and attentional focus measurements

Associative thoughts and RPE were monitored at every 1-km interval. RPE was measured using the Borg 15-point scale [5]. The participants were instructed to incorporate both muscular and central cardio-respiratory feelings into an overall perception of effort. The percentage of associative thoughts (attentional focus) was assessed with a 10-cm bipolar line, on which participants indicated the extent to which their thoughts were either associated with or dissociated from the exercise [4]. The participants were fully informed about the distinction between associative and dissociative thoughts and completed a brief questionnaire before starting each run to ensure that they were able to distinguish between the two, as suggested by Baden et al. [4]. The reliability and validity of these scales have been reported in previous studies [8,27].

Statistical Analyses

Data distribution was analysed using the Shapiro-Wilk test. The paired t-test, intraclass correlation coefficient (ICC) and technical error of measurement (TEM) were used to determine the reliability of the performance during the two control trials. A one-way analysis of variance with repeated measures was used to compare the time to complete the 5-km time trial for the conditions. When a significant effect for time to complete the 5-km time trial was observed, post-hoc comparisons were made using a Bonferroni correction. A two-way analysis of variance with repeated measures (distance x conditions) followed by a Bonferroni adjustment was used to compare the velocity, RPE or associative thoughts. When assumptions of sphericity were violated, the critical value of F was adjusted using the

Greenhouse–Geisser epsilon value from the Mauchley test of sphericity. All analyses were performed using SPSS (13.0) software.

Results

The time required to run 5 km was not significantly different between the first and second control trials [25.8 ± 1.8 and 25.7 ± 1.8 min, respectively, $p < 0.05$; ICC: 0.98; $p < 0.05$; TEM: 0.33 min (1.28%)]. The time to complete the first and last 1.5 km in the control trials was not significantly different and was highly reproducible (ICC: 0.93 and 0.97, $p < 0.05$, respectively). Because no difference was observed, the fastest time obtained for each participant during the control trials was compared with the other experimental conditions.

The mean total time was less ($p < 0.05$) in the M_{start} (25.2 ± 1.8 min) than in the control condition (25.6 ± 1.8 min), but there was no significant difference between the M_{start} and M_{finish} (25.4 ± 1.8 min; $p = 0.35$) or between the control and M_{finish} conditions ($p = 0.08$). The mean time to cover the first 1.5 km was significantly shorter in M_{start} than control ($p < 0.05$), but there was no significant difference between M_{start} and M_{finish} ($p = 0.15$) or between control and M_{finish} ($p = 0.21$). The mean time in the last 1.5 km was not significantly different between the three conditions ($p = 0.66$).

There was a significant main effect for condition and distance, and an interaction between these factors ($p < 0.05$), on velocity during the trials. The post-hoc test revealed that the mean velocity was significantly higher during M_{start} than M_{finish} and control conditions ($p < 0.05$). The velocities during the 1-, 1.5- and 2.0-km sections were significantly higher for the M_{start} than for the control condition ($p < 0.05$). The velocity during the first 0.5 km was lower than all velocities between 1.5 and 5.0 km (fig. 1). The velocity at the last 0.5 km was significantly higher than all previous velocities ($p < 0.05$).

The RPE values increased significantly every 1.0 km (fig. 2a), but there was no main effect for condition ($p > 0.05$) or interaction between condition and distance ($p > 0.05$). There was a significant main effect for condition and distance and an interaction between these factors ($p < 0.05$) for associative thoughts (fig. 2b). The post-hoc test revealed that associative thoughts were significantly lower during M_{start} than M_{finish} and control conditions ($p < 0.05$).The associative thoughts in the first 1.0 km were significantly lower in M_{start} than in the control and were higher for the last 1.0 km than for the other distances for all conditions ($p < 0.05$).

Discussion

In the present study, the velocity between the 1- and 2-km sections was significantly greater (compared with the control condition) when music was introduced during the first but not the last 1.5 km, resulting in a reduction in the time needed to complete the 5-km time trial. The introduction of music was associated with a decrease in attentional focus during the first, but not the last, part of the race. There was no change in RPE at any of the measured time points.

Our results have demonstrated that music introduced during the first 1.5 km was accompanied by a reduction in associative thoughts during the first kilometre. This decrease was accompanied by an increased running velocity, even though RPE was not altered. These results corroborate the findings of Dyrlund and Wininger [9], who reported lower levels of associative thoughts when participants exercised while listening to music, compared with a no-music condition. Edworthy and Waring [10] also showed that during a 10-min self-paced exercise on the treadmill, the participants reported a more positive affect and higher treadmill speed during the music condition. Interestingly, similar to our results, RPE was not altered by the music manipulation. Together, these findings suggest that music modifies some psychological factors, such as affect and attentional focus, allowing participants to increase their running velocity without altering RPE [23,28].

The absence of a significant difference in RPE between conditions in the present study, even with a significant increase in velocity from 1 to 2 km in the M_{start} condition, suggests that participants were able to run with a higher velocity/RPE ratio when listening to music.[7,29,32]. In other words, participants were able to run with a higher intensity during the music condition, but felt similar effort, strain, discomfort and fatigue as that experienced during the no-music condition. It has previously been shown that, independently of the condition, athletes normally adopt an increase in RPE which is proportional to the exercise distance completed [11,19]. Even when unexpected and unfavourable premature metabolic disruption occurs, such as when hypoxic air is breathed in the middle of a trial, subjects rapidly decrease their power output to maintain the same RPE pattern over the course of a 5-km cycling time trial [19]. Similarly, Abbiss et al. [1] showed that power output and muscle activation of the biceps femoris and soleus were reduced during a 100-km cycling time trial in a hot condition (34º) when compared a cold condition (10º), but RPE and pain intensity were not significantly different between trials, suggesting that participants adjusted their pacing to maintain similar values to RPE during the trial. It has been proposed that this is important to prevent premature disturbances in physiological systems and energetic reserves, and to be able to conclude the trial [32]. On the other hand, our results suggest that when favourable conditions such as music are available during the trial, the “blockage” of undesirable feelings enables participants to increase their running velocity while maintaining the same RPE pattern over the course of a 5-km running time trial.

Several studies have hypothesised that pacing strategy is controlled in an anticipatory manner designed to prevent large homeostatic disturbances during the race [7,12,29,32]. However, in a recently proposed model, Tucker [32] suggested that changes in the homeostatic status allows alteration of power output/velocity in both an anticipatory and responsive manner based on pre-exercise expectations and peripheral feedback from different physiological locals during the race. As a consequence of this integrated mechanism, the RPE may represent the conscious/verbal manifestation of the integration of these multiple afferent signals [24,25,32]. Recently, de Koning et al. [7] have also suggested that an index derived from the product of the momentary RPE and the fraction of the race distance remaining, so-called the Hazard Score, defines the probability that athletes will change their pacing strategy and may represent the manner by which an anticipatory regulation of muscle power output occurs. This model suggests that the athlete is continuously comparing how they feel at any moment in a competition with how they expected to feel at that moment. Accordingly, Garcin et al. [12] have proposed that, as for RPE, the regulation of exercise intensity during closed-loop exercises may utilize the estimated time limit as an important mediator of production strategy. Therefore, the process of controlling pacing via RPE seems to occur continuously throughout a time trial and takes into account both the amount of distance remaining to be covered and the momentary value of RPE. This is in accordance with the hypothesis that continuous adjustments in running velocity during exercise are determined by a psychophysiological process involving the brain, peripheral physiological systems and environmental conditions, to ensure that the maximal RPE is not attained before the end of exercise [7,29,32].

Although there was a reduction in associative thoughts during the first 1 km in M_{start}, these returned to values similar to those found in the control condition when the music was removed (fig. 2b). This response was accompanied by a decrease in running velocity (fig. 1), which suggests that the participants changed their pacing strategy after the distracting effect of music had been removed. These results suggest that the pleasurable external cues provided by music may compete with cues arising from physiological alterations, occupying an important part of information that is consciously perceived to occupy the attentional focus [31]. It has been suggested that there is a link between associative thoughts and RPE, but it still unclear if the direction of attentional focus is the cause or the effect of RPE [4]. However, the fact that music partially “blocked” associative thoughts during the beginning of the race, resulting in an increase in the running velocity but without an increase in RPE, suggests that attentional focus may be a component of the RPE. We suggest that when music was introduced, participants may have been distracted from unpleasant feelings and they would have reduced RPE if running velocity had not been altered. However, as the task was a time-trial, where participants were free to adjust their pace, they may have optioned to increase running velocity and finish the trial as fast as possible. The subsequent decrease in running velocity after the music was removed may have been needed to maintain the RPE profile over the remaining distance.

Another important observation was that music introduced during the final 1.5 km did not have the same effect as music introduced during the first 1.5 km. Instead, associative thoughts increased significantly in the last 1 km in all conditions. This result is consistent with the findings presented by Baden et al. [4], which showed a tendency for associative thoughts to increase at the end of 8- and 10-mile races, probably as a result of the increase in fatigue sensations when approaching the end of the exercise. A parallel processing model proposed by Rejeski predicts that sensations derived from many different sources compete for focal awareness, but the extent to which these sensations are transmitted to aware attentional focus depends on the strength and magnitude of the stimulus [28]. Thus, our results suggest that during self-paced exercise, participants are able to retain a reasonable focus on more pleasant external cues when listening to music during the first part of the race, when metabolic and physiologic perturbations are not a dominant factor generating attentional focus [31]. However, metabolic and physiologic perturbations may become the dominant factor occupying attentional focus at the end of the race.

In accordance with the finding that music had no effect on associative thoughts during the last 1 km, the velocities from 3.5 to 5 km were not significantly different among the three conditions. Instead, the participants performed an end spurt in all three conditions and velocity during the last 500 m was significantly higher than all previous velocities (fig. 1). However, it seems that the subjects were able to apply a more aggressive and early end spurt during the M_{finish} condition (fig. 1). The start of this end spurt was coincident with the introduction of music, suggesting music may have motivated the subjects to change their pacing strategy in the last part of the trial and to try and make up the time lost at the beginning. It is interesting to observe that an end spurt can significantly increase performance during a time-trial [13], although we have observed no significant differences between control and M_{finish} conditions. On the other hand, the end spurt during the M_{start} condition was more discrete. This is in accordance with several studies which have shown that a fast-starting strategy is followed by a more discrete end spurt [2,16]. Our results suggest therefore that the time saved during the first part of the trial at M_{start} condition was lost in part during the end spurt. Likewise, athletes may try to compensate for a more discrete start in the M_{finish} condition by accelerating earlier during the end spurt. However, as the mean velocity during the last 1.5 km was not significantly different between the conditions, it could be suggested that music introduced in last 1.5 km is not sufficient to compensate for a slow-start strategy. Our results suggest therefore that the time saved during the first part of a 5-km running race may be more important for the final performance.. The results of the present study suggest that music could induce a “spontaneous” fast start, resulting in a small but important performance benefit.

A limitation of the present study is that we did not include a condition that had music for the whole 5 km. A condition with music during whole 5-km time trial would be useful to know if deception with music being removed after first 1.5 km would have any negative effect on performance. However, we were intended to blind the participants for when music would be introduced or removed. If we had included one more condition it could have influenced our counterbalanced order design. Participants that had been asked to run firstly the M_{start} could have expected that music would be equally removed during the music entire condition, becoming a probable confounding factor. Further, we have used an auditory deprivation condition as control to guarantee that any potential noise comes from environment would have minimal interference in pacing and performance and participants would have been not conscious when music would be introduced or removed. However, auditory deprivation *per se* may be any influence factor on performance. Therefore, future studies should clarify if the results found in the present study are reproduced when music is listened during whole time trial and if auditory deprivation during control condition makes any interference in music and non-music comparisons during a time-trial. Furthermore, studies should attend to measure others psycho-physiological variables to have a more detailed picture of the mechanisms controlling the pacing.

In conclusion, the introduction of music during the first 1.5 km of a 5-km running race was able to reduce thoughts related to the physical sensations associated with exercise, allowing for an increase in running velocity and an improvement in performance. Participants appear able to retain this focus on more pleasant external cues only during the first part of a race. Furthermore, RPE seems to increase linearly, independently of the condition.

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