Does Running in Synchrony with Sound Improve Endurance Performance and Save Energy?

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Abstract. There is a tight link between the rhythm of external auditory information and movement. This can be observed when we spontaneously or deliberately move on the beat of music (e.g., dancing) or while performing physical activities (e.g., running) by listening music. Synchronization with rhythm is something natural, developed very precociously and hard-wired. In this study, we exploit this compelling link between sound and movement for improving individual performance. We hypothesized that if the auditory stimulation tempo corresponds to the participant's preferential stride frequency then the auditory rhythm will stabilize the participant's behavior and lead to minimal oxygen consumption. These results will clarify the role of sound tempo to support athletic performance at any level of expertise. We anticipate that the greatest benefits of rhythmic auditory stimulation will be obtained if rhythmic auditory stimulation tempo is adapting to the movement of the participant in real-time.

Keywords: rhythmic auditory stimulation, running, performance, energy consumption

1 Introduction

Humans exhibit a natural propensity to coordinate movement with rhythmical stimuli. This can be observed when we spontaneously or deliberately move on the beat of music (e.g., by foot tapping or dancing) or while performing physical activities (e.g., running or cycling) by listening music. Synchronization with rhythm is something natural, developed very precociously and hard-wired [1, 2]. Some evidence showed that moving in synchrony with an auditory rhythm enhanced motor efficiency in bimanual coordination [3], industrial productivity [4], or sport activities (for a review, see [5]).

In the bimanual coordination field, a Rhythmic-Auditory Stimulation (RAS) can stabilize both in- and anti-phase coordination (local stabilization) and postpones the transition from anti-phase to in-phase (global stabilization) with the increase of the movement frequency ("anchoring effect"; [3]). Moreover, stabilization increased significantly when both finger flexion and extension were paced by an isochronous auditory stimulus (i.e., double-metronome situation). Then, richer auditory stimulus (e.g., music) seems to be more useful for improving motor performance. Indeed, music entrains rhythmic movement [6, 7], and consequently has considerable application in physical activities. Music is beneficial in exercise performance by enhanced levels of endurance, strength, and lower perceived effort (see [5], for a review), by a reduction of the metabolic cost during exercise by promoting greater neuromuscular or metabolic efficiency [8].

A great number of studies focused their attention on improving the motor efficiency via isochronous RAS. However, sequences of stimuli taken into account the biological variability may be more efficient for improving movement performance [9]. An interesting research issue is to provide RAS triggered directly by participants' behavior. In line with embodied perception theories, this enhanced feedback should reinforce the participant's awareness of her/his own actions, thus favoring additional movement regulation, and leading to higher motor efficiency. For instance, Hoffmann *et al.* [10] showed more stable coupling between locomotor and respiratory systems in presence of RAS in cycling. In this case, rhythm-induced stabilization is accompanied by decreased oxygen consumption. However, athletes need flexibility to modulate and adapt their behavior to changing environmental constraints (e.g., running uphill or downhill). In these situations, RAS driven by individual motor performance (e.g., stride frequency) is likely to lead to more efficient motor performance. However, auditory-motor synchronization is never assessed in such cases.

In this study, we aimed at testing if (i) RAS (i.e. metronome or music) lead to better performance (i.e. less energy to cover the same distance) in running as compared to silence and (ii) which RAS (i.e. periodic or adaptive) maximize the benefic effect of stimulation on movement kinematics and physiological response.

2 Method

2.1. Procedure

20 men participants (18 – 35 years) are yet completing the protocol on a motorized treadmill. In a first session, all participants performed a maximal incremental test (VO_2max) to assess their speed at their anaerobic threshold (SV_1). In a second and third sessions, they were asked to run at SV_1 during 7 minutes to determine their preferred running frequency. Then, they were instructed to run under three conditions: silence, periodic external auditory stimulation (i.e. metronome or music) or adaptive auditory stimulation, during 7 minutes for each condition.

2.2. Music Selection

A music-rating panel (BMRI-3, [6]) was used to rate the motivational qualities of the music selections. 60 songs from different styles and periods were played to participants and they were asked to answer to 6 items referring to an action, a time, a context and a target (e.g., "the rhythm of this music would motivate me during running"). Participants answered on a 7-point Likert scale where 1 is "strongly disagree" and 7 is "strongly agree". Only songs with a total score in the range 36 - 42 (i.e. indicating high motivational qualities of music) were used in this experiment.

2.3. Materials and Technology

We used an intelligent technological architecture, capable of delivering embodied, flexible, and efficient rhythmical stimulation adapted to individuals' motor performance (e.g. heel strike). The method involved on-line recording of movement kinematics during the run via gyroscopes attached to the participants' ankles. The architecture was able to select and adapt the auditory stimulation (i.e. metronome or music) to the heel strike from a music library containing the pre-selection of motivational songs and metronome, including the average beats per minute (BPM) and timings of the beat (phase information). The tempo was adapted to synchronize each beat with heel strike by a real-time music time stretcher permitting to alter the tempo of a song without changing the pitch of this one.

Physiological variables (VO_2, VCO_2, VE, VE/VO_2, VE/VCO_2) were recorded by an automated breath-by-breath gas analyzer ($K4b^2$, Cosmed, Rome, Italy). Rating perceived exertion was assessed from a Borg-Scale after each condition.

3 Expected Results

We hypothesized that if the RAS tempo corresponds to the participant's preferential stride frequency then the auditory rhythm will reduce the participant's motor variability. As suggested by our recent work (e.g., [10]), this stabilizing effect of RAS will lead to a decrease in energy consumption. These results will clarify the role of tempo to support athletic performance at any level of expertise. We aimed that the greatest benefits of RAS will be obtained if its tempo is very close to the natural stride frequency of the participant. For this reason, a more precise attraction of rhythmic movement to auditory rhythms is expected if the RAS is adapting to the movement of the participant in real-time. Indeed, because the adaptive stimulation is more representative of natural behavior including biological variability, it will be more in line with the energetic demand of the organism at a given time. To adopt the most efficient behavior, runners need to modulate their frequency-amplitude ratio regarding the continuously changing environmental conditions. From the perception-action and embodied perception point of views, we are expecting that auditory information, when directly enacted from the participants' movement, reinforce their perception of their own action and contributing to a better regulation and stabilization of ongoing movements.

4 Discussion

To date, many studies exploited the rhythm as an efficient way to improve movement performance. In bimanual coordination [3], periodic auditory stimulation is useful to enhance the stability of in- and anti-phase pattern of coordination. In the field of sport and exercise, simple auditory stimulation (i.e. metronome) is also used to entrain a reduction of energy consumption, an increase in endurance and desire to do a physical activity [10]. Thus, there are some indications that auditory rhythmic stimulation may be beneficial to enhance individual motor performance. Moreover, music seems to have an advantage over simpler stimuli by having an activating effect on healthy subjects [11]. For instance, Leman and collaborators (2010) recently found that some musical excerpts have an activating effect (i.e., subjects tend to walk faster), while other stimuli have a relaxing effect (i.e., subjects tend to walk slower). In sum, music has the power to entrain different aspects (activating or relaxing) of motivational effort.

The frequency of RAS is a crucial element in explaining the effect of sound on performance and physiological variables. Moreover, movement frequency was identified as a critical parameter influencing the metabolic cost of the physical activity. Here, we aim to assess the potential effect of tempo on stride variables in running. We expect a stabilization of the participant's behavior by RAS which rhythm corresponds to the natural stride frequency of participants and leading to minimal oxygen consumption. These results will be particularly interesting in the sport domain.

However, one main limitation in research on the link between rhythm and motor efficiency is the absence of adaptation of the auditory stimulation to individual motor performance. A crucial step is to consider individuals' differences for generating an adapted RAS then maximize the effects of RAS and thus improving movement performance. First, the auditory stimulation needs to be triggered by individual information on motor performance (e.g., spontaneous gait frequency and variability). In addition, user's preferences should be taken into account to maximize stimulus effectiveness (e.g., using a musical excerpt which is taken from participants' preferred playlist). Finally, the auditory stimulation must be adapted in real time to individual motor and physiological performance. We aimed at produce a rhythmical stimulation adapted to the individuals' behavior with the goal of maximizing the beneficial effects of rhythmic stimulation on movement kinematics and physiology. This issue has great potential for enhancing motor behavior in healthy individuals, aiding the rehabilitation of movement dysfunctions in patients with motor disorders, and generally stimulating an active lifestyle, healthy ageing, thus eventually preventing future illness.

5 References

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