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When music tempo affects the temporal congruence between physical practice and motor imagery

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ABSTRACT

When people listen to music, they hear beat and a metrical structure in the rhythm; these perceived patterns enable coordination with the music. A clear correspondence between the tempo of actual movement (e.g., walking) and that of music has been demonstrated, but whether similar coordination occurs during motor imagery is unknown. Twenty participants walked naturally for 8 m, either physically or mentally, while listening to slow and fast music, or not listening to anything at all (control condition). Executed and imagined walking times were recorded to assess the temporal congruence between physical practice (PP) and motor imagery (MI). Results showed a difference when comparing slow and fast time conditions, but each of these durations did not differ from soundless condition times, hence showing that body movement may not necessarily change in order to synchronize with music. However, the main finding revealed that the ability to achieve temporal congruence between PP and MI times was altered when listening to either slow or fast music. These data suggest that when physical movement is modulated with respect to the musical tempo, the MI efficacy of the corresponding movement may be affected by the rhythm of the music. Practical applications in sport are discussed as athletes frequently listen to music before competing while they mentally practice their movements to be performed.

1. Introduction

Whether music influences our physical movement, especially in sport psychology and physical rehabilitation, has raised considerable interest among researchers over last two decades (Karageorghis & Terry, 1997; Karageorghis, Terry, Lane, Bishop, & Priest, 2012; Koelsch, 2009; Zimmerman & Lahav, 2012). Although different features of music have been shown to have large effects on aspects of human behavior ranging from mood to endurance, one of the most important components underlying motor skill acquisition and performance is the rhythm of the music (Smoll & Schult, 1982). Indeed, when people listen to musical rhythm, they perceive a tempo corresponding to the strongest or most salient temporal pulse, and these perceived patterns enable body coordination with the music (Large, 2000). Accordingly, Moelants (2002) stated that there is a clear correspondence between the tempo of spontaneous movements, as observed in walking, clapping and finger tapping, and tempo perceived in music. In a seminal experiment, Styns, van Noorden, Moelants, and Leman (2007) focused on the basic link between walking tempo, walking speed, and musical tempo. They showed that people can synchronize walking movements with music over a broad range of tempi, and concluded that music, as a background phenomenon, is likely to influence a basic bodily activity in an unconscious way. Nowadays, a substantial number of experimental studies found that faster tempo in music makes people move faster when doing physical work compared to slow music (Crust & Clough, 2006; Edworthy & Waring, 2006; Waterhouse, Hudson, & Edwards, 2010).

Motor imagery (MI) has been extensively used to improve an athlete's or musician's performance, and to accelerate recovery from injury. MI is the conscious mental simulation of actions involving our brain's motor representations in a way that is similar to when we actually perform movements (Jeannerod & Decety, 1995). Psychophysical experiments have shown that imagined and executed movements preserve the same spatiotemporal characteristics, especially in highly automatic or cyclical movements, hence suggesting that covert and overt stages of actions share similar motor representations (for review, see Guillot, Hoyek, Louis, & Collet, 2012), that support the principal of functional equivalence (Holmes & Collins, 2001). Accordingly, mental chronometry paradigms are commonly used to assess the ease/difficulty encountered in preserving the temporal characteristics of the motor performance (Guillot & Collet, 2005; Malouin et al., 2007; Papaxanthis, Pozzo, Skoura, & Schieppati, 2002). It is worth noting that previous research provided strong evidence that unless MI time is equivalent to that of physical practice (PP), it will not be as effective in achieving its

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desired effects (Guillot & Collet, 2008; Holmes & Collins, 2001). Such temporal congruence between MI and PP, however, is not systematic as several influencing factors may lead to an over- or underestimation of the movement duration during MI (e.g., complexity and duration; Debarnot, Sahraoui, Champely, Collet, & Guillot, 2012; Guillot & Collet, 2005).

Previous research has integrated music into imagery in order to contribute to the vividness of the imagined scenes, and facilitate the formation of the mental images. Indeed, it has been demonstrated that participants used visual imagery more readily when listening to music (Osborne, 1981; Quittner & Glueckauf, 1983). Tham (1994) further found significantly higher movement imagery vividness when participants imagined while listening to music, when compared to a no-music group. However, these studies failed to mention the types of music, how the music was selected, the imagery instructions, or the modality of imagery used. Yet, research that has examined the effect of musical features (e.g., tempo) on imagery ability remain unknown, despite the fact that Clark, Williamon, and Redding (2012) recently confirmed the reliability of mental chronometry recordings for assessing musical imagery ability.

Spurred by the results mentioned above and considering the growing interest and application of both MI and music in sport and rehabilitation, the present study was designed to determine whether and to what extent different music tempi may contribute to MI ability (i.e., temporal equivalence between MI and PP). We tested whether fast and slow tempi of music could elicit a modulation of PP and MI locomotion times with respect to soundless condition, and consequently whether the temporal congruence may be maintained with respect to such different patterns of musical tempo.

2. Method

2.1. Participants

A sample of 20 healthy volunteers aged between 23 and 44 years (mean age: 30.9 $\pm$ 6.2 years, 11 women) was recruited. Participants with chronic and current major medical illness or injury, medication and drug consumption were excluded from the experiment. All participants reported that they had not received formal musical education for more than five years during their school years nor did they play any musical instrument in the last 5 years. By using a Likert-type scale (from 1 = never to 5 = frequently), participants indicated to what extent they usually listen to music while they walk or run. The mean score was 2.55 $\pm$ .30, and few ($n = 5$) indicated that they listen to music quite a lot/frequently during day-time walking. Prior ethical approval was granted by the local ethics committee at the University of Paris Descartes, and all participants signed an informed consent form. The procedure of the experiment and the tasks were explained, but no information was provided about the objectives of the study or the variables of interest.

2.2. Questionnaires

First, all participants filled out a subjective measure of alertness and fatigue using the Stanford Sleepiness Score (Hoddes, Dement, & Zarcone, 1972). This is an introspective measure of sleepiness in which participants rate their alertness at the beginning of the experiment, using an 8-point scale. The individual MI ability was then evaluated to ensure that the sample did not include individuals with extremely high or low MI ability, which could have influenced the capacity to imagine in real-time, and therefore explain changes in the MI times. The revised Movement Imagery Questionnaire (MIQ-3, Williams et al., 2012) was thus administered to each participant.

2.3. Musical apparatus and stimuli

In order avoid contaminating the music with extra-musical associations and surface cues (such as those related to popularity, language, ethnic origin, gender, and gender preference), music stimuli did not include vocal performances involving lyrics, nor instrumental cover-versions of well-known popular tunes. Only neutral sounding instrumental pieces were included. Given those criteria, two slow tempo tracks (56 and 63 bpm, total duration: 7.43 min) and two fast tempo tracks (both 132 bpm, total duration: 8.12 min) were chosen from a selection of music used in the study by Brodsky (2002). The music was played with an mp3 player (Apple IPod Nano, weight 30 g) and headphones (Sennheiser IE 80). The subject adjusted the music volume comfortable to him or her, and remained with the same volume for the other musical condition (individuals differed in the volume they preferred but peak values were in the range 70–85 dB). During music walking conditions, participants kept the mp3 player in their pockets.

2.4. Experimental procedures

The experiment took place in a quiet room, lit by homogeneous white light, that is, in stable and reproducible environmental conditions. All participants performed a simple locomotion task similar to that used in previous studies, i.e. mentally and physically walking over a distance of 8 m along a specified straight path toward a finish line drawn on the floor (Debarnot et al., 2012; Decety, Jeannerod, & Prablanc, 1989; Papaxanthis et al., 2002). They performed three walking conditions (soundless, slow music and fast music) with a randomized-design between mental and physical trials. Then, in order to avoid order effects, the experimental conditions were also randomized within each session, and counterbalanced between subjects.

Before the first walking condition, two PP trials without music were run to keep participants from imagining doing the task without having physical information beforehand. Participants were required to physically and naturally walk at a self-selected paced speed along a delimited path. After completing these two trials, they began one of the three walking conditions (soundless, slow and fast), and randomly performed 10 PP and 10 MI trials. A total of 30 PP and 30 MI trials were thus performed, and both PP and MI times were recorded. Each experimental condition lasted approximately 8 min, hence no music section had to be repeated on a subsequent trial, and participants had no trouble remaining focused due to mental fatigue (Roure et al., 1999). Importantly, before beginning the two musical conditions, participants stood upright and listened to the music for 1 min before beginning the first trial. During the condition without music, the experimenter audibly instructed the participant to either practice physically or mentally the path, but while the music was administrated, the experimenter motioned a thumbs-up for a PP trial or a thumbs-down for an MI trial. An electronic digital stopwatch (model 365515; Extech Instruments, Waltham, MA) with a temporal resolution of .001 s was used by the participants to record PP and MI times. They were requested to trigger the timer as soon as they physically or mentally left the initial position, then practiced the entire movement, and stopped the timer when arriving at the finish line, before giving back the timer to the experimenter. They never received feedback on their movement timing to avoid any influence for subsequent trials. Walking conditions were separated by a 5-min break period during which individual debriefings were scheduled to investigate adherence to the intervention and individual compliance with the instructions. Specifically, participants were asked to describe the nature of their imagery and, to inform the experimenter of any difficulties encountered in forming the mental images. To measure MI vividness, participants were requested to evaluate the quality of their mental images using a Likert-type scale (from 1 = inaccurate MI to 5 = extremely vivid MI). After each musical condition, participants further completed the second version of the Brunel Music Rating Inventory (BMRI-2, Karageorghis, Priest, Chatzisarantis, & Lane, 2006) to assess