Acta Psychologica 149 (2014) 40–44

Contents lists available at ScienceDirect

Acta Psychologica

journal homepage: www.elsevier.com/locate/actpsy

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

Ursula Debarnot [a,b,*], Aymeric Guillot [c,d]

[a] *Département des Neurosciences Fondamentales, CMU, Université de Genève, Michel-Servet 1, 1211 Genève, Suisse*
[b] *Centre de Psychiatrie et Neurosciences (Inserm UMR S894), Université Paris Descartes, Paris, France*
[c] *Centre de Recherche et d'Innovation sur le sport, EA 647, Université Claude Bernard Lyon 1, Université de Lyon, France*
[d] *Institut Universitaire de France, Paris, France*

ARTICLE INFO

Article history:
Received 11 October 2013
Received in revised form 28 January 2014
Accepted 28 February 2014
Available online 28 March 2014

PsycINFO codes:
2340
2330

Keywords:
Imagery
Music
Temporal congruence
Mental chronometry

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

---

[*] Corresponding author at: Département des Neurosciences Fondamentales, CMU, Université de Genève, Michel-Servet 1, 1211 Genève, Suisse. Tel.: +41 22 37 95 346; fax: +41 22 37 95 402.
E-mail address: Ursula.debarnot@gmail.com (U. Debarnot).

http://dx.doi.org/10.1016/j.actpsy.2014.02.011
0001-6918/© 2014 Elsevier B.V. All rights reserved.

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 ± 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 ± .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 the motivational qualities of music with each item referring to an action, a time, a context, and a target (e.g., "The rhythm of this music would motivate me during the locomotion"). It is a 6 single-factor, where participants responded using a 7-point Likert-type scale, anchored by 1 "strongly disagree" and 7 "strongly agree".

An imagery script based on previous published imagery studies was read to the participants (see Appendix A), who were explicitly instructed to combine internal visual imagery (first-person perspective) and kinesthetic imagery concurrently (Callow & Roberts, 2010). Accordingly, participants imagined the skill from their own vantage point during the first-person imagery perspective, while kinesthetic imagery involved the sensations of how it feels to perform the action, including the force and effort involved in movement and balance (Callow & Walters, 2005).

2.5. Data analysis

For each experimental condition (soundless, slow and fast music), we reported mean PP and MI locomotion times. To assess temporal congruency, we further computed the absolute value of difference between PP and MI times (|PP − MI|). Given that MI duration may be longer or shorter than that of actual execution, absolute values are appropriate as a result near zero, and therefore indicated a strong ability to elicit accurate mental images. Afterwards, 2 (PP vs. MI) × 3 (soundless, slow and fast music) analyses of variance with repeated measures (ANOVARM) and Bonferroni post-hoc comparisons were performed to evaluate the effect of music on PP and MI locomotion times. In a subsequent analysis, in order to minimize possible baseline differences among subjects, an ANOVARM was also performed on the absolute difference between PP and MI times (|PP − MI|) for each experimental condition. The Pearson's correlation test was also used to assess the linear correlation between PP and MI times in each condition. We finally used scores from questionnaires to provide descriptive information about individual MI ability. The results are presented as a mean (standard error), with $p < .05$ being considered critical for assigning statistical difference.

3. Results

3.1. Baseline measures

The mean Stanford Sleepiness Score was 1.85 (.74), and no subject was assessed above the sleepy value (i.e., 3), thus attesting to the "good level" of alertness. Mean MIQ-3 scores were 22.05 (.99) for external visual imagery, 20.35 (1.13) for internal visual imagery, and 18.15 (1.14) for kinesthetic imagery. An ANOVARM showed a main effect of MI modalities ($F_{3,53} = 1.55$, $p = .21$), and as expected, external visual imagery scores were higher than kinesthetic imagery scores ($p < .05$), but did not differ from internal visual imagery scores ($p = .79$).

3.2. Behavioral data

The data, as summarized in Table 1, revealed a main effect of music ($F_{1,19} = 4.26$, $p < .05$), but no effect of practice condition ($F_{1,19} = .03$, $p = .86$) nor a music × practice condition interaction ($F_{2,19} = .46$, $p = .25$). Bonferroni post-hoc comparisons showed a difference when comparing slow and fast times (p < .01), regardless of the practice condition; but these durations did not differ from soundless times ($p = .31$ in the slow condition and $p = .66$ in the fast condition, Fig. 1).

Table 1
Mean (standard deviations) movement times in the soundless, slow and fast conditions.

		Soundless	Slow	Fast
PP	Mean	6.88	6.97	6.58
	SE	*.21*	*.20*	*.20*
MI	Mean	6.73	7.25	6.58
	SE	*.32*	*.44*	*.45*
|PP − MI|	Mean	.63	1.11	1.37
	SE	*.12*	*.22*	*.19*

In a second analysis, focus was placed on the temporal congruence given by the relative time difference between PP and MI practice |PP − MI|, with respect to each experimental condition. An ANOVARM on |PP − MI| showed an effect of music ($F_{2,38} = 7.80$, $p < .001$), and post-hoc comparisons revealed that the ability to achieve temporal congruence between PP and MI times significantly decreased when listening either to slow ($p < .05$) or fast music ($p < .001$, Fig. 2).

Finally, correlation analyses revealed a positive, but decreasing, correlation between PP and MI times in the soundless (r = .83, $p < .001$), slow music (r = .71, $p < .001$) and fast music (r = .58, $p < .01$) conditions.

3.3. Assessment of imagery use and tempo motivation

The rating of the vividness of mental images after the soundless condition was 3.2 (.21), whereas it was 2.9 (.23) in the slow condition and 2.55 (.15) in the fast condition. No difference was found when comparing MI ratings in soundless and slow conditions ($t = .96$, $p = .76$), while subjects reported more difficulties in forming mental images during the fast condition ($t = .2.4$, $p < .05$). During the debriefing, participants reported that they used the MI type outlined in the scripts.

The BMRI-2 scores for the motivational music condition was 14 (1.50) for the slow tracks and 21.25 (2.14) for the fast tracks. As expected, results revealed a significant difference between the motivational quotients of these selections ($t = 2.98$, $p < .05$).

4. Discussion

The purpose of the present study was to test the effects of slow and fast musical tempi on the ability to achieve temporal congruence between PP and MI. First, data showed a difference when comparing locomotion times during slow and fast music conditions, but these durations did not differ from that of the soundless condition, hence showing that background music does not necessarily modulate movement speed. The main finding of this experiment revealed that the temporal congruence between PP and MI was altered with both musical tempi. These results provide evidence that MI quality might be affected while listening to music and that MI temporal features may be primarily impacted, which may, in turn, be harmful to the subsequent overt execution of movement (Guillot & Collet, 2008).

There is compelling evidence that people spontaneously coordinate periodic motor activity with musical rhythms, a phenomenon defined earlier as generalized synchrony (Chen, Penhune, & Zatorre, 2008; Phillips-Silver & Trainor, 2005). The present results seem to challenge this statement as it was found that compared to the soundless

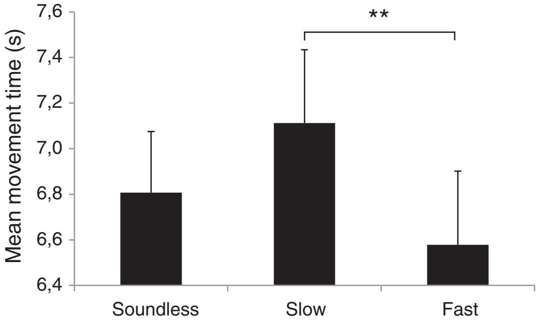

Fig. 1. Physical and MI locomotion times during soundless, slow and fast music conditions. Walking time modulated between the incorporation of slow and fast musical tempi, though no significant difference was found in the soundless condition.

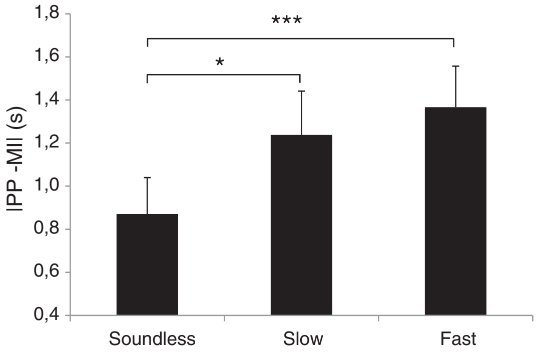

Fig. 2. Temporal congruence between PP and MI during soundless, slow and fast music conditions. Based on the slight modulation of walking time induced by the administration of music, the temporal congruence was expressed by an index |PP − MI| in each experimental condition. Walking with slow or fast musical tempo had an impact on the ability to use MI.

condition, slow and fast musical tempi did not significantly modulate the walking speed during both physical and mental practice. However, analyses revealed that there was a difference between slow and fast musical conditions, hence indicating that changes in background tempo influenced the locomotion speed. Speed was further modulated with respect to the type of the tempo, independent of the practice conditions. Interestingly, using a locomotion task, Murray, Drought, and Kory (1964) asked subjects to walk along a limited path of 4.9 m, in pace with a metronome at 112 steps/min. The authors found that subjects did not reach a "steady state" of locomotion over such short distances, and there was the possibility that a predetermined path may cause an adjustment of stride length to accommodate the available distance. Here, subjects were required to walk at a self-paced speed in a straight ahead direction which was limited (8 m), while no explicit instruction was given to synchronize steps with the musical tempo, neither physically nor mentally. Taking these factors into account, it can be hypothesized that locomotion movement may have required more time to synchronize with musical tempi.

The major innovative finding of this study is that the temporal congruence between PP and MI was altered during musical conditions. More specifically, when computing the |PP − MI| index, we found that both slow and fast musical tempi impacted the ability of using MI, with the stronger effect occurring during the fast music condition. This finding is consistent with the subjective assessment following this condition, which is in keeping with the conclusions by Johansson (2011), who postulated that fast musical tempo might make the imagery of musical excerpts more difficult due to the smaller window of time to maintain the integrity of imagined pitches and rhythms. Here, we postulate that a musical tempo adjunct was harmful by limiting the reactivation of movement within the working memory (WM). Baddeley (1986) developed the concept of WM into a three-component system, comprising a limited capacity attention controller, aided by two subsystems, one concerned with acoustic and verbal information (phonological loop) and the other performing with visual and spatial information (visuospatial sketchpad). Accordingly, musical information is thought to be processed by the phonological loop (Sharps & Pollitt, 1998), while the image generation process operates within the visuo-spatial sketchpad (Quinn & McConnell, 2006). During this process, MI information can then be subjected to different transformations, and further maintained in the WM, which requires the allocation of mental effort. Here, cognitive overload can result from overtaxing the limited cognitive resources in the WM during MI when listening to music, hence altering the temporal congruence between PP and MI. Likewise, the network underlying MI includes the prefrontal and the anterior cingulate cortex (Decety, 1992), brain regions which are also involved in WM and attention (Smith & Jonides, 1995). Accordingly and based on the present findings, it would be advantageous to carry out further research to test whether listening to music influences MI time when task complexity and duration are also taken into consideration.

In a neuroimaging study, Oullier, Jantzen, Steinberg, and Kelso (2005) reported that real and imagined rhythmic coordination of movement with auditory pacing sequences recruit similar brain regions, including motor and auditory networks, albeit the magnitude of activations were lower during MI. The authors suggested that the greater activity in the pre- and post-central gyri (M1/S1) and the superior temporal gyrus (auditory cortex) during covert movement may reflect processes in which perceptual and motor systems can interact to influence coordinative stability. Likewise, Zatorre, Chen, and Penhune (2007) further suggested that interactions between posterior auditory and premotor cortices mediate the higher-order temporal organization (rhythm) that is responsible for integrating feedforward and feedback information during performance and perception. However, there is a lack of direct feedback during mental practice, which is supported by the lower activation in the cerebellum compared to motor execution (Ivry et al., 1988; Rao et al., 2001). Thus, the absence of direct feedback during MI added with less activation in the motor system and especially superior temporal gyrus might have impacted the efficacy of MI.

Although it is premature to draw definitive conclusions about the music constraint on MI efficiency, the present study demonstrates that background musical tempo is likely to alter the temporal congruence between PP and MI. Exploring further this issue is of importance in the sport context as several athletes listen to music before competition, mostly to relieve stress (Vlachopoulos, Karageorghis, & Terry, 2000), while they mentally (sometimes simultaneously) repeat their movements to be performed. In the same vein, MI is frequently used by musicians, who attach great importance to the audiomotor loop to guide motor performance (Lotze, 2013). Accordingly, Wöllner and Williamon (2007) provided evidence that timing performance consistency might be substantially improved when using imagery along with kinesthetic feedback. Finally, there is no doubt about the respective beneficial effect of MI and music during the classical course of physical therapy (Sarkamo & Soto, 2012; Sharma, Pomeroy, & Baron, 2006), but whether their combination is valuable is still unknown.

Appendix A

The following guidelines were given to participants in an MI script: "Try imagining yourself performing the locomotor task with your eyes open by visualizing and feeling the different movements as if you had a camera on your head — you see and feel only what you would if you were physically performing the action. Pay attention to each movement. Only start the timer when you start feeling and seeing the first movement, and keep the same speed throughout the entire motor sequence. Just see and feel yourself going through the different steps of the sequential motor action".

References

Baddeley, A. (1986). *Working Memory*. Oxford: Clarendon Press.

Brodsky, W. (2002). The effects of music tempo on simulated driving performance and vehicular control. *Transportation Research Part F*, *4*(4), 219–241.

Callow, N., & Roberts, R. (2010). Imagery: Perspectives, order, and angle. *Psychology of Sport & Exercise*, *4*, 325–329.

Callow, N., & Walters, A. (2005). The effects of kinesthetic imagery on the sports confidence of flat-race horse jockeys. *Psychology of Sport and Exercise*, *6*, 443–459.

Chen, J. L., Penhune, V. B., & Zatorre, R. J. (2008). Moving on time: Brain network for auditory–motor synchronization is modulated by rhythm complexity and musical training. *Journal of Cognitive Neuroscience*, *20*, 226–239.

Clark, T., Williamon, A., & Redding, E. (2012). Imagining the music: Methods for assessing musical imagery ability. *Psychology of Music*, *40*, 471–493.

Crust, L., & Clough, P. J. (2006). The influence of rhythm and personality in the endurance response to motivational asynchronous music. *Journal of Sports Sciences*, *24*, 187–195.

Debarnot, U., Sahraoui, D., Champely, S., Collet, C., & Guillot, A. (2012). Selective influence of circadian modulation and task characteristics on motor imagery time. *Research Quarterly for Exercise and Sport*, *83*, 442–450.

Decety, J. (1992). Neurobiologie des représentations mentales motrices. *Psychologie Médicale*, *24*, 261–265.

Decety, J., Jeannerod, M., & Prablanc, C. (1989). The timing of mentally represented actions. *Behavioural Brain Research*, *34*, 35–42.

Edworthy, J., & Waring, H. (2006). The effects of music tempo and loudness level on treadmill exercise. *Ergonomics*, *49*, 1597–1610.

Guillot, A., & Collet, C. (2005). Contribution from neurophysiological and psychological methods to the study of motor imagery. *Brain Research. Brain Research Reviews*, *50*, 387–397.

Guillot, A., & Collet, C. (2008). Construction of the motor imagery integrative model in sport: A review and theoretical investigation of motor imagery use. *International Review of Sport and Exercise Psychology*, *1*, 32–44.

Guillot, A., Hoyek, N., Louis, M., & Collet, C. (2012). Understanding the timing of motor imagery: Recent findings and future directions. *International Review of Sport and Exercise Psychology*, *5*, 3–22.

Hoddes, E., Dement, W. C., & Zarcone, V. (1972). The development and use of the Stanford sleepiness scale. *Psychophysiology*, *9*, 150.

Holmes, P. S., & Collins, D. J. (2001). The PETTLEP approach to motor imagery: A functional equivalence model for sport psychologists. *Journal of Applied Sport Psychology*, *13*, 60–83.

Ivry, R. B., Keele, S. W., & Diener, H. C. (1988). Dissociation of the lateral and medial cerebellum in movement timing and movement execution. *Experimental Brain Research*(73), 167–180.

Jeannerod, M., & Decety, J. (1995). Mental motor imagery: A window into the representational stages of action. *Current Opinion in Neurobiology*, *5*, 727–732.

Johansson, B. B. (2011). Current trends in stroke rehabilitation. A review with focus on brain plasticity. *Acta Neurologica Scandinavica*, *123*, 147–159.

Karageorghis, C., Priest, D. -L., Chatzisarantis, N., & Lane, A. (2006). Redesign and initial validation of an instrument to assess the motivational qualities of music in exercise: The Brunel Music Rating Inventory 2. *Journal of Sports Sciences*, *24*, 899–909.

Karageorghis, C. I., & Terry, P. C. (1997). The psychophysical effects of music in sport and exercise: A review. *Journal of Sport Behavior*, *20*, 54–68.

Karageorghis, C. I., Terry, P. C., Lane, A. M., Bishop, D. T., & Priest, D. L. (2012). The BASES expert statement on use of music in exercise. *Journal of Sports Sciences*, *30*, 953–956.

Koelsch, S. (2009). A neuroscientific perspective on music therapy. *Annals of the New York Academy of Sciences*, *1169*, 374–384.

Large, E. W. (2000). On synchronizing movements to music. *Human Movement Science*, *19*, 527–566.

Lotze, M. (2013). Kinesthetic imagery of musical performance. *Frontiers in Human Neuroscience*, *7*, 280.

Malouin, F., Richards, C. L., Jackson, P. L., Lafleur, M. F., Durand, A., & Doyon, J. (2007). The kinesthetic and visual imagery questionnaire (KVIQ) for assessing motor imagery in persons with physical disabilities: A reliability and construct validity study. *Journal of Neurologic Physical Therapy*, *31*, 20–29.

Moelants, D. (2002). Preferred tempo reconsidered. In C. Stevens, D. Burnham, D. Burnham, G. McPherson, E. Schubert, & J. Renwick (Eds.), *Proceedings of the 7th international conference on music perception and cognition*. Adelaide: Causal Productions (pp. 580–583).

Murray, M., Drought, A., & Kory, R. (1964). Walking patterns of normal men. *The Journal of Bone & Joint Surgery*, *46*, 335–360.

Osborne, J. W. (1981). The mapping of thoughts, emotions, sensations, and images as responses to music. *Journal of Mental Imagery*(5), 133–136.

Oullier, O., Jantzen, K. J., Steinberg, F. L., & Kelso, J. A. (2005). Neural substrates of real and imagined sensorimotor coordination. *Cerebral Cortex*, *15*, 975–985.

Papaxanthis, C., Pozzo, T., Skoura, X., & Schieppati, M. (2002). Does order and timing in performance of imagined and actual movements affect the motor imagery process? The duration of walking and writing task. *Behavioural Brain Research*, *134*, 209–215.

Phillips-Silver, J., & Trainor, L. J. (2005). Feeling the beat: Movement influences infant rhythm perception. *Science*, *308*, 1430.

Quinn, J. G., & McConnell, J. (2006). The interval for interference in conscious visual imagery. *Memory*, *14*, 241–252.

Quittner, A., & Glueckauf, R. (1983). Facilitative effects of music on visual imagery: A multiple measures approach. *Journal of Mental Imagery*, *7*, 105–120.

Rao, S. M., Mayer, A. R., & Harrington, D. L. (2001). The evolution of brain activation during temporal processing. *Nature Neuroscience*(4), 317–323.

Roure, R., Collet, C., Deschaumes-Molinaro, C., Delhomme, G., Dittmar, A., & Vernet-Maury, E. (1999). Imagery quality estimated by autonomic response is correlated to sporting performance enhancement. *Physiology & Behavior*, *66*, 63–72.

Sarkamo, T., & Soto, D. (2012). Music listening after stroke: Beneficial effects and potential neural mechanisms. *Annals of the New York Academy of Sciences*, *1252*, 266–281.

Sharma, N., Pomeroy, V. M., & Baron, J. C. (2006). Motor imagery: A backdoor to the motor system after stroke? *Stroke*, *37*, 1941–1952.

Sharps, M. J., & Pollitt, B. K. (1998). Category superiority effects and the processing of auditory images. *The Journal of General Psychology*, *125*, 109–116.

Smith, E. E., & Jonides, J. (2002). Working memory in humans: neuro- psychological evidence. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 1009–1020). Cambridge, MA: The MIT Press.

Smoll, F. L., & Schult, R. W. (1982). Accuracy of rhythmic motor behavior in response to preferred and nonpreferred tempos. *Journal of Human Movement*, *8*, 123–128.

Styns, F., van Noorden, L., Moelants, D., & Leman, M. (2007). Walking on music. *Human Movement Science*, *26*, 769–785.

Tham, E. K. K. (1994). Effects of music on vividness of movement imagery. *Ann Arbor*. MI: University Microfilms International.

Vlachopoulos, S. P., Karageorghis, C. I., & Terry, P. C. (2000). Motivation profiles in sport: A self-determination theory perspective. *Research Quarterly for Exercise and Sport*, *71*, 387–397.

Waterhouse, J., Hudson, P., & Edwards, B. (2010). Effects of music tempo upon submaximal cycling performance. *Scandinavian Journal of Medicine and Science in Sports*, *20*, 662–669.

Williams, S. E., Cumming, J., Ntoumanis, N., Nordin-Bates, S. M., Ramsey, R., & Hall, C. (2012). Further validation and development of the movement imagery questionnaire. *Journal of Sport & Exercise Psychology*, *34*, 621–646.

Wöllner, C., & Williamon, A. (2007). An exploratory study of the role of performance feedback and musical imagery in piano playing. *Research Studies in Music Education*, *29*, 39–54.

Zatorre, R. J., Chen, J. L., & Penhune, V. B. (2007). When the brain plays music: Auditory–motor interactions in music perception and production. *Nature Reviews Neuroscience*, *8*, 547–558.

Zimmerman, E., & Lahav, A. (2012). The multisensory brain and its ability to learn music. *Annals of the New York Academy of Sciences*, *1252*, 179–184.