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Effects of task complexity on rhythmic reproduction performance in adults

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ABSTRACT

The aim of the present study was to investigate the effect of task complexity on the capability to reproduce rhythmic patterns. Sedentary musically illiterate individuals (age: 34.8 ± 4.2 yrs; $M \pm SD$) were administered a rhythmic test including three rhythmic patterns to be reproduced by means of finger-tapping, foot-tapping and walking. For the quantification of subjects' ability in the reproduction of rhythmic patterns, qualitative and quantitative parameters were submitted to analysis. A stereophotogrammetric system was used to reconstruct and evaluate individual performances. The findings indicated a good internal stability of the rhythmic reproduction, suggesting that the present experimental design is suitable to discriminate the participants' rhythmic ability. Qualitative aspects of rhythmic reproduction (i.e., speed of execution and temporal ratios between events) varied as a function of the perceptual-motor requirements of the rhythmic reproduction task, with larger reproduction deviations in the walking task.

1. Introduction

Rhythm is a fundamental component of the organization and the execution of body movements, easily observable during normal daily activities (e.g., walking, running, clapping hands, drumming fingers), and in dance, music, and sport (e.g., rhythmic gymnastics and synchronized swimming) contexts. Theories in cognitive and musical sciences considered the "dynamogenous" effect of rhythm (Fraisse, 1979) and highlighted the role of the body as a mediator for music awareness (Dalcroze, 2008; Leman, 2007). In fact, music emerges from physical movement (Tood, Cousins, & Lee, 2007;

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Trainor, 2007) and rhythm is embodied and expressed through movements (Philliphs-Silver & Trainor, 2007), which require the organization of muscular activity to execute a specific chronological order of motor actions (Meinel & Schnabel, 1998; Sakai, Hikosaka, & Nakamura, 2004). Actually, studies on human coordination refer to rhythm as a crucial aspect for movements such as walking (Hausdorff, Peng, Ladin, Wei, & Goldberger, 1995) and tapping (Chen, Ding, & Kelso, 1997, 2001), which fluctuates in relation to higher nervous system centres and/or lower motor neuron control (Golubitsky, Stewart, Buono, & Collins, 1999; Ijspeert, 2008; Ivanenko, Poppele, & Lacquaniti, 2006).

The capability to translate an acoustic perception into a corresponding motor behavior is considered a fundamental characteristic of rhythmic ability (Fraisse, Pichot, & Clairouin, 1949), which is defined as the ability to perform a succession of regulated, recurring gross motor events requiring both spatial and temporal accuracy (Zachopoulou & Mantis, 2001). In considering that performances mainly depend upon the rhythmic structure (Gilden, Thornton, & Mallon, 1995), to discriminate the rhythmic ability of different populations, the use of a large range of pitch intervals and several complex rhythms is recommended (Persichini & Capranica, 2004; Trehub & Hannon, 2009). In particular, the ability to accurately process and reproduce rhythmic patterns depends on the interval ratios between events, with spontaneous reproduction of 1:1 and 2:1 rhythmic structures (Drake, 1993; Essens & Povel, 1985) and preferences for small integer ratios (1:2, 1:3, or 1:4) as compared to larger (1:5) or non-integer (in the sense of non-simple) (1:2.5 or 1:3.5) ratios (Drake, 1993; Essens, 1986; Sakai et al., 1999). In general, during learning or rehearsal, non-integer ratios are often distorted and shifts toward simpler ratios are observed (Drake, 1993; Essens, 1986; Essens & Povel, 1985; Sakai et al., 1999; Summers, 1975; Trehub & Hannon, 2009). Furthermore, binary subdivisions are easier to be discriminated and reproduced with respect to ternary subdivisions (Jones, 1987; Povel, 1981; Trehub & Hannon, 2009).

To evaluate the individual ability to correctly reproduce a rhythmic pattern, both its quantitative (i.e., number of events) and qualitative (i.e., speed of execution and temporal ratios among events) aspects must be considered (Persichini & Capranica, 2004). In fact, individuals might repeatedly deviate from the intervals between events around a constant value, thereby creating a considerable error in the speed of execution (i.e., overall faster or slower performances), yet producing the prominent rhythmic structure. On the other hand, individuals could correctly reproduce the established total time of the pattern even though the proportionality between intervals of rhythmic structures is not respected (Persichini & Capranica, 2004).

Unfortunately, thorough comparison of evidence concerning rhythmic ability is hard because of large evaluation differences such as the use of heterogeneous stimuli (i.e., auditory, visual or audio-visual), procedures (i.e., different forms of coordination, in-phase or anti-phase movements), effectors (i.e., hands, feet, or voice), and rhythmic variables (i.e., number of events, total duration of the pattern, intervals between events) (Drake, 1993; Hennig et al., 2011; Joiner & Shelhamer, 2009; Meeuwsen, Flohr, & Fink, 1998; Persichini & Capranica, 2004; Repp, 2005; Smoll & Palmatier, 1977).

A further relevant aspect in rhythmic ability evaluation is related to the movement task requirements for rhythmic pattern reproduction. To generate wide possibilities of motor programs in relation to rhythmic movements, a modular control of limb kinematics based on various feedback and feed-forward parameters has been hypothesized (Ivanenko et al., 2006). Although it has been hypothesized that a general timing process assists the individual in performing movements of different limbs and body parts (i.e., finger, forearm and foot tapping) (Keele & Hawkins, 1982; Keele, Ivry, & Pokorny, 1987), some authors (Getchell, Forrester, & Whitall, 2001; Robertson et al., 1999) argued that specific timing processes are needed when tasks are not dynamically equivalent, such as tapping, clapping, galloping, etc.

In daily life, individuals are confronted with tasks of different perceptual-motor complexity, entailing various patterns of inter-limb coordination under varying time constraints. This calls for research involving different rhythmic structures to be reproduced by means of motor tasks requiring various body segments (i.e., hand, foot, and whole body). A theoretical framework appropriate to jointly consider and operationalize the complexity of rhythmic patterns and movement task requirements is that proposed by Wood (1986) in the general study of tasks. He proposed to combine the frameworks of (1) "task as behavior requirements" and (2) "task qua task", providing a feasible operationalization of tasks as (1) behavioral responses involving motor activities and (2) patterns of stimuli impinging on the individual, requiring processing of information cues. The relationship between behavioral responses and information cues is one dimension of task complexity. The timing requirements to per-