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The effect of instruction to synchronize over step frequency while walking with auditory cues on a treadmill



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ABSTRACT

Walking to a pacing stimulus has proven useful in motor rehabilitation, and it has been suggested that spontaneous synchronization could be preferable to intentional synchronization. But it is still unclear if the paced walking effect can occur spontaneously, or if intentionality plays a role. The aim of this work is to analyze the effect of sound pacing on gait with and without instruction to synchronize, and with different rhythmic auditory cues, while walking on a treadmill.

Firstly, the baseline step frequency while walking on a treadmill was determined for all participants, followed by experimental sessions with both music and footstep sound cues. Participants were split into two groups, with one being instructed to synchronize their gait to the auditory stimuli, and the other being simply told to walk. Individual auditory cues were generated for each participant: for each trial, cues were provided at the participant's baseline walking frequency, at 5% and 10% above baseline, and at 5% and 10% below baseline.

This study's major finding was the role of intention on synchronization, given that only the instructed group synchronized their gait with the auditory cues. No differences were found between the effects of step or music stimuli on step frequency.

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In conclusion, without intention or cues that direct the individual's attention, spontaneous gait synchronization does not occur during treadmill walking.

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1. Introduction

Body motion, including gait, can be influenced by rhythmic sounds. Music, for example, is the external source of information that aerobics practitioners and dance pairs use in order to coordinate their movements (Styns, Van Noorden, Moelants, & Leman, 2007). This paced movement enabled by external stimuli presents great potential for a wide variety of fields, including education, sports and rehabilitation. The scope of this work lies within the influences of intention on the effect of sound over human gait. Throughout this article, the terms *spontaneous-* and *unintentional synchronization* are used interchangeably, referring to a lock to an external stimulus in time and/or frequency without deliberately deciding to do so, or without intention. Conversely, *intentional-* and *forced synchronization* refer to gait lock to an external stimulus in time and/or frequency with intention (*intentional*) or specifically because of explicit instruction/training/constraints (*forced*). *Motor stabilization* is used to refer to reduced gait variability either in velocity, frequency, or step amplitude.

In the clinical field, walking with the pacing of rhythmic sounds has been used widely and successfully as a strategy in the motor rehabilitation of some pathological conditions such as stroke (Roerdink, Lamoth, Kwakkel, van Wieringen, & Beek, 2007; Roerdink et al., 2009), hemiparesis (Pelton, Johannsen, Chen, Chen, & Wing, 2010), Parkinson's disease (de Bruin et al., 2010; Picelli et al., 2010; Rochester et al., 2007), and Huntington's disease (Thaut, Miltner, Lange, Hurt, & Hoemberg, 1999). Such rehabilitation approaches can be implemented both in overground and in treadmill walking. Harris-Love, Forrester, Macko, Silver, and Smith (2011) compared the gait patterns of chronic hemiparetic stroke patients during overground and treadmill walking. They found that treadmill induces immediate alterations toward more consistent and symmetric gait patterns, unlike overground walking. As a result, it has been suggested that treadmill might be preferable to overground walking in therapeutic approaches. Combined therapeutic methods, including both treadmill and overground walking, have also revealed positive results in motor rehabilitation (Ada, Dean, Hall, Bampton, & Crompton, 2003).

Overground walking exhibits a greater potential to be modulated by external cues, since it allows for unconstrained movement. Conversely, walking on a treadmill allows for large periods of motion in highly controllable conditions. However, in treadmill walking there is a limit to the individual's range of step frequency and amplitude due to the treadmill's imposed speed and carpet size. When instructed to synchronize their gait with auditory cues, individuals are forced to change their walking parameters, which may require them to abandon their comfort frequency (Parvataneni, Ploegi, Olney, & Brouwer, 2009). Nessler and Gilliland (2010) demonstrated that forced synchronization to auditory stimuli while walking on a treadmill resulted in steps that were significantly smaller and faster when compared to independent, unintentional synchronization. The authors concluded that unintentional synchronization might be preferable to intentional synchronization in certain subjects. However, in that study, subjects synchronized to other walkers, which might be unpractical to implement in rehabilitation contexts.

The role of intention in motor synchronization has been studied by presenting individuals with different instructions, either by explicitly asking them to synchronize their gait or by just allowing individuals to walk freely side-by-side (Nessler & Gilliland, 2009, 2010). Unintentional interpersonal synchronization has been shown to occur often in free walking (Zivotofsky, Gruendlinger, & Hausdorff, 2012; Zivotofsky & Hausdorff, 2007). On a treadmill it has been mostly observed in the context of interpersonal walking, but not for all participants (Nessler & Gilliland, 2010), and although it decreased when visual or auditory interpersonal information was limited (Nessler & Gilliland, 2009). A study by Sejdić, Jeffery, Kroonberg, and Chan (2012) also found some effect of sounds on treadmill

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