The ramp paradigm: uncovering individual differences in walking to an auditory beat

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Introduction

It is well known that rhythmic interventions (e.g. rhythmic auditory cuing) can help patients with gait disorders[1]. However, studies also reveal significant individual differences in the way patients respond to rhythmic cuing. Yet, very little is known about the mechanisms underlying spontaneous synchronization nor individual differences in a gait task.
Gait is an excellent model to study spontaneous auditory-motor synchronization because it is:

- Natural and automatic
- Influenced by the characteristics of an external auditory stimulus (e.g. tempo, regularity)[2]
- Reflective of individual differences in responsiveness to the stimulus tempo[3]

Problem. There is no suitable method which is highly sensitive to individual differences in adapting to rhythmic stimulation while walking.

Objective. Devise a method of gait measurement that:

- Is highly sensitive to individual differences in responding to an auditory stimulus
- Can define a stability window in the vicinity of spontaneous gait cadence

Method

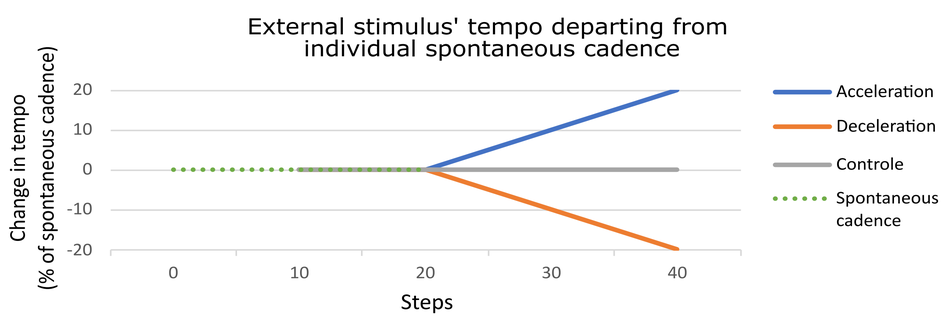
In order to measure individual differences in gait synchronization, we propose a new method called TeensyStep. TeensyStep is based on TeensyTap[4], and detects steps in real time via a force-sensitive resistor (FSR) connected to a custom Arduino device. After measuring the initial spontaneous cadence, a metronome begins in time with the participant's next step:

FSR → Arduino → Audio output

Prior to this study, TeensyStep step detection was validated compared to a gold standard ("Delsys").

Protocol

A ramp protocol trial starts with participants walking naturally at their preferred cadence without any external stimulus. A metronome then starts in synchrony with the footsteps and progressively departs from their initial cadence.



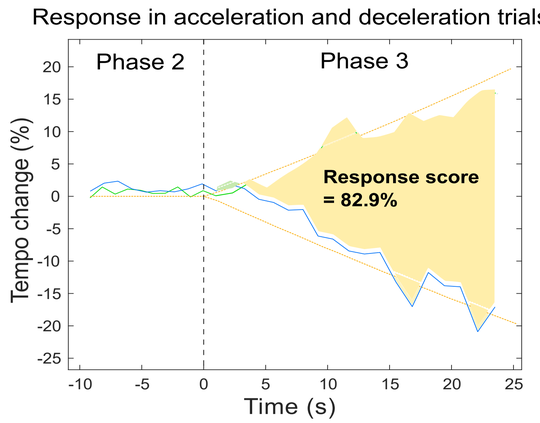
This allows to study the individual response to that tempo change depending on the instructions.

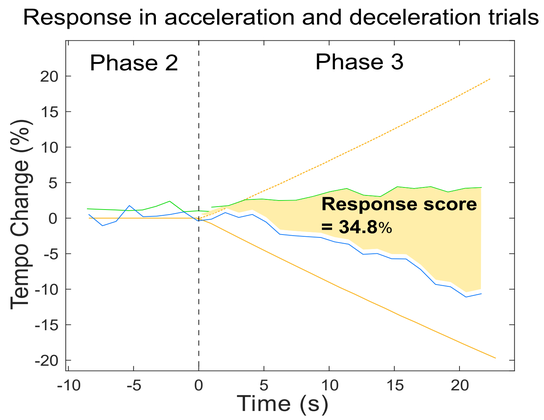
References. 1: Dalla Bella et al., (2017) Scientific Reports, 7. 2: Leow, L.-A., Parrott et al., (2014) Frontiers in Human Neuroscience, 8. 3: Crosby et al., (2020) Frontiers in Neurology, 11. 4: Van Vugt, (2020). Advances in Cognitive Psychology, 16, 302–308.

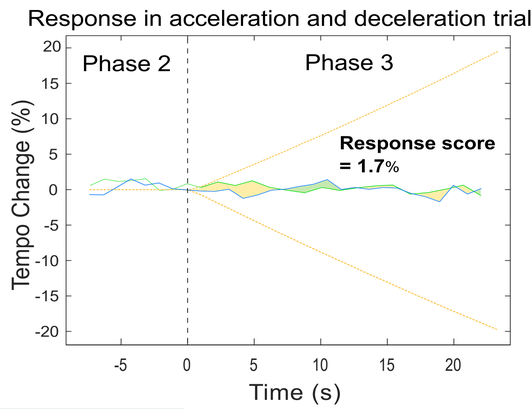
Type of response to the auditory stimulation

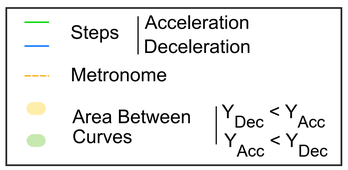
When participants are asked to walk naturally with the stimulus, some of them tend to adapt or even synchronize their cadence to the external stimulus, (the "Responders"), and and others show little or no adjustment of their pace, (the "Non-Responders"). We also observed variability in the intensity of the response.
To measure the overall magnitude of the response, accounting for both acceleration and deceleration, we calculated the total area between both curves as the "Response score".

The Response score to quantify the response in both conditions









Response score = Area between curves / Area between metronomes

Conclusions

- This method allows us to observe distinct response profiles, quantify the response and provides an empirical basis to explain and predict these responses.
- The TeensyStep-based Ramp paradigm is currently used as a way to test the effect of explicit and implicit individual response to the stimulus change by manipulating instructions.
- A better understanding of gait synchronization in Responders and Non-Responders can potentially help in individualizing rhythmic interventions to improve gait disorders.