Beta and alpha/mu rhythms during gait synchronization

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Humans and animals have been demonstrated to exhibit behavioural coordination, likely for many reasons which include to signal affiliation within a group, and to induce cohesion in group or partnered activities (Wilson & Cook, 2016). In humans, synchronization has been studied during tasks such as hand movements and finger tapping (Repp, 2005; Tognoli, et al., 2007; Naeem et al., 2012; Dumas et al., 2010), music (Zamm, 2018; Zamm et al., 2021), moving on rocking chairs (Richardson et al., 2007), and walking (Bocian et al., 2018; Nessler & Gilliand, 2009; van Ulzen, et al., 2008; Zivotofsky et al., 2007). However, it is not clear yet how individuals coordinate during activities such as walking at the neural level. Some studies have looked at brain activity using elecroencepahlography (EEG) during hand movement synchronization (Tognoli et al., 2007; Naeem et al., 2012; Dumas et al., 2010), demonstrating alterations in right parietal channel alpha/mu (8-12 Hz) rhythms. At this moment however, as far as we know, all studies of walking synchronization have been behavioural (Nessler & Gilliand, 2009; van Ulzen, et al., 2008; Zivotofsky et al., 2007). With a combination of mobile EEG and inertial motion tracking, there is now a possibility to observe neural correlates of this phenomenon during natural, outdoor walking.

Data were collected together with a previous study (Scanlon et al., 2020), in which 18 participants came into the lab twice to collect data with with foot accelerometers (Faros 180° eMotion) and mobile EEG (64 channels) using active (actiCAP, EasyCap GmbH, Brain Products GmbH) or passive electrode configurations (EasyCap GmbH, Brain Products GmbH) for the different recordings. Participants walked with an experimenter in three counterbalanced conditions: In the first condition participants walked with their view on the experimenter blocked (*blocked*), using side-blinder glasses (similar to Zivotofsky et al., 2007). In the second condition participants were asked to walk naturally (*natural*), with no instruction about their walking in relation to the experimenter. In the third condition participants walked while trying to intentionally synchronize their steps in-phase with the experimenter (*sync*), meaning that they attempted to temporally align their left heel-strike with the experimenter's left heel-strike, and vice versa on the right side. Both participants and the experimenter had accelerometers placed on their right foot, and the experimenter walked following a headphone metronome to keep their steps consistent for all conditions. Using data from the foot accelerometers, we were able to find the right heel-strike (RHS) and right toe-off (RTO) events in order to define step cycles. Behavioural step synchronization was then analyzed using differences in step frequency and phase between the participant and experimenter, similar to Nessler & Gilliand (2009). EEG data was preprocessed and then artifact attenuated using artifact subspace reconstruction (ASR) with standard deviation threshold of 20, and extended infomax independent component analysis (ICA). Event-related spectral perturbations (ERSPs) were time-warped to the gait cycle using markers for the RHS and RTO, in order to analyze alpha/mu (7.5-12.5 Hz) and beta rhythms (16-32 Hz) over the whole step cycle (Figure 1).

We found that participants were more synchronized to the experimenters in both frequency and phase in the *sync* condition than in the *natural* or *blocked* conditions. Right parietal channel (C4, C6, CP4, CP6) alpha/mu power was lower for the *sync* condition, possibly due to the engagement of networks related to social coordination and the mirror-neuron system (Debnath et al., 2019; Rizzolatti & Craighero, 2004). Central channel (C1, Cz, C2) beta power was lower in the *sync* condition than the natural and blocked conditions, likely due to motor system engagement from the more active walking style in this condition (Jain et al., 2016; Wagner et al., 2012). No significant differences were found between the *natural* and *blocked* conditions. Artifact correction and validation during gait tasks are also discussed. Our results are compatible with the view that intentional synchronization employs the central motor system as well as systems associated with social coordination**.**

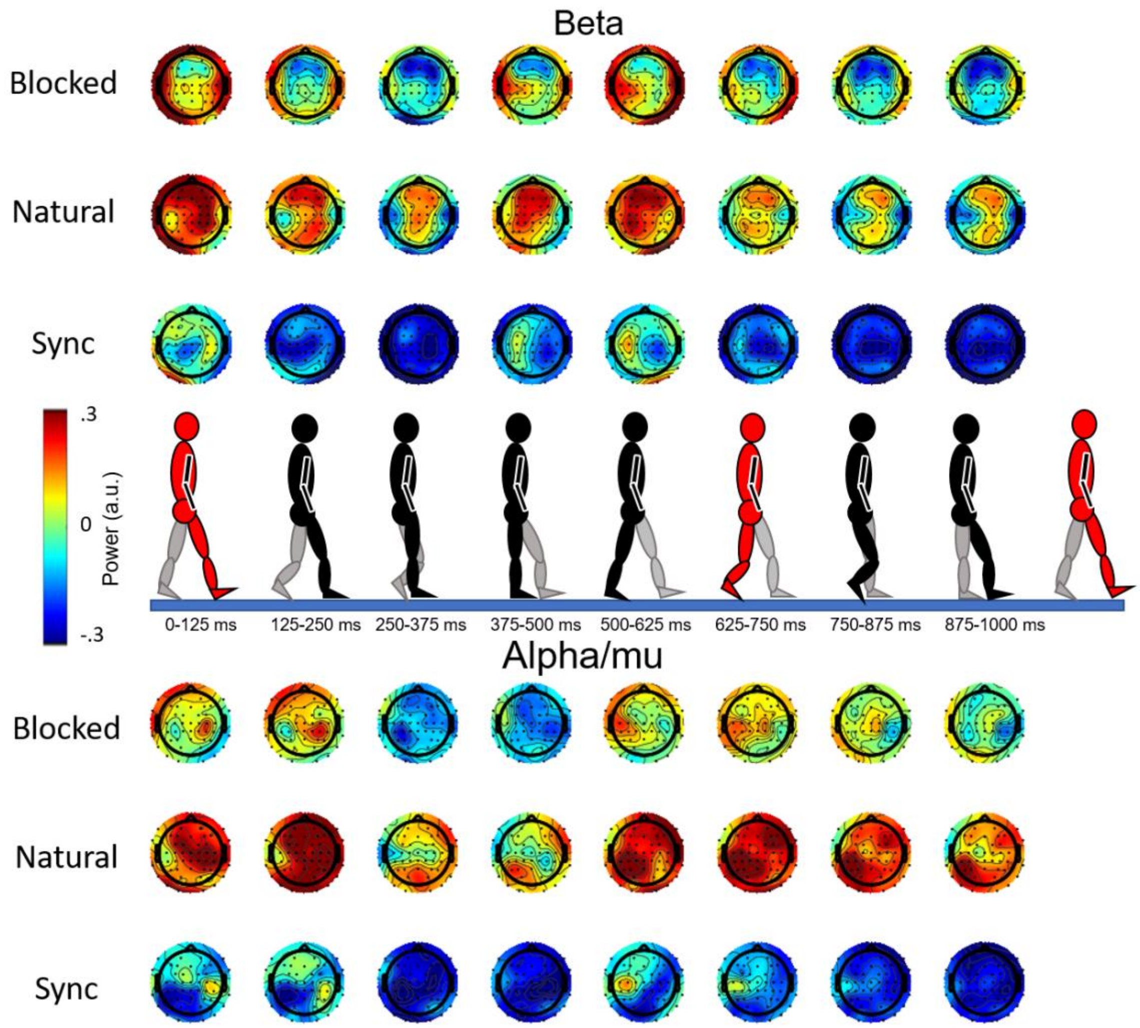

Figure 1: Time resolved topographies. Topographies for beta (top) and alpha/mu (bottom) for each condition, resolved into averaged 12.5% sections over the step cycle. Time frequency data was time-warped to the gait cycle using markers for the right heel-strike (RHS), and right toe-off (RTO).

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