How many steps are required to recover from a gait rhythm perturbation?

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I. MOTIVATION

Maintaining balance is fundamental to locomotion. Unexpected perturbations during walking, intrinsic (noise in the muscular or sensory systems) or extrinsic (uneven walking surface), leads to small variations in the walking behavior from cycle to cycle. However, humans are able to generate a quick and accurate recovery response, and possibly without requiring much attention to facilitate balance recovery in the event of a destabilization. It is challenging to characterize responses to perturbations (resilience) because we do not yet have an accepted definition of the steady state threshold to which the human participant will return after the perturbation [1]. This is despite the fact that gait characteristics under steady-state conditions are fundamentally constrained and does not characterize walking dynamics under infinitesimally small perturbations of both indoor and outdoor walking. When gait is externally perturbed, stability of walking can be assessed by quantifying the response to the applied perturbation. However, current indices of locomotor stability [2], while being correlates of a continuous dynamic system recovering from perturbations from one step to another, do not provide directly an assessment of a system's response behavior. Previously, we proposed a novel framework [3] to quantify the rate of recovery from a perturbation using attractor reconstruction of gait kinematic data. In the present study, we aim to validate this framework in healthy young adults using external auditory stimuli perturbations.

II. METHODS

Participants (*N*=20, 13 males and 7 females, 24.9 ± 2.3 yr., 72.6±6.3 kg., 1.76±0.1 m) were asked to complete three, 6-min walking trials on a treadmill (h/p/cosmos): (1) unpaced Pre, (2) acoustically paced including perturbation, (3) unpaced Post. The inter beat intervals of acoustic pacing (*0.1s of the note A, sine wave with frequency 440Hz*) were matched to the unpaced step time of the participants. We then embedded five perturbation steps set to twice the standard deviation of the unpaced step time and introduced around three minutes. The participants were asked explicitly to walk in time to the auditory cues. 3D kinematics of the lower body (37 markers) were collected and the body center of mass (COM) was approximated using the sacrum marker. We calculated local dynamic stability of vertical COM data using the maximum Lyapunov exponent (LyE). Participant's response to perturbation was characterized using the framework developed in [3] and recovery time was calculated.

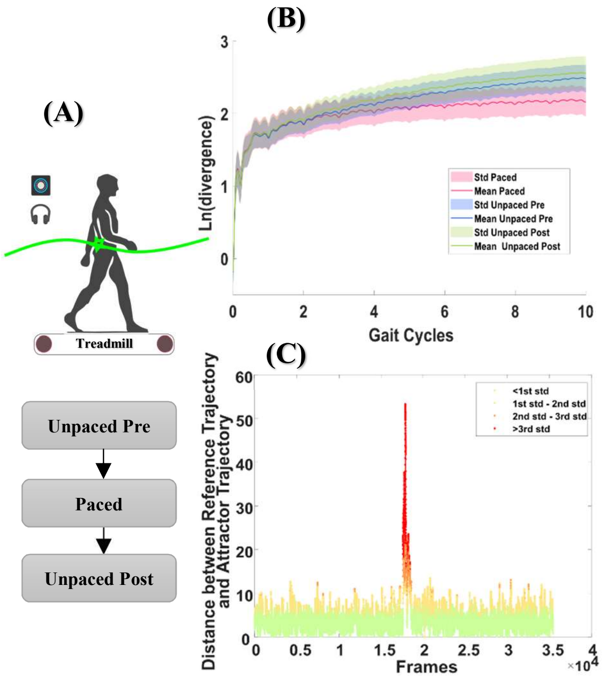

Fig. 1. (A) Experiment Protocol (B) Divergence curves (C) Resilience characteristics from an example participant

III. RESULTS AND FUTURE WORK

Short-term LyE (0-0.5 strides) computed from the unpaced Pre vs acoustically paced perturbation trials showed only marginal effect (Hedges'g effect size = -0.06) while long-term stability (4-10 strides) exhibited a significant effect (-0.813). Analysis of resilience characteristics (Fig.1.(C)) revealed that 15 out of the 20 participants were perturbed (state of COM trajectory as a result of the perturbation greater that the second standard deviation of the mean of unperturbed walking states). The correlation between recovery time and local dynamic stability, influences of walking speed and auditory-motor synchronization will be presented at the conference. Finally, the study of stability using the resilience indices has obvious behavioral and ecological relevance (synonymous to the duration needed to achieve recovery and qualify as a sensitive marker for fall risk) allowing early identification of individuals with a potential risk for falling.

REFERENCES

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