Exploring walking entrainment with vertical force oscillations

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I. Introduction

In walking, the legs mediate interactions between the individual's body mass and the substrate. How would the control policy change if that interaction were artificially altered? In this study, we impart vertical force oscillations via a body harness and alter frequency or amplitude (in real time) during two experiments. Under certain circumstances subjects match steps to the oscillation frequency and this defines a "Basin of Entrainment" [1] for external oscillations.

II. Methods

A custom mechatronics system imparted periodic forces to subjects walking on a treadmill [2]. The system used electric motors to pull up and down on a body harness, where frequency and amplitude were prescribed, depending on the experiment.

In the "Sensitivity" experiment (Fig. 1A), constant-frequency oscillations (different from the subject's baseline step frequency) were prescribed, starting at low amplitude and gradually increasing to 30% Body Weight (BW). In the "Range" experiment (Fig. 1B), constant-amplitude oscillations were prescribed, starting at the subject's baseline frequency and gradually drifting away before eventually returning. In both experiments, the amplitudes and frequencies where subjects synchronized their steps to the oscillations determined a "Basin of Entrainment".

III. Results & Discussion

Subjects entrained more consistently with high-amplitude oscillations (Fig. 1C). However, they also entrained at lower amplitudes (increased sensitivity) when oscillations were closer to baseline step frequencies. Interestingly, subjects also entrained more with oscillation frequencies below baseline versus above. Treadmill speed was constant, so entrainment to lower frequencies required an increase in stride length, and subjects appeared more amenable to this adjustment. Regardless, some subjects still eventually entrained to frequencies as much as 9% above baseline, but this required amplitudes approaching 30% BW. Entrainment range also

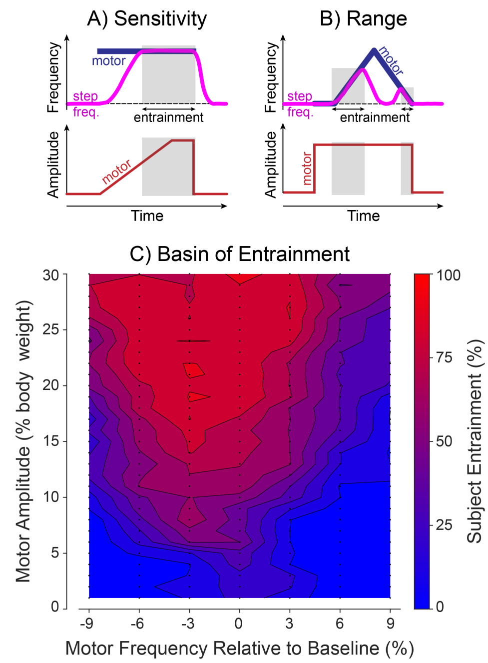

Fig. 1 A) Sensitivity experiment with varied amplitude, constant frequency. B) Range experiment with varied frequency, constant amplitude. C) Basin of Entrainment for subjects per amplitude/frequency combinations.

increased with oscillation amplitude and with frequencies below baseline.

These results allow us to construct a "Basin of Entrainment" (Fig. 1C) indicating the range and sensitivity of individuals to vertical force oscillations. This study can help inform rehabilitation strategies where, for example, entrainment motivates patients to relearn faster walking speeds during recovery from stroke or other neuromuscular injuries.

References

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