Properties of the Phase Resetting Curve for Human Gait

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1 Motivation

Gait is sometimes modeled as a limit cycle oscillator. This approach assumes that when perturbed, the oscillator will converge toward its limit cycle, and its overall behavior can therefore be described in terms of a phase resetting curve (PRC). A PRC represents the transient change in the cycle period of an oscillator induced by a perturbation that is a function of the phase in which it is received [1]. Study of the PRC for human gait may help to explain how external influences might contribute to falling [2-3].

Currently, the PRC for human gait is not well defined. Previous study has demonstrated that, in general, perturbations applied early during the swing phase of gait result in a flexor response, while perturbations that occur later during swing result in an extensor response [3]. Beyond these results, several questions remain. For example: 1) How is the PRC affected by changes in walking speed? 2) Is the PRC consistent across all individuals, including those with neurological impairments? 3) Can the PRC be used to predict synchronization during side by side walking?

2 State of the Art

Several approaches have been used to apply perturbations to walking subjects. These generally include 1) pulling or applying a break to a cable that is attached to the swing leg of a subject, 2) placing obstacles on the walking surface that hinder or obstruct swing, 3) applying a mechanical "push" to the center of mass walking subject, and 4) reproducing a "slip" type of perturbation with a walking surface that moves upon heel strike.

3 Own Approach

Our approach is similar to that employed by [2]. Subjects walk on a treadmill while a lightweight rope is attached to their right ankle. An electric motor is used to actuate an arm, which pulls on the rope from behind the subject with a force up to 180 N. The rope is kept under constant tension with an elastic cord. An overhead harness system is used to ensure safety, and an 8 camera motion capture system is used to record movement of the legs.

The first of our studies focused on the effects of altered treadmill speed on the PRC of human gait. Fourteen subjects walked at 4 different treadmill speeds: their preferred walking speed (PWS), 1.8 mph, 2.5 mph, and 3.2 mph. An ankle perturbation was applied in a pseudo random fashion every 12-20 strides.

4 Current Results

Walking speed appeared to alter phase resetting behavior. Specifically, phase advance during late swing was increased for lower walking speeds in a manner that was similar to that reported in neurons [4]. In addition, we noted that most subjects exhibited atypical behavior when the perturbation was applied at a very specific time during mid-swing. These data suggest that there is a small region during mid-swing where perturbation will generate a larger than normal phase delay.

5 Best Possible Outcome

We surmise that this perturbation "sweet spot" may lie at the interface of the flexor and extensor response to perturbation. Future experiments will focus on exploring whether a delay in muscle activation (secondary to increased CNS processing time) can be implicated.

Acknowledgement

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References

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[4] Beverlin et al. (2012) J Comp Neurosci