# Determining the Control Goal for Treadmill Walking when Belt Speed Varies

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## Summary

Since treadmill walking is a redundant task, there is an underlying control goal such as matching treadmill speed or maintaining constant position. For unperturbed walking and running, the goal is matching average treadmill speed. It is unknown how robust this goal is. This abstract shows that the goal remains constant even when treadmill speed varies within a step. This is done by examining how deviations from potential goals are corrected.

## Introduction

There are infinite combinations of step length and duration that produce the same walking speed [1]. It is assumed that there is an ideal set of parameters that would be used if the system had no noise. Because there is noise, there is step-to-step variation [2]. Examination of this variation can be used to deduce the control goal because some variability will affect the goal while some will not [3]. Deviations from the goal are expected to both be small and quickly corrected [1]. For treadmill locomotion, two logical choices for the goal are matching treadmill speed or maintaining a constant position on the treadmill [1]. For unperturbed walking [1] and running [4], the goal appears to be matching speed. However, it is unknown if the control goal generalizes to cases when treadmill speed is not constant.

## Methods

Ten healthy adults participated in two 6 min trials. Subjects walked on a split-belt treadmill at a nominal speed of 1.1 m/s. For the control condition, treadmill speed was constant. For the perturbation condition, treadmill speed was adjusted for leading leg during double support. Specifically, belt speed was reduced to 0.7 m/s as quickly as possible, held at 0.7 m/s for 0.2 s, then increased back to 1.1 m/s as quickly as possible. These perturbations might make matching treadmill speed more difficult because the treadmill is no longer running at a constant speed for the entire step. Subjects practiced for 10 min prior to the perturbation trial. Because these perturbations are not random, this condition represent a less practiced task rather than reactions to unexpected conditions. To determine if the control goal was still speed, average speed and absolute position at heel strike were analysed using three methods [1]. The ideal speed and position were assumed to equal the mean values, and errors were the difference from the mean. The amount of variation was quantified using the coefficient of variation (CV, standard deviation divided by mean); higher CV suggests that the parameter is not tightly controlled. The speed at which errors were corrected was quantified using the Hurst exponent $\alpha$; $\alpha < 0.5$ indicates an anti-correlated series and tight regulation while $\alpha > 0.5$ indicates a positively correlated series and weak regulation. The effect of error size on the subsequent correction was quantified by plotting $\Delta e_{n+1}$ vs $e_n$ and finding the slope where $e_n$ is the error for step $n$ and $\Delta e_{n+1} = e_{n+1} - e_n$ is the size of the correction; slopes near 0 indicate that error size has little effect on the next step while slopes near $-1$ indicate that errors are mostly corrected within one step. This parameter will be termed 'Slope.' Statistical testing was performed using the Wilcoxon signed-rank test with significance set at 0.05.

## Results and Discussion

The perturbations were of sufficient magnitude to significantly shift the mean step length (0.56 m to 0.50 m) and duration (0.55 s to 0.57 s). Despite these changes, none of the parameters used to identify the control goal changed significantly between the two conditions (Fig. 1). In most cases, the CV was smaller for speed than for position, suggesting tighter control of speed. The Hurst exponent was slightly less than 0.5 for speed and much greater than 0.5 for position regardless of condition, indicating that errors in speed were corrected much more quickly than errors in position. This is consistent with [1]. It is also supported by the significant difference in Slope. Errors in speed were typically slightly overcorrected the next step (Slope $< -1$) while errors in position were rarely corrected the next step (Slope $\approx 0$). This is also consistent with [1]. Taken together, this indicates that healthy humans do not alter their control goal for treadmill walking even when faced with the less practiced task of variable belt speed.

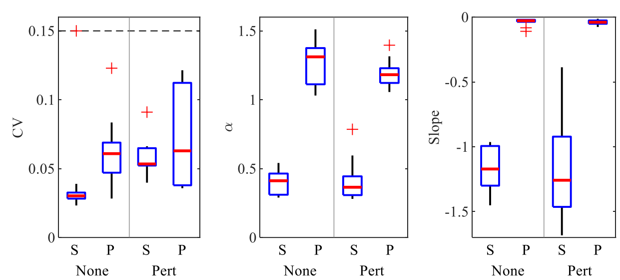


**Figure 1**: The coefficient of variation (CV), Hurst exponent ($\alpha$), and Slope parameter for speed (S) and position (P) for trials with constant treadmill speed (None) and variable treadmill speed (Pert).

## Conclusions

These results suggest that the control goal for treadmill walking is robust to changes in belt speed. Regardless of if the belt speed is constant or variable over a step, humans appear to prioritize matching average belt speed over the alternative control goal of maintaining a constant position on the treadmill.

## References

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