Autocorrelation and Probability Distributions in Gait-Metronome Synchronization

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INTRODUCTION

Recent studies have shown that the temporal structure of pacing signals (e.g., visual and auditory metronomes) influences the gait dynamics observed when coordinating with those signals [1,2]. Those studies typically involve pacing signals with interbeat intervals that are either constant over time or 'noisy', with the latter case referring to a class of signals that vary with respect to their autocorrelation function. To-date, however, no studies have directly examined the role that probability distribution functions play in gait-metronome synchronization. This study examines both structure of autocorrelation functions (ACFs) and the shape of probability distribution functions (PDFs) in noisy metronomes as possible sources of information involved in the synchronization process. Pacing signals varied in terms of both ACF decay and PDF shape. Statistical results support the idea that both the ACF and PDF exert independent effects on the temporal structure of gait.

METHODS

Participants. Ten healthy subjects from the University of Nebraska at Omaha volunteered to participate.

Apparatus and Procedure. In this experiment, individual Noraxon FSR SmartLead footswitches (Noraxon USA Inc, Scottsdale, Az) were connected to the heel of each foot of each subject. Then the subject covered the foot switches with their socks and shoes. The footswitches were used to collect stride time intervals. The subject was then instructed to walk around on a track surface for 12 minutes. This baseline trial was self-paced and stride time intervals were collected. The self-paced trial was used to find the average and standard deviation for each subject's preferred walking speed and variability. Computations were performed using custom MATLAB code (MathWorks, Natick, MA).

After performing the baseline condition, subjects walked in four pacing conditions. Trial order was randomized. The trials were Pink-Gaussian, Pink-Uniform, White-Gaussian, and White-Noise. Here, Pink and White refer to long-range and zero autocorrelation, respectively. Gaussian and Uniform refer to standard probability distributions. The noises were delivered as a visual stimulus. A small video screen was attached to a pair of glasses to allow the subject to see the screen with their right eye, and the environment with their left eye. The stimulus screen consisted of two fixed horizontal bars, one on the top and one on the bottom of the display. A third moving horizontal bar was placed between the two bars and moved up and down. When the bar reached the top, the subject was instructed to strike with their right heel while walking. The moving bar timing was based on the mean and standard deviation of the subject's preferred walking speed, and the statistical properties implied by each experimental condition (e.g., Pink-Gaussian). All trials lasted for 12 minutes.

Analysis Strategy. Stride time series were analyzed using Detrended Fluctuation Analysis in order to compute the Hurst exponent, a measure of statistical persistence. Experimental data were analyzed with 2_W(ACF: Pink, White) × 2_W(PDF: Gaussian, Uniform) ANOVA.

RESULTS AND DISCUSSION

That statistical analysis revealed a main effect of ACF, $F(1,9)=93.16$, $p<0.001$, as well as a main effect of PDF, $F(1,9)=6.35$, $p<0.05$. The two-way interaction was not significant. These results show that the Hurst exponents were larger in the Pink condition than in the White condition. Similarly, Gaussian distributions produced larger Hurst exponents than did Uniform conditions.

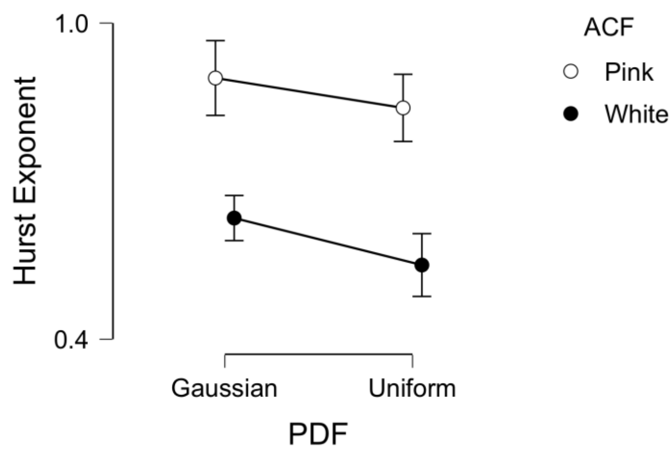

Figure 1: Hurst exponent as a function of autocorrelation and probability distribution functions.

CONCLUSIONS

In this study, we investigated the relative influence of autocorrelation and probability distribution functions on gait variability. These results suggest that both ACFs and PDFs provide relevant information that influences the time-varying structure of stride time intervals. Importantly, these properties appear to exert their influence in a relatively independent manner. Future research will investigate a broader range of ACFs and PDFs and their relevance to pathological gait.

REFERENCES

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