Walking at stability’s edge

JOHN MILTON, DAVID NICHOLS, ADAM COLEMAN, COURY CLEMENS, ANNIE NGUYENTAT, AMI RADUNSKAYA, The Claremont Colleges — During self-paced human walking, the variability in inter-stride intervals exhibit fractal dynamics characterized by long-range correlations having a power-law decay with exponent $\alpha$. We used diffusion fluctuation analysis (DFA) to estimate $\alpha$ as a function of the roughness of the walking surface for eight (8) healthy subjects (1200-1400 inter-stride intervals for each walking surface). For each subject the highest $\alpha$ (mean 0.96, range 0.88-1.10) occurred for walking on a running track and $\alpha$ was 15–20% lower for walking on either a relatively smoother (tennis hard court) or a rougher (dirt path) surface. These observations are captured by a stochastic discrete time cubic map: $I_{i+1} = a(\xi_i)I_i - bI_i^3 + \eta_i$, where $I_i$ is the $i$–th inter-stride time, $a(\xi_i) = a_0(\xi) + \xi_i$ describes parametric, colored noise where $a_0(\xi)$ is a constant that depends on surface roughness and $\xi_i$ is colored noise with mean zero, $\eta_i$ is low-intensity additive white noise, and $b$ is a constant. As the roughness, and hence $a_0(\xi)$, of the walking surface increases, the fluctuations in the inter-stride interval are predicted to obey a power law whose exponent changes non-monotonically: the highest values of $\alpha$ determined with DFA occur when $a_0(\xi)$ is close to the deterministic stability boundary $a = 1$. Thus the neural control of walking appears to involve a dynamical system tuned close to the edge of stability subjected to the effects of parametric noise.