Transient stabilization of unstable states: why a stick balanced at the fingertip always falls?

John Milton
Claremont, California, USA

The prevention of falls in the elderly, and their accompanying mortality and morbidity, are major challenges faced by aging industrialized societies. Increased risks of falling are associated with diseases of aging, such as diabetes, which enlarge sensory dead zones of peripherally located sensory receptors related to balance control. The sensory dead zone represents a range of the controlled variable over which no output is generated. Consequently mathematical models for balance control are posed as switching, or hybrid, type models in which the feedback control is turned on whenever the controlled variable exceeds a sensory threshold. From a dynamical point of view the presence of a dead zone represents a small-scale nonlinearity which does not affect large-scale linear stability, but can produce complex dynamics including limit cycle oscillations and micro-chaos. Here it is shown that for such systems it is possible that balance can be maintained for as long as minutes even though the feedback control is asymptotically unstable! Thus, for example, a stick balanced at the fingertip, an important laboratory paradigm for investigating the neural control of balance, can eventually fall no matter how skilled the stick balancer. These observations support the hypothesis that techniques which modify sensory dead zones, such as noisily vibrating insoles, may be useful to reduce the risk of falling in the elderly.