Comparing Internal Models of the Dynamics of the Visual Environment

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It is well known that the human postural control system responds to visual stimuli but the implicit assumptions that the nervous system makes about the visual environment and what quantities, if any, it estimates to predict the motion of the visual environment are unknown. This study compares four models of the postural control system. Three include internal models of the visual environment that implicitly assume its dynamics to be, respectively, a random walk, a general first order linear stochastic process, and a general second order linear stochastic process. The fourth model does not predict the environment.

In each of the three predicting cases, all of the coefficients that describe the process are estimated by an adaptive scheme that is based on maximum likelihood. For comparison, the only other adaptive model of posture so far published [4] uses a random walk internal model of the visual environment (as does our first model), but a different adaptive scheme. Our adaptive scheme, unlike the Myers and Tapley scheme [1] used in [4] has the desired property that its estimates converge as the step size tends to zero.

We find that the internal model of the visual environment makes a significant difference in how the postural system responds to stimuli. Notably, the second order process model outperforms the human postural system in its response to sinusoidal visual stimulation. Specifically, the second order process model can correctly identify the frequency of the stimulus and completely compensate so that the stimulus has no effect on sway. In this case the postural control system extracts the same information from the visual modality as it does when the visual scene is stationary. This result starkly contrasts with the well known experimental observation that the human postural control system responds to a sinusoidal stimulus with a nonzero gain. Thus we can rule out the possibility that the human postural system predicts the motion of the visual environment with a general second or higher order internal model.

However the question remains does the postural control system predict the motion of the visual environment at all? To address this question, we considered the gain and phase of sway in response to a sinusoidal stimulus as a function of the amplitude and frequency of that stimulus. We have found that an increase in phase (with sway increasingly leading the stimulus), as the stimulus amplitude increases is a robust feature of the random walk and first order models.

We compare this behavior with the behavior of the fourth postural model that does not predict the environmental dynamics. The fourth model is the only one that reproduces the experimentally observed result [3] [2] that, across different frequencies of stimulation, the gain drops but the phase remains roughly constant as the amplitude of the stimulus increases. Our results suggest that the human postural control system does not predict the dynamics of the visual environment.

References

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