Self-Oscillator Model of Cognitive Bistability Explains Percept Reversal Rate Characteristics with Periodically Interrupted Ambiguous Stimulus

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Abstract

A stochastic nonlinear dynamics model is presented which explains published experimental results with periodically interrupted ambiguous stimuli [1][2]. Experiments with the Necker cube with stimulus-off times $t_{off} < 1$ s exhibit a maximum of the percept reversal rate of $R_{max} \approx 36\ min^{-1}$ at $t_{off} \approx 200$ ms (with on-time = 300 ms). According to [1] for $t_{off} > 200$ ms the percept is stabilized with increasing t_{off} due to recovery from neural fatigue. Within the present model these results are quantitatively explained by dynamical coupling of behavioral perception, attention, and memory (PAM) variables with delayed feedback. The model is related to the synergetic order parameter approach of Ditzinger & Haken [5] and was recently used for explaining long range correlations of the percept reversal time series [3][4]. A mapping of the PAM equations to basic Thalamo-Cortical reentrant loops was suggested.

In the present work the the percept choice dynamics [6] during the ambiguous stimulus on-off switching is the focus of data analysis of the numerically simulated reversal time series. The deterministic bifurcation of the perception state at the critical stimulus ambiguity parameter value (percept choice) adds to the phase oscillator self-oscillations and to stochastic attention noise (a fluctuating Langevin force). Delayed perception state feedback via an attention control parameter (adaptive gain) is used, which in turn is modulated through a slowly varying bias (memory). The t_{off} value at R_{max} and the absolute reversal rate values are determined by the time constants (fatigue, recovery, feedback delay = 40 ms) and by the attention noise power as parameters of the nonlinear PAM-state space equations. A linear approximation in the form of a Langevin equation allows for an analytic estimate of the percept reversal rate ($R_{max} = 30 – 40$ 1/min) and of the deterministic damping time constant ($\tau_v \approx 1$ s). Within a free energy (thermodynamic equilibrium) approximation the Fluctuation-Dissipation theorem relates the noise power spectral density and damping to an index of cognitive inertia and a cognitive perceptual energy value of at least 16 orders of magnitude above the thermal noise level at body temperature.

[1] Orbach. J., Zucker, E., Olson, R. (1966). Reversibility of the Necker Cube: VII. Reversal rate as a function of figure-on and figure-off durations. Percept. and Motor Skills (22), 615-618

[2] Kornmeier, J., Ehm, W. Bigalke, H., Bach, M. (2007): Discontinuous presentation of ambiguous figures: How interstimulus-interval durations affect reversal dynamics and ERP's. Psychophysiology, 44, 552-560

[3] Fürstenau, Norbert (2010). A nonlinear dynamics model for simulating long range correlations of cognitive multistability. Biol. Cybern., vol. 103. (3) 175-198

[4] Gao, J.B., Merk, I., Tung W W, Billok V, White, K.D., Harris J G, Roychowdhury V P. (2006) Inertia and memory in visual perception. Cogn. Process 7 105-112

[5] Ditzinger, T., Haken, H. (1989). Oscillations in the Perception of Ambiguous Patterns. Biol. Cybern. (61) 279-287

[6] Noest, A.J., van Ee, R., Nijs, M.M., van Wezel, R.J.A. (2007) Percept-choice sequences driven by interrupted ambiguous stimuli: A low-level neural model. J of Vision 7, 1-14