Percept Choice Dynamics of Stochastic Self-Oscillator Model Dominates Percept Reversal Rate Characteristics under 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 stimulus [1][2]. The model is related to the synergetic order parameter approach of Ditzinger & Haken [4] and was recently used for explaining long range correlations of the percept reversal time series [3]. Delayed perception state feedback via an attention control parameter (adaptive gain) is used, which in turn is modulated through a slowly varying bias (memory). A mapping of the perception, attention, memory (PAM) equations to basic Thalamo-Cortical reentrant loops was suggested. 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) [1][2]. 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 the percept choice or stimulus-onset dynamics during the ambiguous stimulus off-on switching turns out to dominate over fatigue with increasing t_{off} in agreement with Noest et al.[5].

This onset dynamics is induced by the off-on switching of the stimulus ambiguity parameter which correspondingly modulates the feedback. Onset-bifurcation of the perception state at the critical ambiguity parameter value (percept choice) adds to the phase oscillator self-oscillations and to the effects of stochastic attention noise (a fluctuating Langevin force). Numerical simulations are based on the dynamical coupling of the behavioral PAM-variables with delayed feedback. 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 second order Langevin equation allows for an analytic estimate of the percept reversal rate ($R_{max} = 30 - 40$ min^{-1}) and of the perceptual damping time constant ($\tau_v \approx 1$ s). Within a thermodynamic equilibrium approximation the Fluctuation-Dissipation theorem (or Einstein diffusion coefficient of Brownian motion) 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.

References

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

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

[5] 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