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A Bistable Counterchange Detector for the Perception of Third-Order Motion

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Background / Purpose: Despite considerable evidence for attention-mediated changes in salience as the basis for third-order motion, the nature of the motion mechanism responsible for its actual perception has not been established. A counterchange-sensitive, directionally selective motion detector has been proposed for this purpose. It entails the detection of oppositely signed changes in activation at pairs of spatial locations. A recently developed computational model based on the counterchange principle (Hock, Schöner & Gilroy 2009) accounts for a wide range of phenomena for both generalized apparent motion stimuli (oppositely signed changes in contrast for two simultaneously visible surfaces) and standard apparent motion stimuli (when a surface is displaced its contrast disappears at its initial location and re-appears at its new location). Main conclusion: An updated version of this model is presented which, in addition, accounts for the dynamical properties of apparent motion perception; i.e., it accounts for its bistability (both motion and nonmotion can be perceived for the same generalized apparent motion stimulus), the temporal persistence of these perceptual states, and the effects of adaptation. Motion/non-motion bistability is established by activation-dependent feedback from the output of the motion detector to its biphasic subunits. The temporal persistence of these states for back-and-forth motion and the temporal integration of successive motions in the same direction are accounted for by activation-dependent interactions among different directionally selective motion detectors. The model makes several novel, experimentally-testable predictions that will further inform its plausibility.

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Introduction

A dynamical counterchange mechanism for 3rd-order motion detection is proposed (Lu & Sperling, 1995)

The mechanism entails oppositely-signed changes in contrast at pairs of locations for detection of motion (from decrease to increase)

The original model accounts for a wide-range of apparent motion phenomena (Hock, Schöner & Gilroy, 2009)

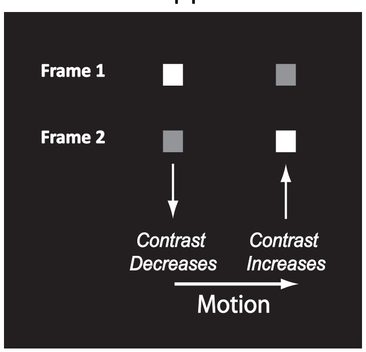
An updated version of the model is presented which accounts, in addition, for dynamical properties of apparent motion perception including:

1) bistability (i.e. both nonmotion and motion can be perceived for the same stimulus)

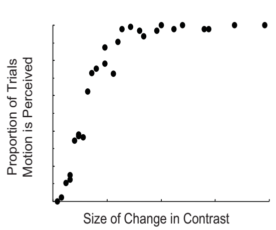
2) the temporal persistence of these states

3) the effects of adaptation on the stability of these states

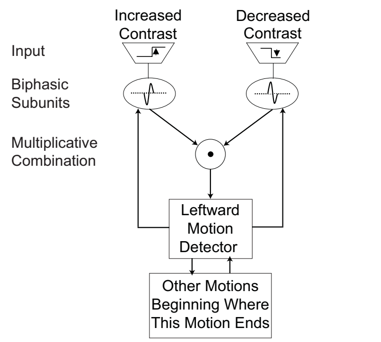
Generalized Apparent Motion



Whether Motion or Nonmotion is Perceived Depends on the Size of the Contrast Change.



Dynamical Counterchange Detector



Experiment 1

Hock, Nichols and Espinoza (2004)

In this experiment, after trials of varying length, participants were asked to indicate whether motion or nonmotion was the initial percept, and whether there was at least one perceptual switch.

Results indicated an increased likelihood of switching per unit time consistent with a destabilization of both the motion and nonmotion state.

The current model accounts for these results through adaptation of the motion state, and a relaxation from adaptation during subsequent nomotion states

Experiment 2

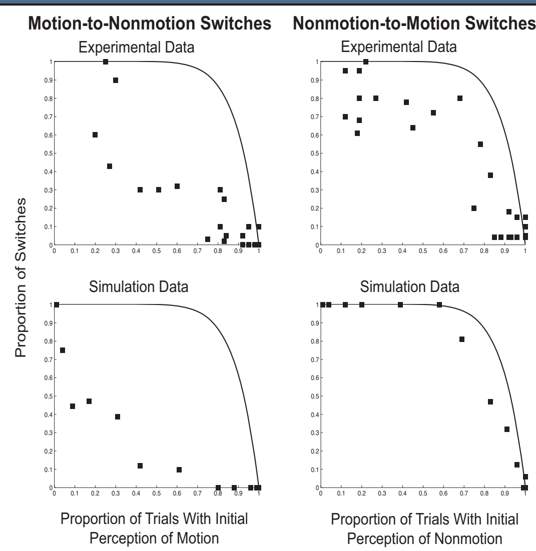
Hock, Kogan and Espinoza (1997)

1. Vary size of contrast change

2. Each trial has 20 frames

3. Subject indicates whether motion or nonmotion was perceived at the start of the trial, and whether there was a switch anytime during the trial

4. Graphed is the frequency of switches as a function of the probability that motion or nonmotion is



Description

- Multiplicative combination signals coincidence of increase and decrease at two locations, signifying motion
- Activation dependent feedback excites biphasic subunits and creates 'detection instability'
- Random fluctuations induce switching between motion and nonmotion states
- Inter-detector excitation facilitates motion detection from location where preceding motion ends
- Adaptation destabilizes motion state
- Relaxation of adaptation destabilizes nonmotion state

Equations

Leftward motion detector

$$\tau_{fast}\frac{du_{mL}}{dt} = -u_{mL} + h + w_{sm}\cdot f(u_{iL})\cdot f(u_{dL}) + w_c\cdot f(u_{mR}) - a_{mL} + \eta$$

Increase detector for leftward motion

$$\tau_{fast}\frac{du_{iL}}{dt} = -u_{iL} + h + S_L + w_{ms}\cdot f(u_{mL}) - v_{iL} + \eta$$

$$\tau_{slow}\frac{dv_{iL}}{dt} = -v_{iL} + S_L$$

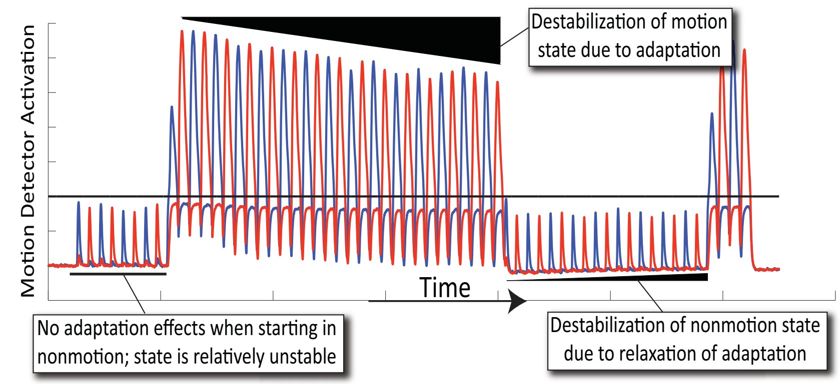
Decrease detector for leftward motion

$$\tau_{fast}\frac{du_{dL}}{dt} = -u_{dL} + h - S_R + w_{ms}\cdot f(u_{mL}) - v_{dL} + \eta$$

$$\tau_{slow}\frac{dv_{dL}}{dt} = -v_{dL} - S_R$$

Adaptation variable for leftward motion

$$\tau_{adapt}\frac{da_{mL}}{dt} = -a_{mL} + w_a\cdot f_{adapt}(u_{mL})$$



Conclusions and References

The model shows activation dependent excitatory feedback creates a detection instability such that for a near-threshold stimulus either non-motion or motion is clearly perceived. Near the detection threshold, noisy fluctuations determine which percept is formed.

A closed feedback loop between motion detectors stabilizes the perception of back-and-forth motion. This motion state destabilizes due to adaptation effects, increasing the likelihood of a noisy fluctuation inducing a switch to the nonmotion state.

The destabilization of the nonmotion state is due to the relaxation of adaptation inherited from the preceding motion state. Consequently, a trial which begins in nonmotion shows no adaptation effects until a noise-induced switch to motion occurs. This is a testable prediction and future experimental work will address this issue.

Hock, Krogan, & Espinoza (1997) Dynamic, state-dependent thresholds for the perception of single-element apparent motion: Bistability from local cooperativity. *Perception & Psychophysics, 59, 1077-1088.*

Hock, Nichols, & Espinoza (2004) When motion is not perceived: Evidence from adaptation and dynamical stability. *Spatial Vision, 17, 235-248.*

Hock, Schöner, & Gilroy (2009) A counterchange mechanism for the perception of motion. *Acta Psychologica, 132, 1-21.*

Lu & Sperling (1995) The functional architecture of human visual motion perception. *Vision Research, 35, 2697-2722*