cbbs
center for behavioral
brain sciences

*iCrea

ESR 9 & 10:
Modelling & MRI

Jochen Braun
Cognitive Biology, University of Magdeburg

Gustavo Deco
ICREA and Unversitat Pompeu Fabra, Barcelona

1. Context-dependent functional connectivity:
emerges from fixed structural connectivity

2. Dynamics of perceptual representations:
characterizing collective stable states

3. Spontaneous ongoing attention dynamics:
multi-stable displays and/or continuous shape morphing

1. Context-dependence of functional connectivity

Deco, Friston, Hagmann, Mantini, Corbetta, 2013

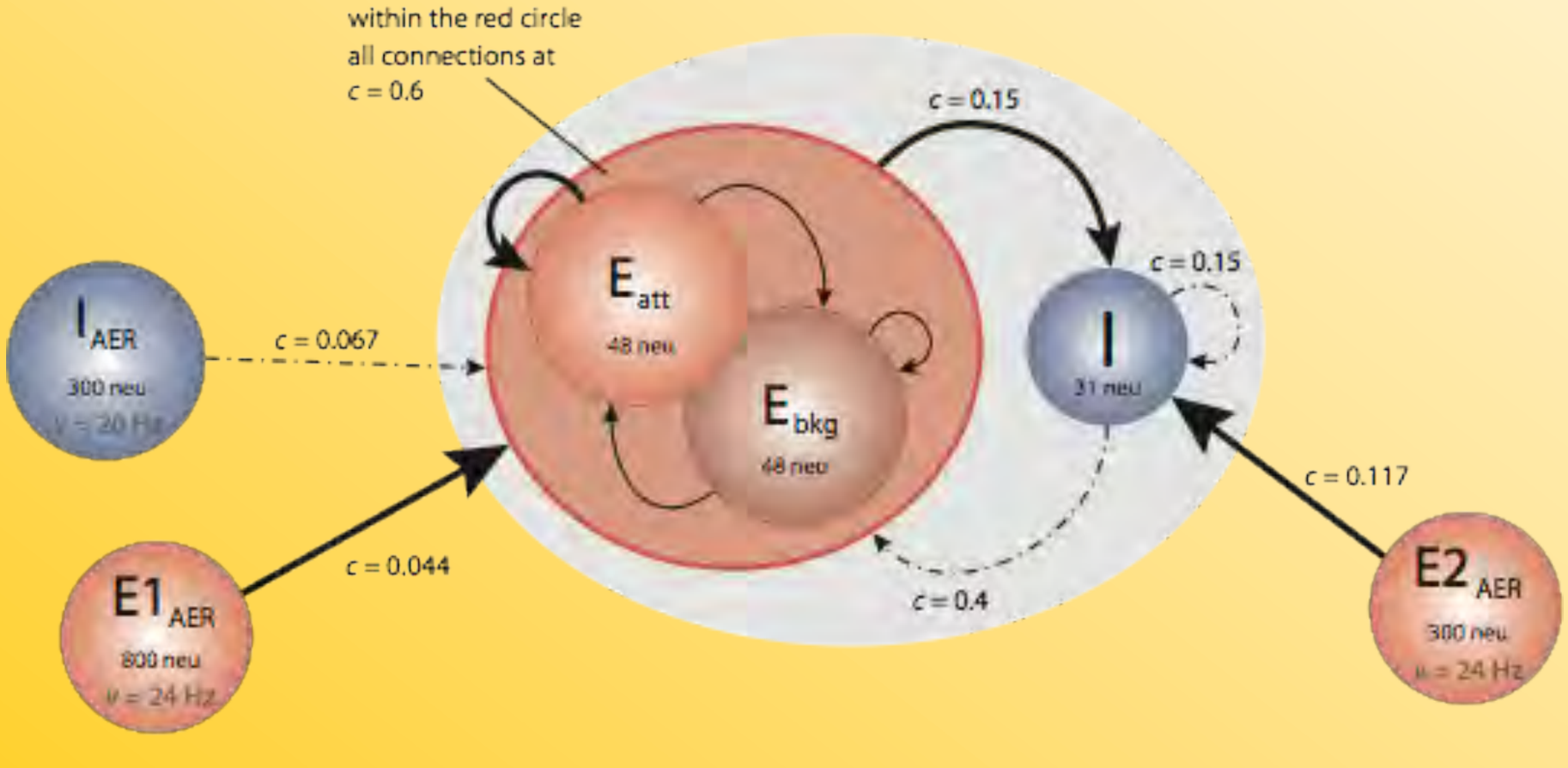
Structural connectivity:
Anatomical connectivity skeleton established by diffusion spectrum imaging.

Functional connectivity:
Statistical dependence between dynamics at remote sites.

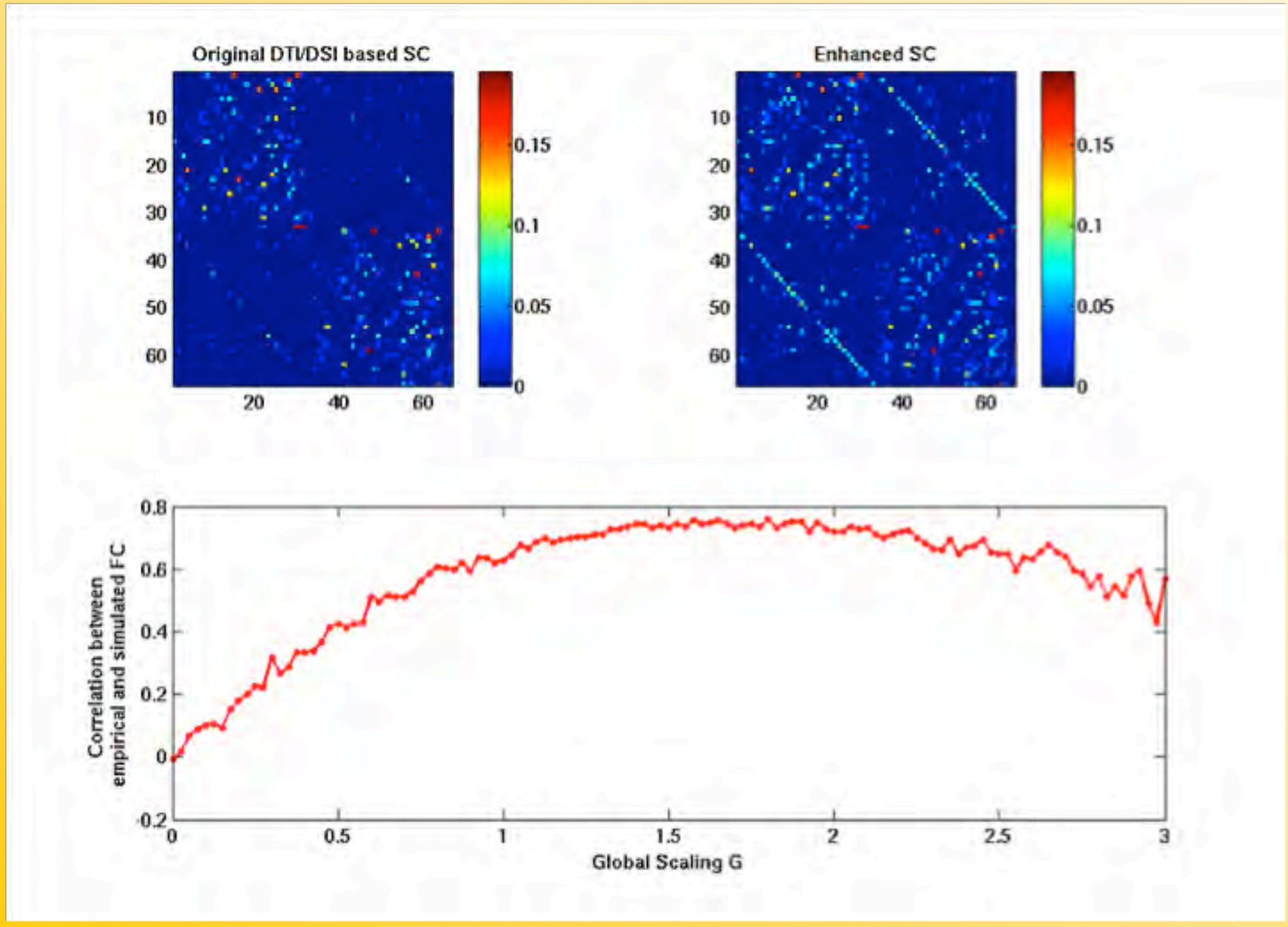
Effective connectivity:
Simplest structural connectivity to replicate functional connectivity (e.g., dynamic causal modelling).

How can the same structural connectivity yield different effective connectivities in different task contexts?

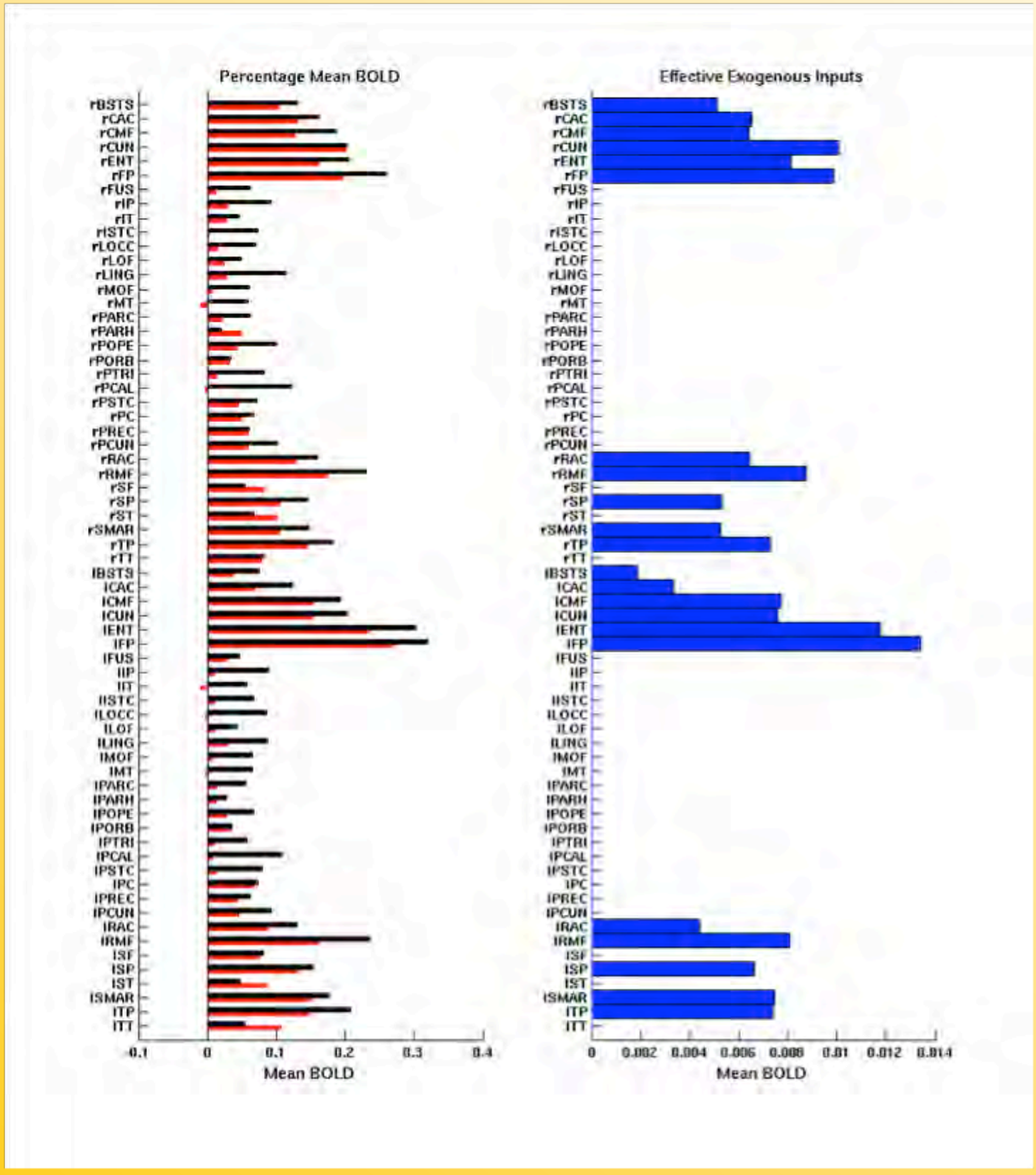
Step 1: Build local nodes with excitatory and inhibitory neurons to obtain spontaneous activity of 3 Hz. In combination with local input, recurrent connectivity may create an additional steady-state at a higher level of activity.



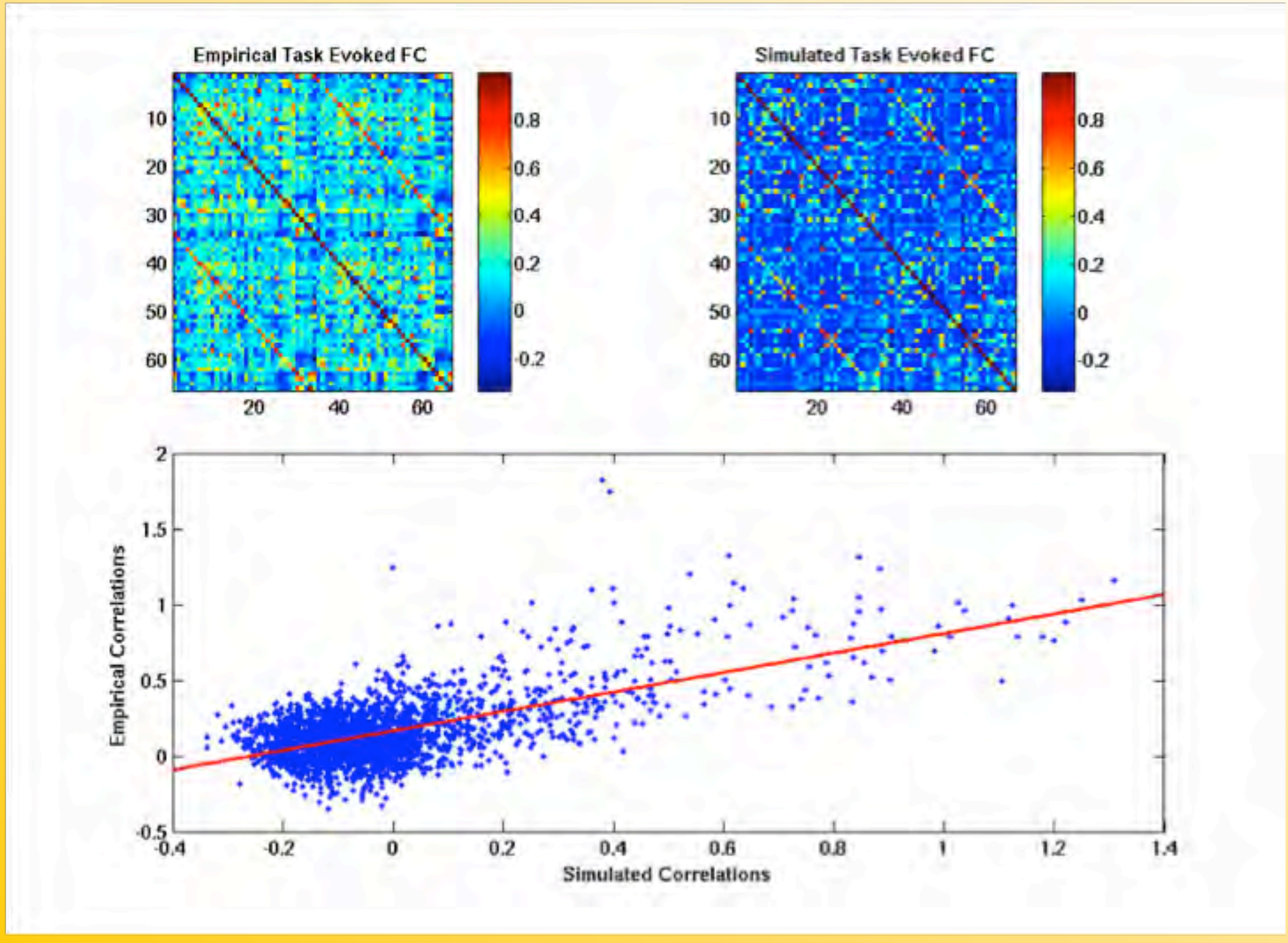
Step 2: Establish structural connectivity matrix SC (with DSI). Scale overall connection strength to destablize global dynamics and to maximize correlation with resting-state FC.

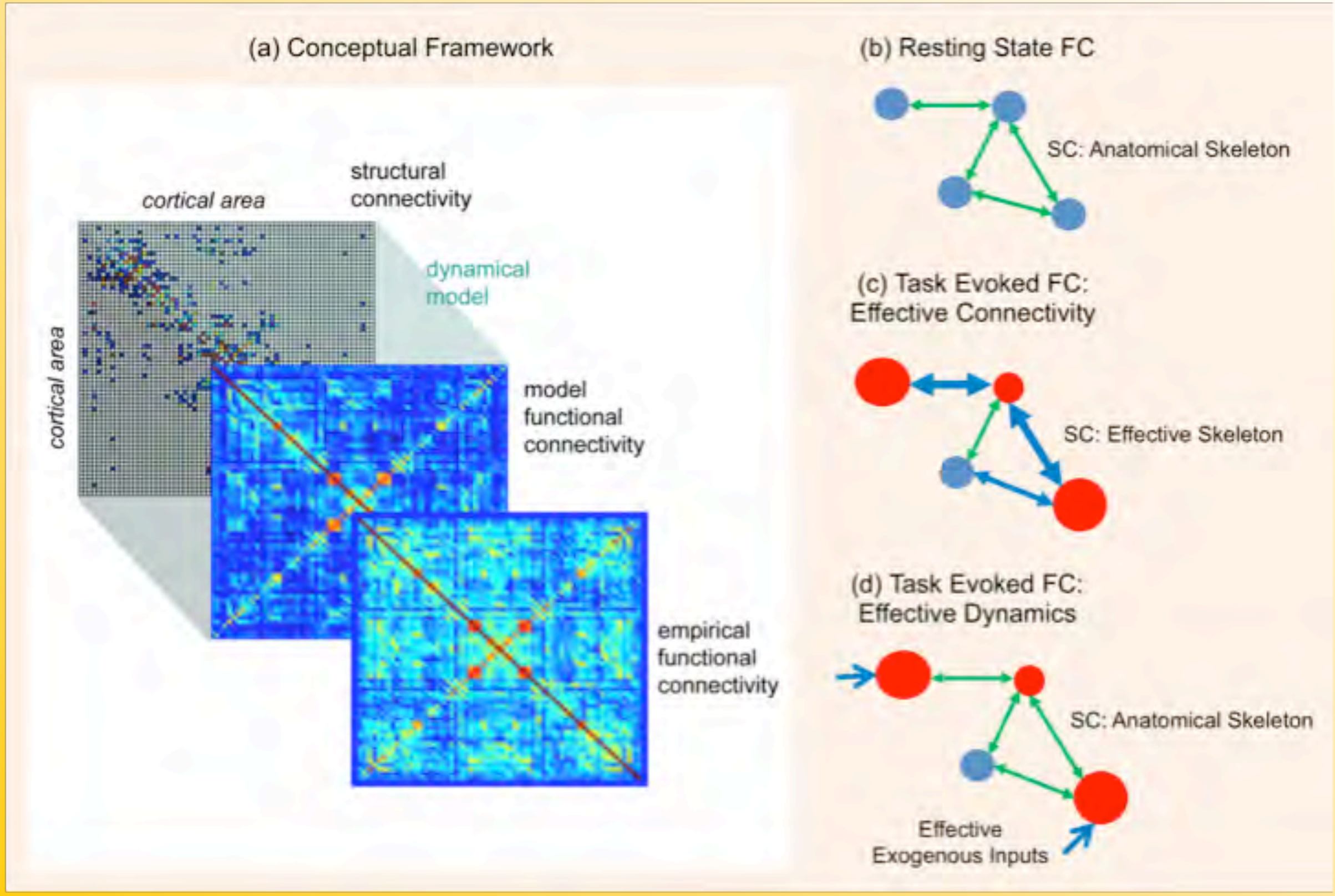


Step 3 (first-order fit): Iteratively adjust local inputs to maximize correlation with task-state BOLD activity.



Step 4 (Second-order validation): Compare FC prediction of driven model with observed task-state FC.





Deco, Friston, Hagmann, Mantini, Corbetta, 2013

A. DCM accounts for FC by individually adjusting N^2 effective connection weights.

Functional connectivity N^2 modelled in terms of effective N^2 connectivity.

B. Gustavo accounts for FC by individually adjusting N local tonic input levels.

Local inputs alter non-linear dynamics of N individual nodes.

Altered average activity predicts N local BOLD signals.

Keeping structural connectivity fixed (apart from scale factor), emerging global dynamics predicts functional connectivity N^2.

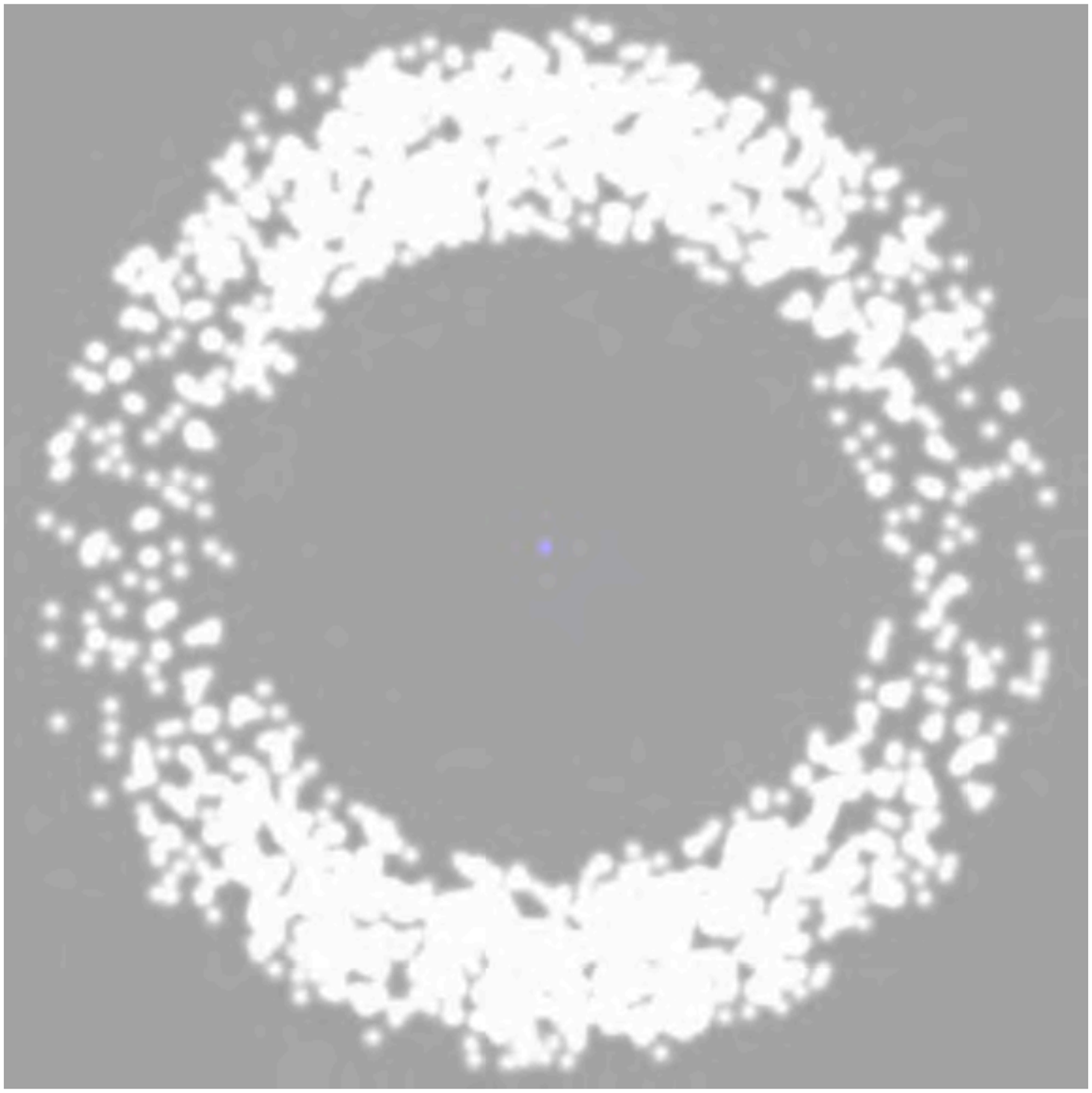
2a. Multi-stable perception:

characterizing collective stable states

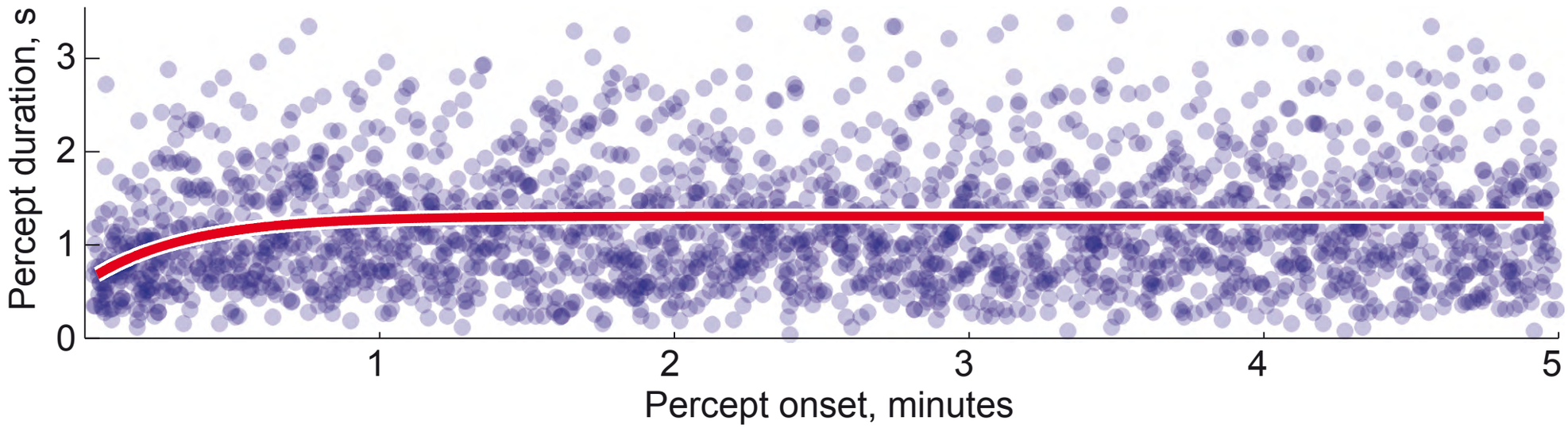
Pastukhov, Garcia-Rodriguez, Haenick, Guillamon, Deco, Braun (2012) Front. Comp.Neurosci.

Kinetic depth effect

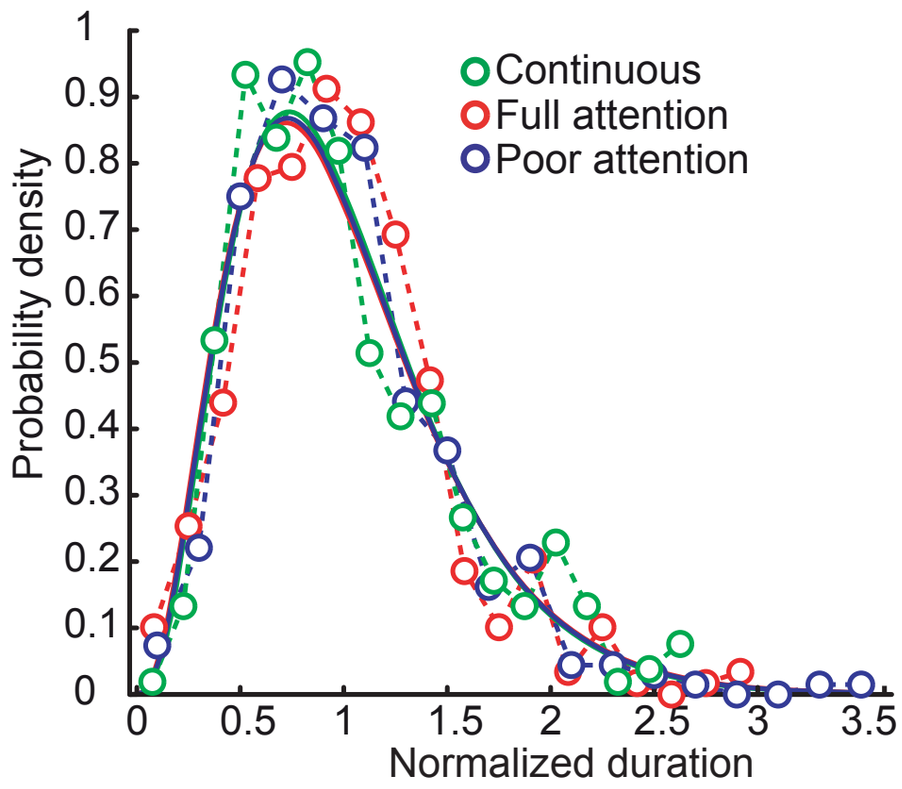
Wallach, O'Connell, 1953



Distribution of dominance periods



T_{dom} C_v

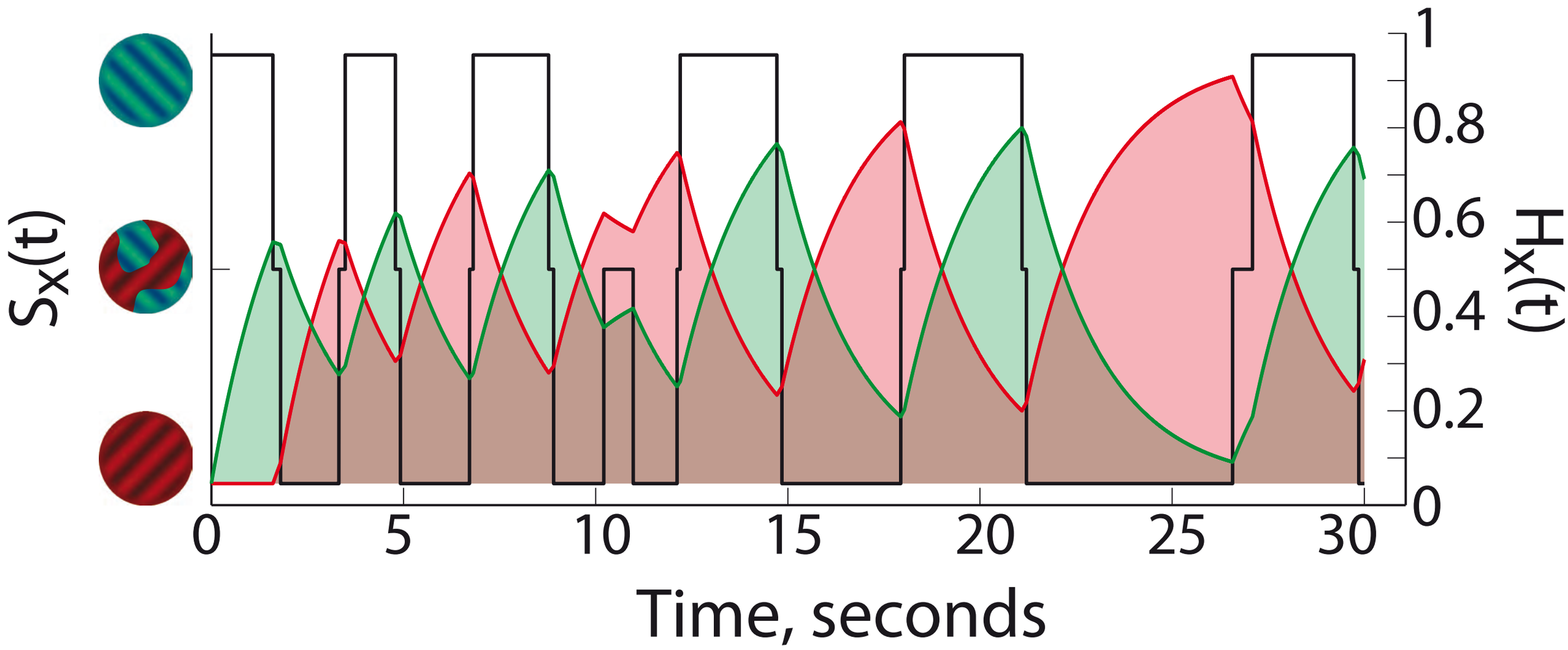


Cumulative history

$S_x(t)$ perceptual appearance

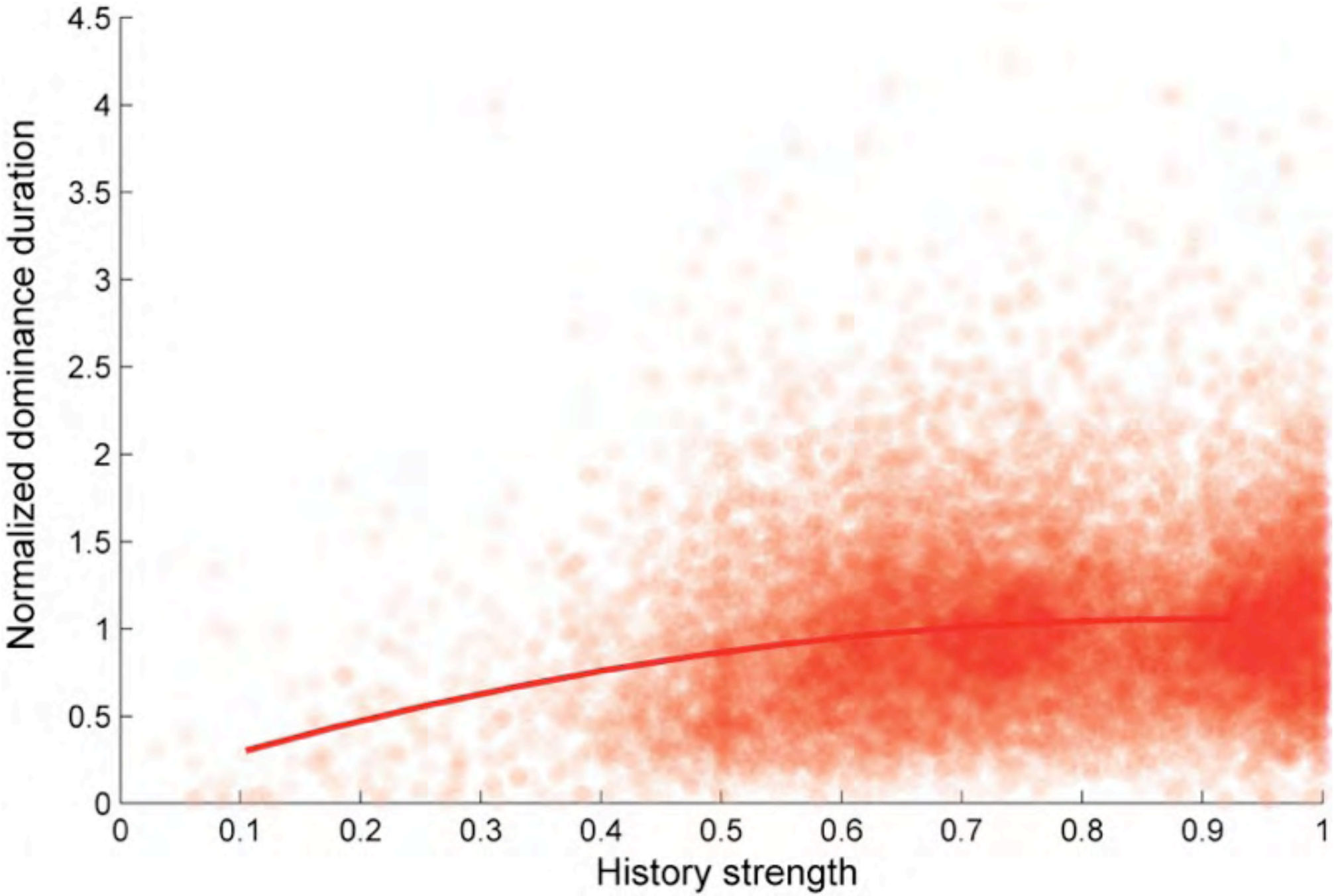
$H_x(t)$ leaky integrator of appearance with time constant τ_H

Pastukhov, Braun (2010) Journal Vision 10(11): 12



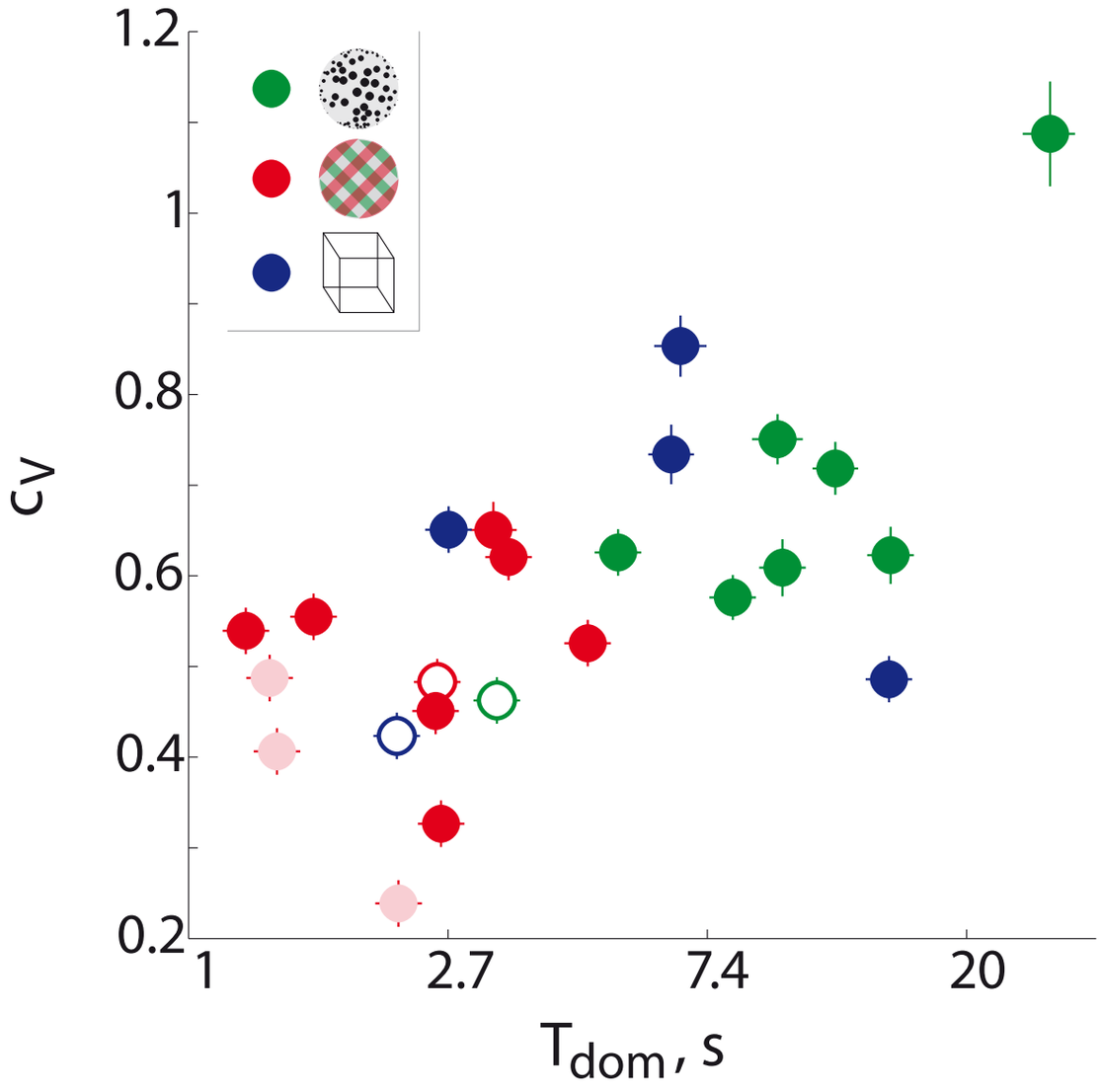
Cumulative history

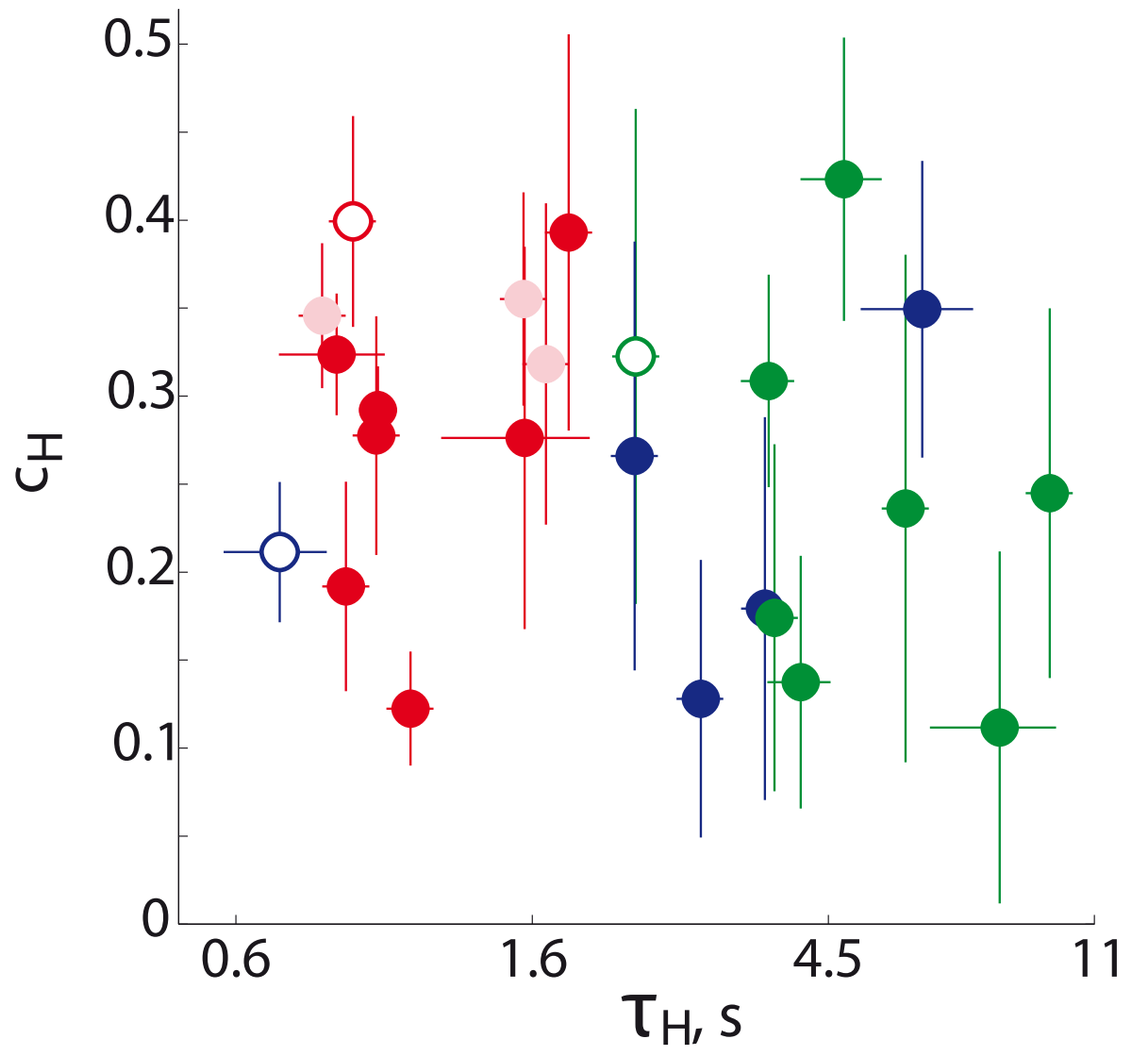
c_H τ_H



The superficial diversity

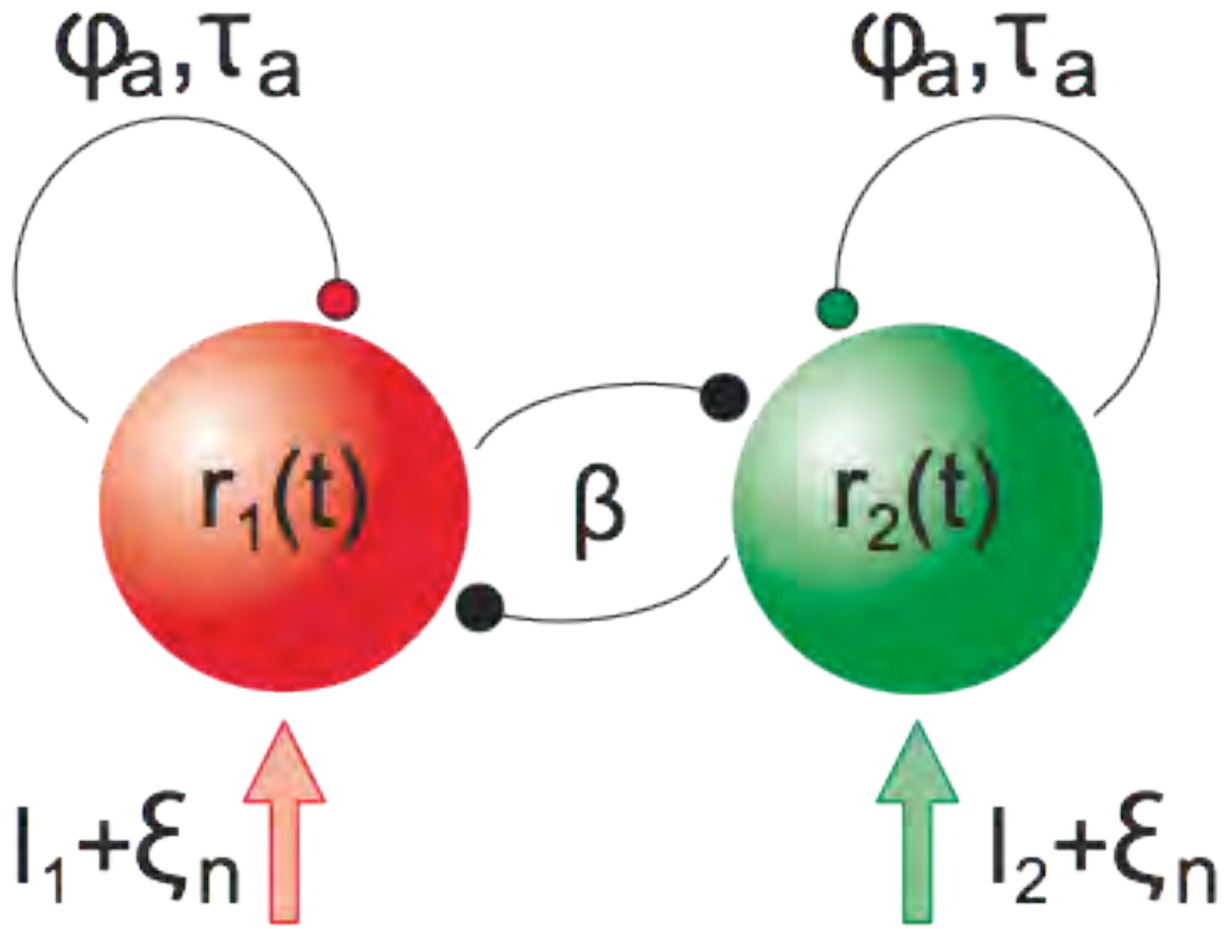
Individual statistical measures vary widely between observers and displays.
Superfically, the perceptual dynamics is anything but consistent!





Balance of competition, adaptation, and noise

A simple model generates a continuum of possible dynamics, which are parametrized by competition β, adaptation ϕ_a, and signal-to-noise ratio I_0

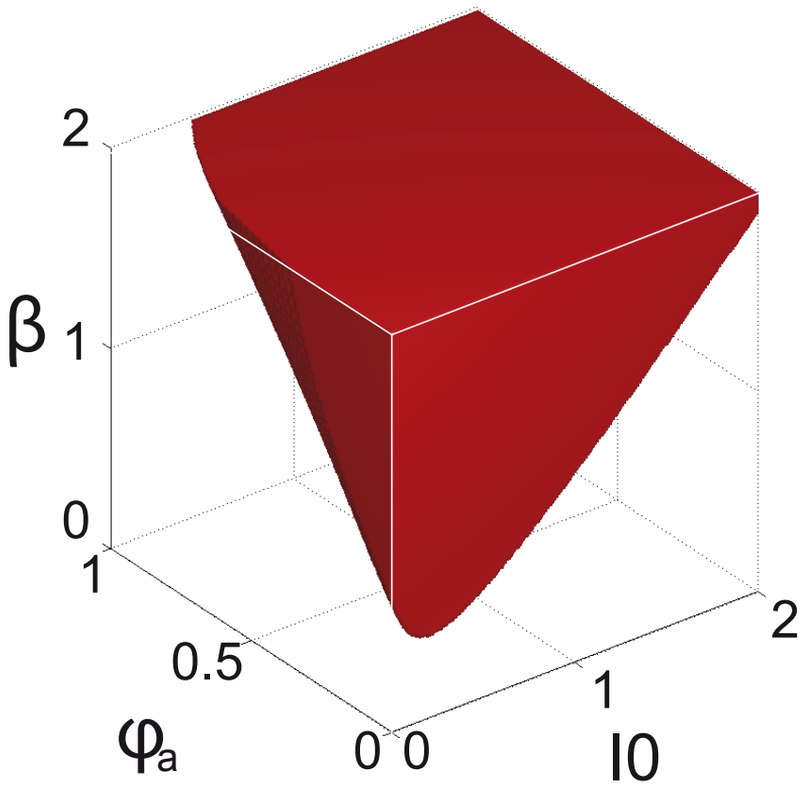


Laing, Chow (2002) Journal Computational Neuroscience 12(1): 39-53.

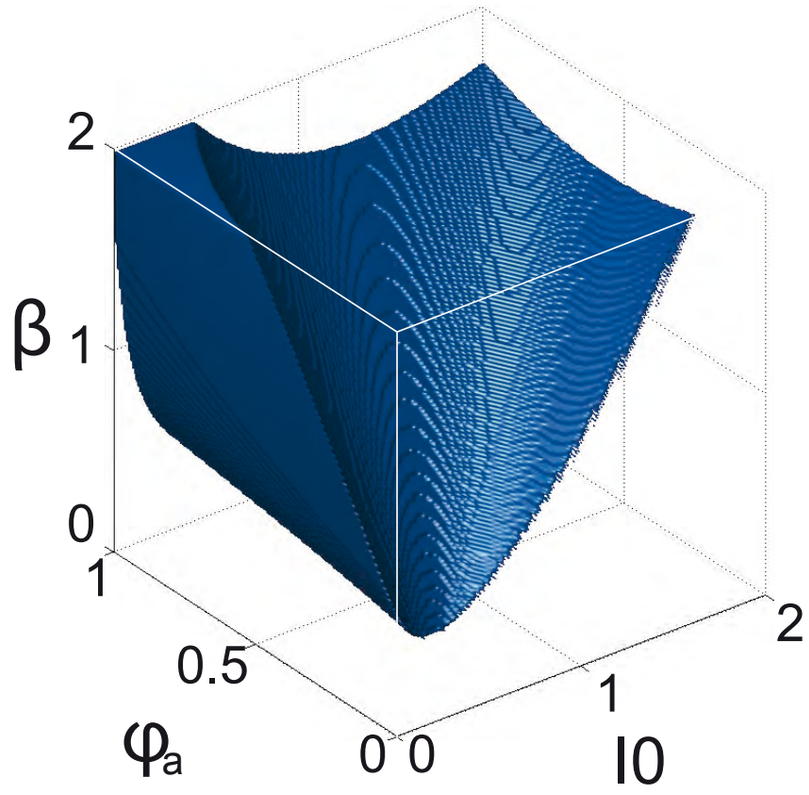
Dynamical regimes I

Different combinations of competition β, adaptation ϕ_a, and signal-to-noise ratio I_0 produce different kinds of reversal sequences.

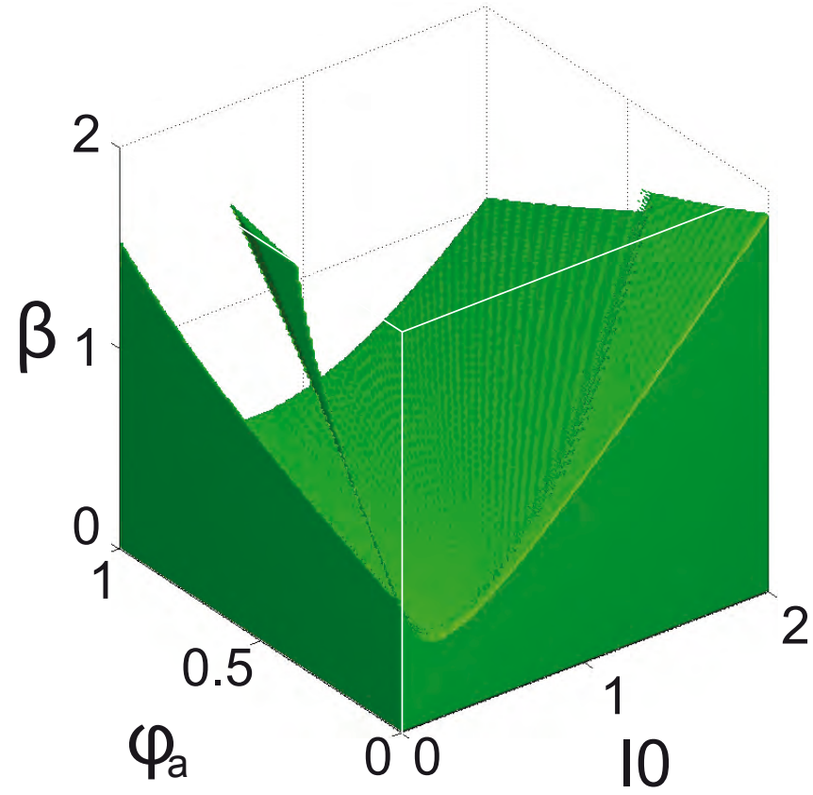
Bistable region



Oscillatory regime

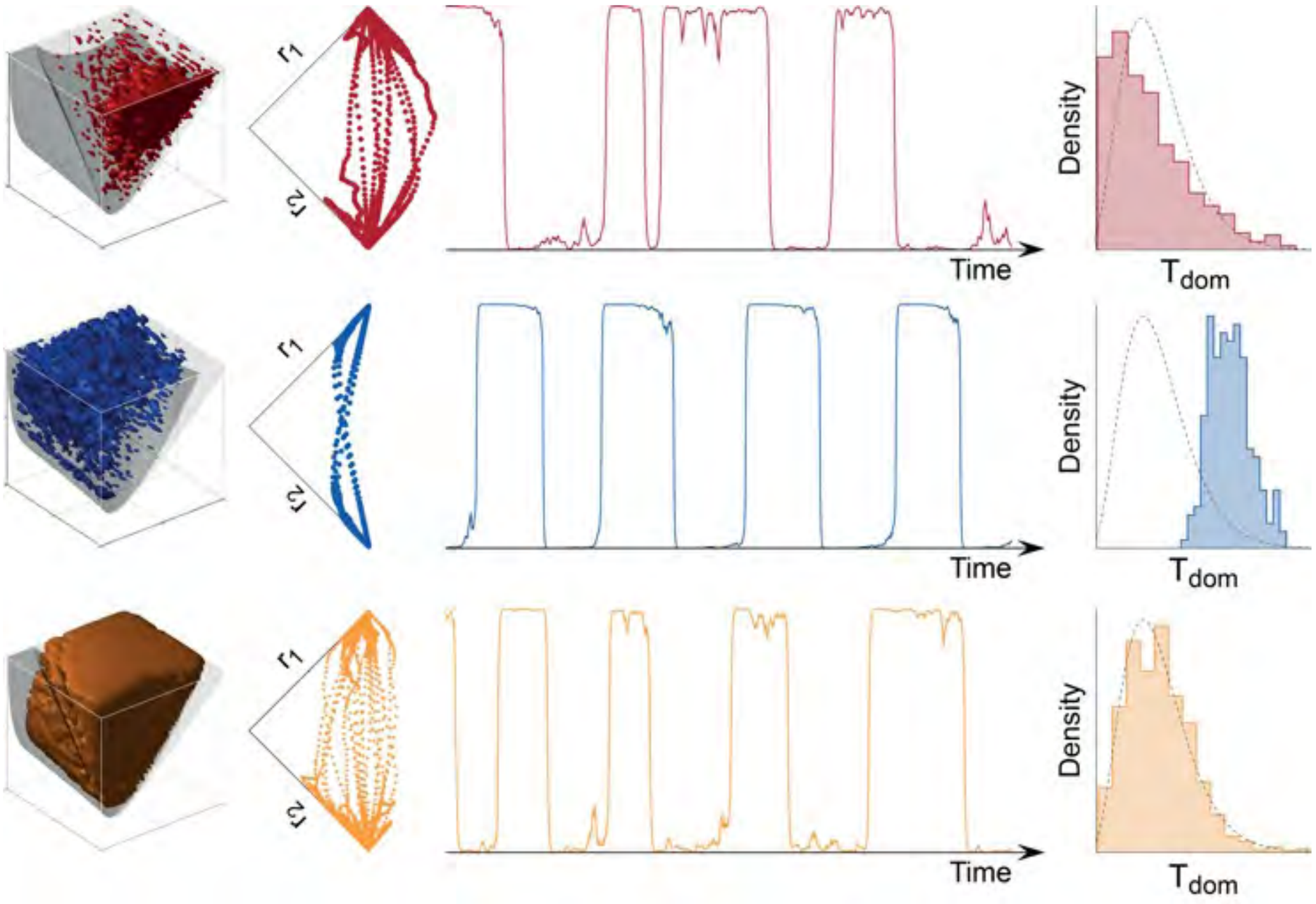


Stationary regime



Dynamical regimes II

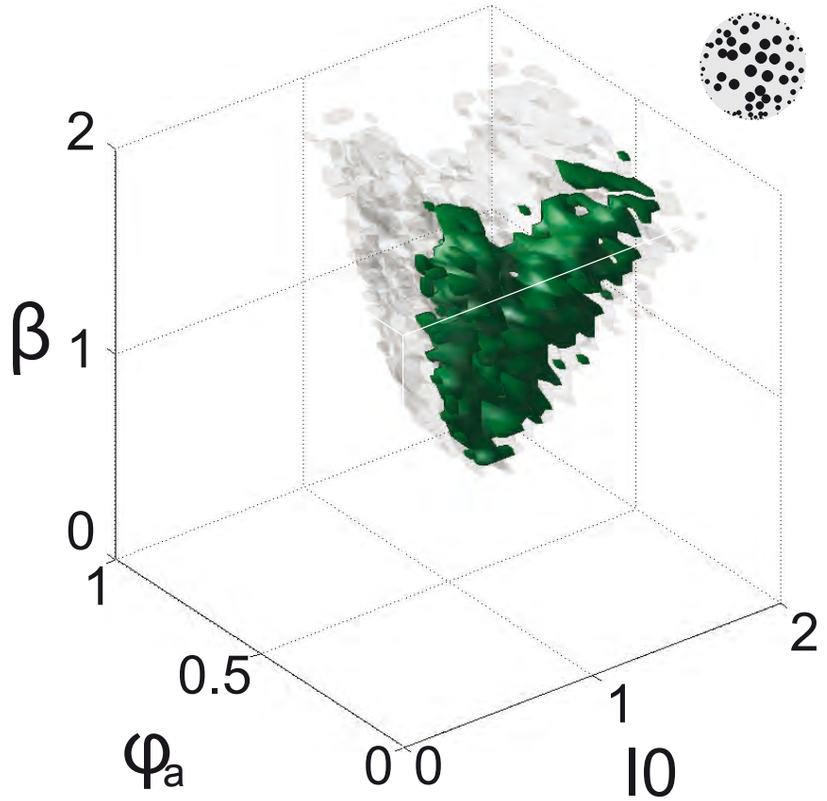
Formally, distinguish "bistable" and "oscillatory" regimes. Human observers typically fall between these extremes.

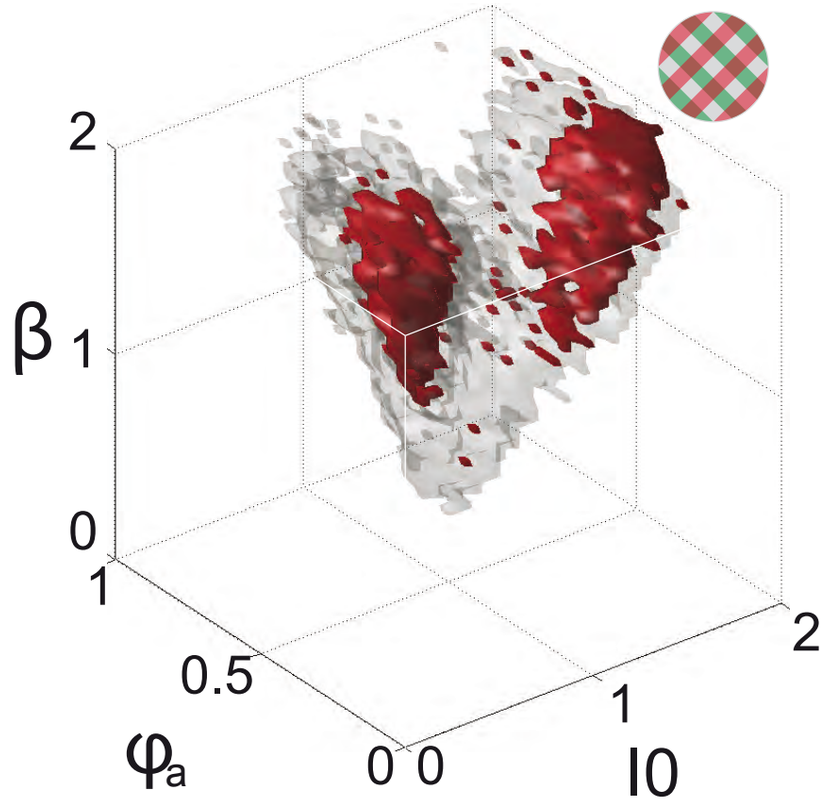


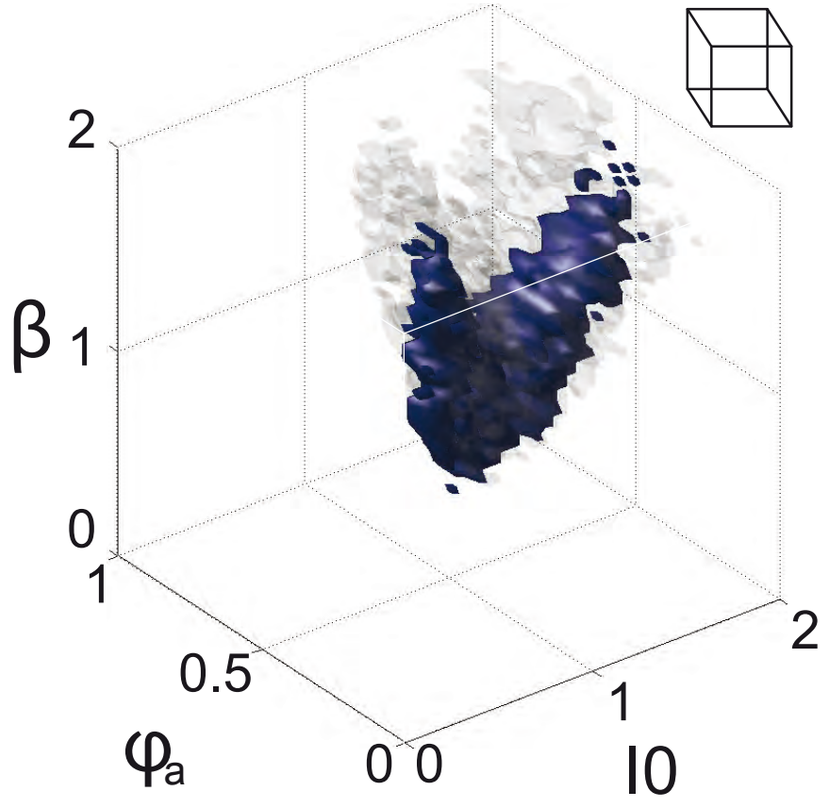
Pastukhov, et al. (2013) *Frontiers in Comp Neuroscience*

Individual observer "operating regime"

Small volumes reproduce dominance distribution & history dependence of individual human observers: ~ 3% of possible parameter space.

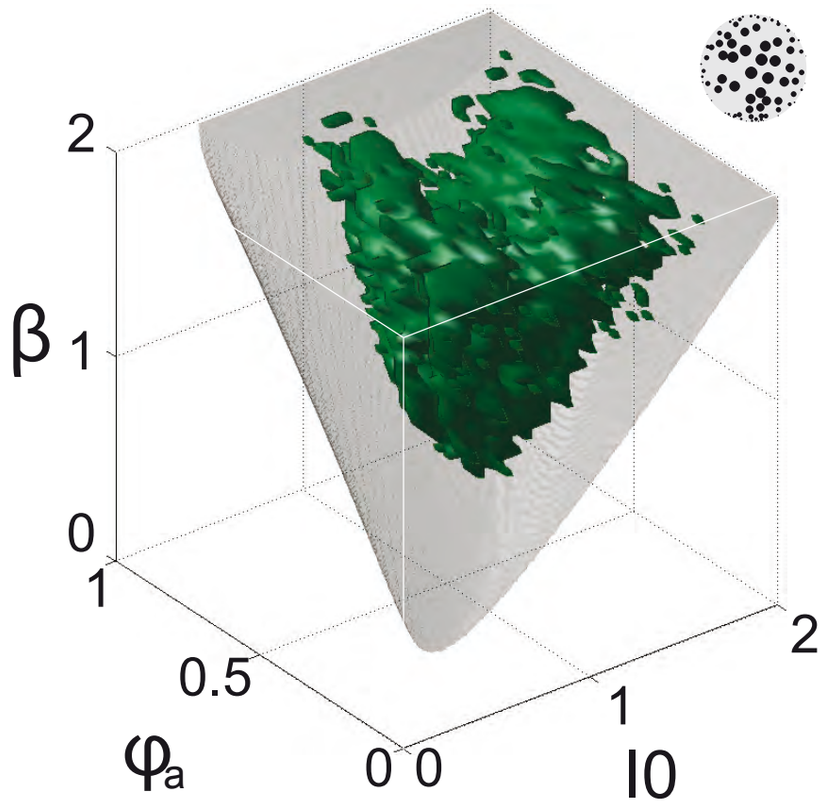


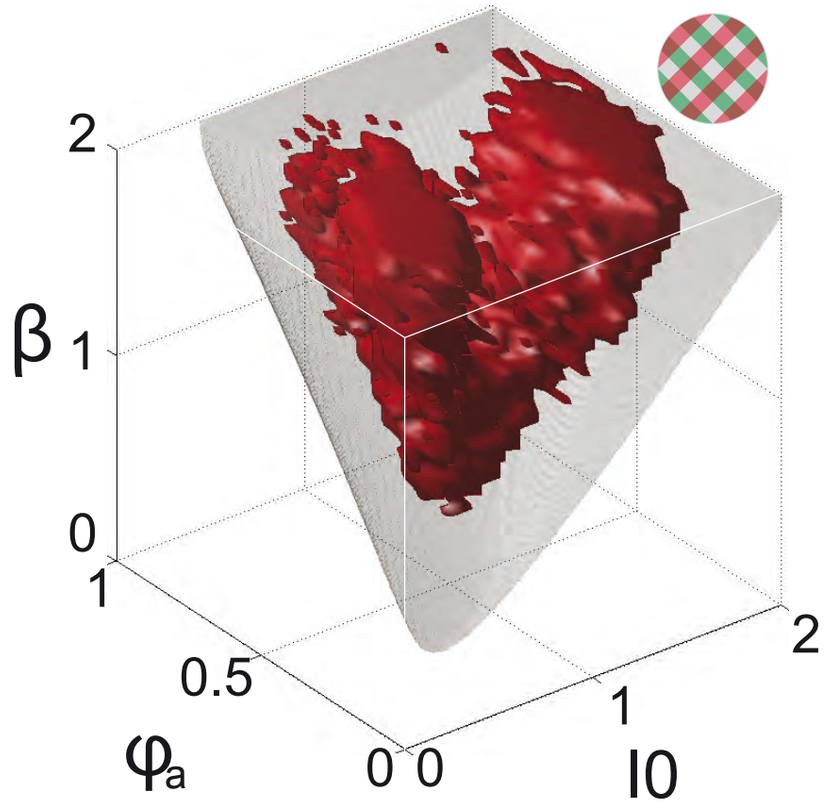


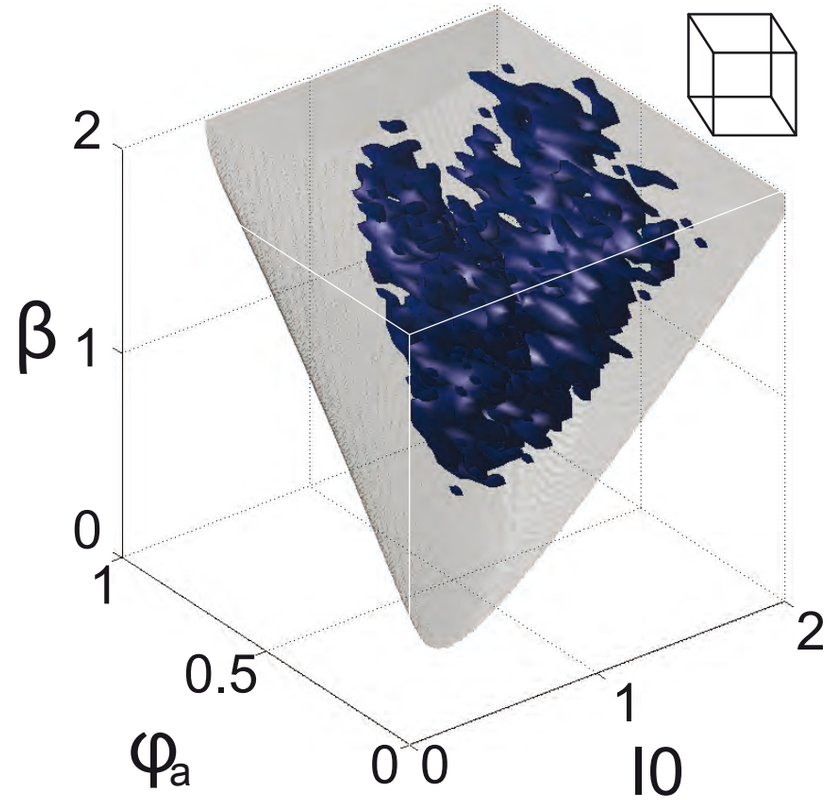


The hidden consistency I

Union of "operating regimes" of all observers, ~15% of possible parameter space. Clustering is significant p <.02

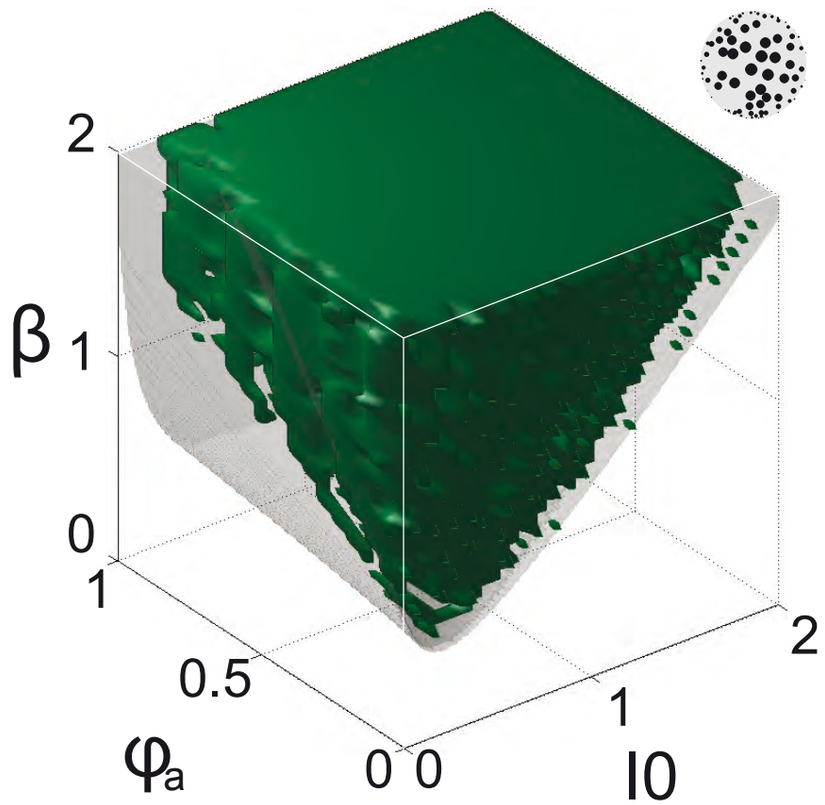


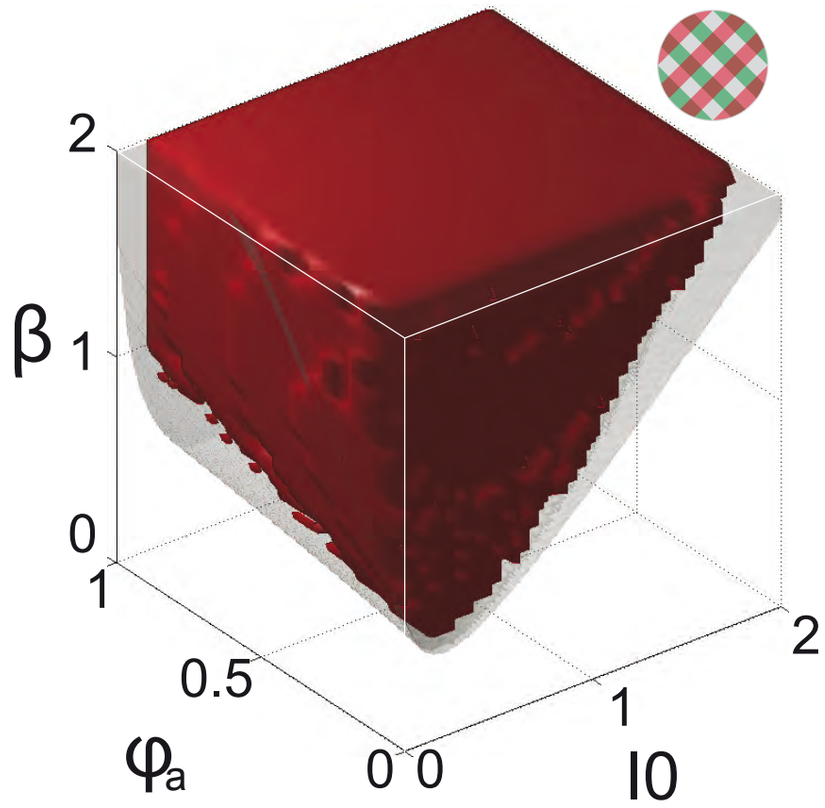


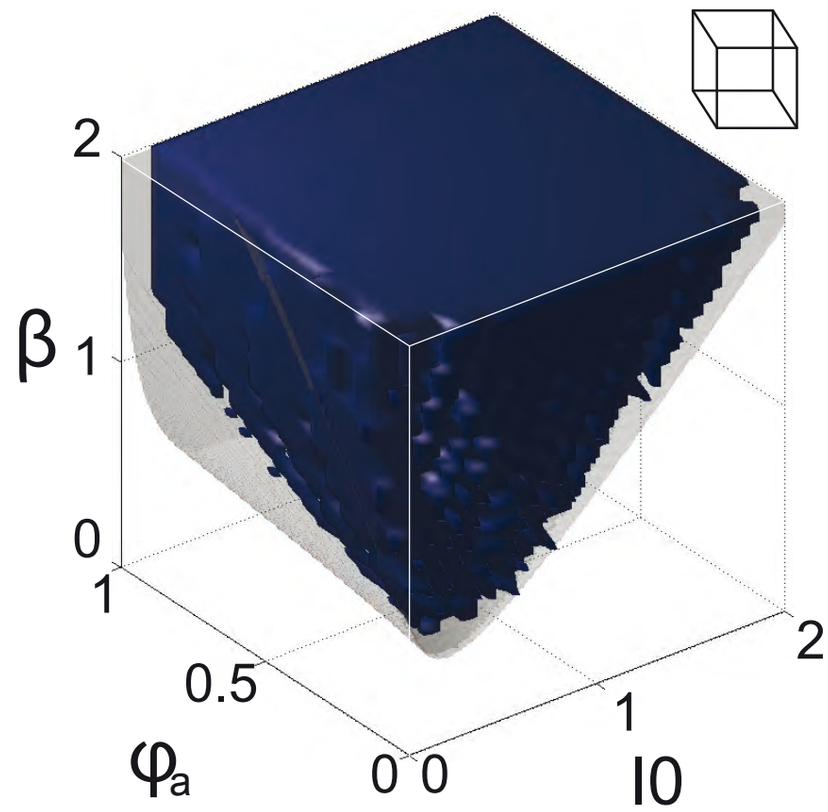


The hidden consistency II

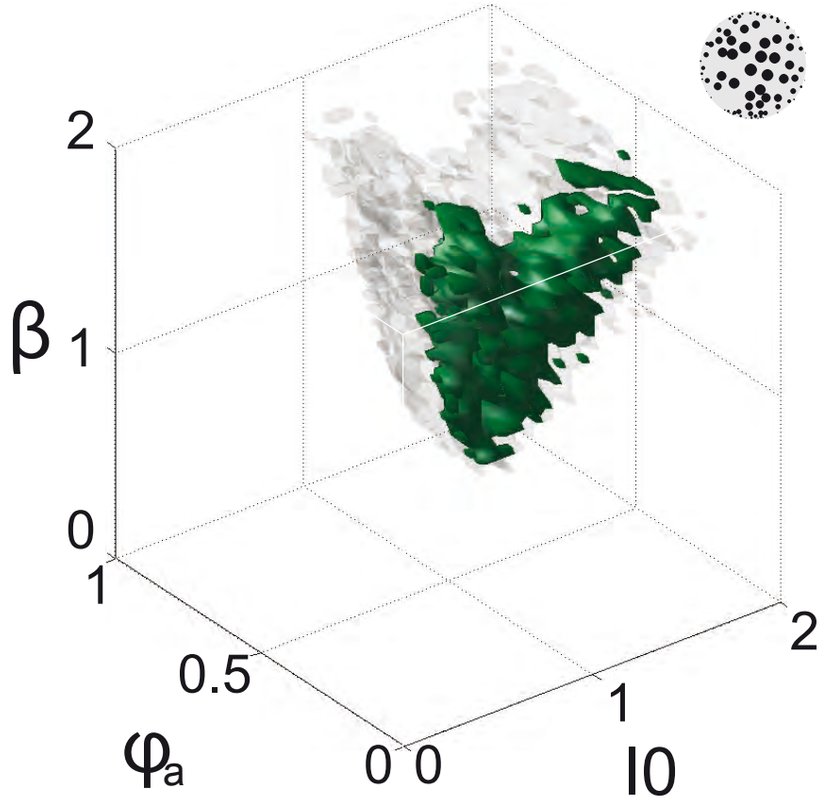
Region matching only dominance distribution (not history dependence) of all observers: ~75% of possible parameter space.

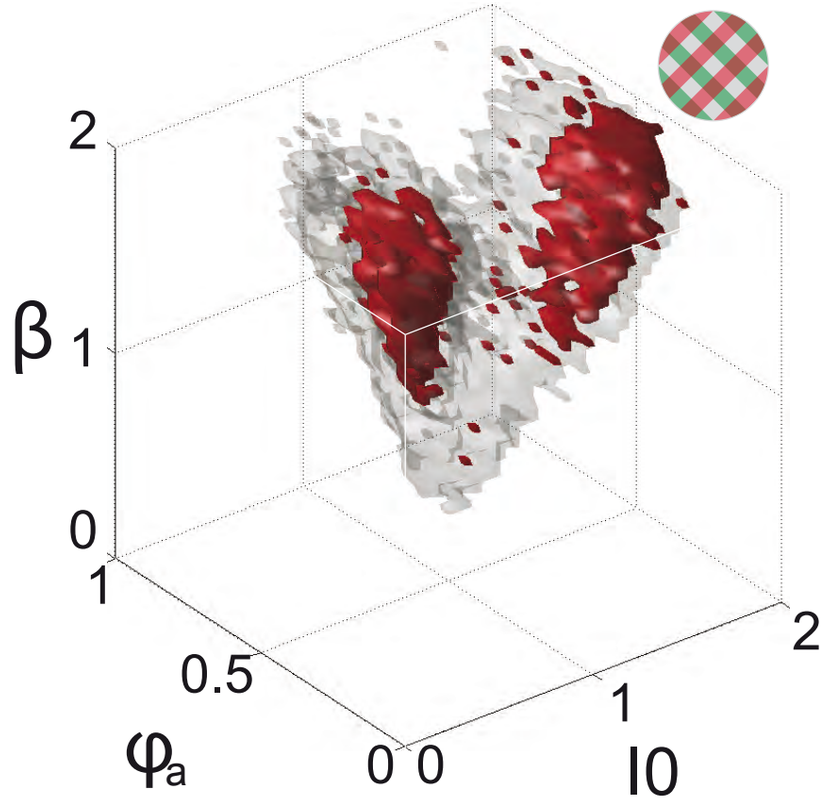


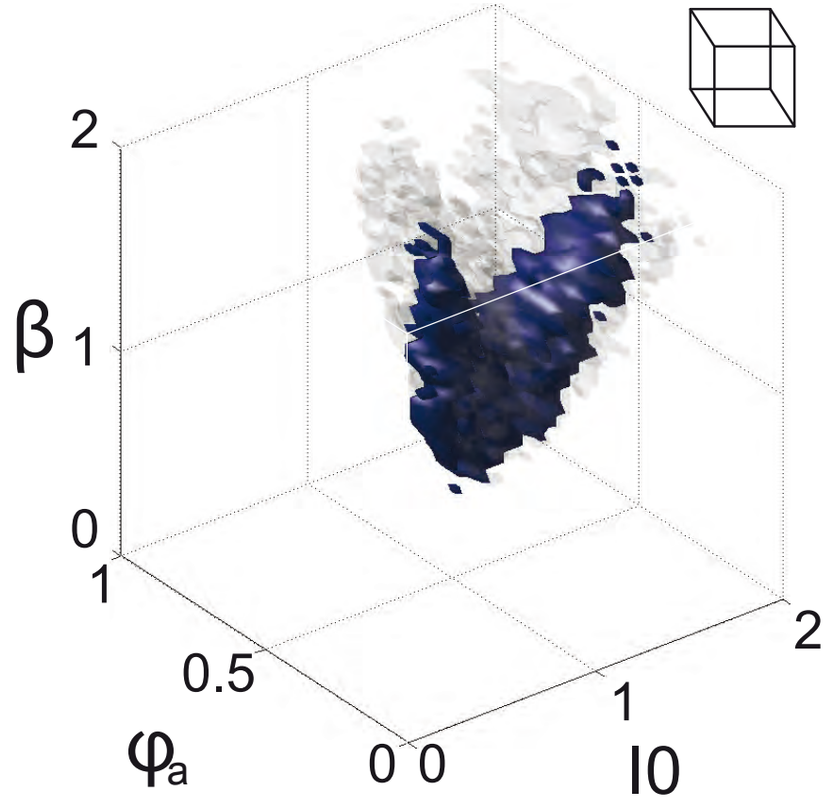




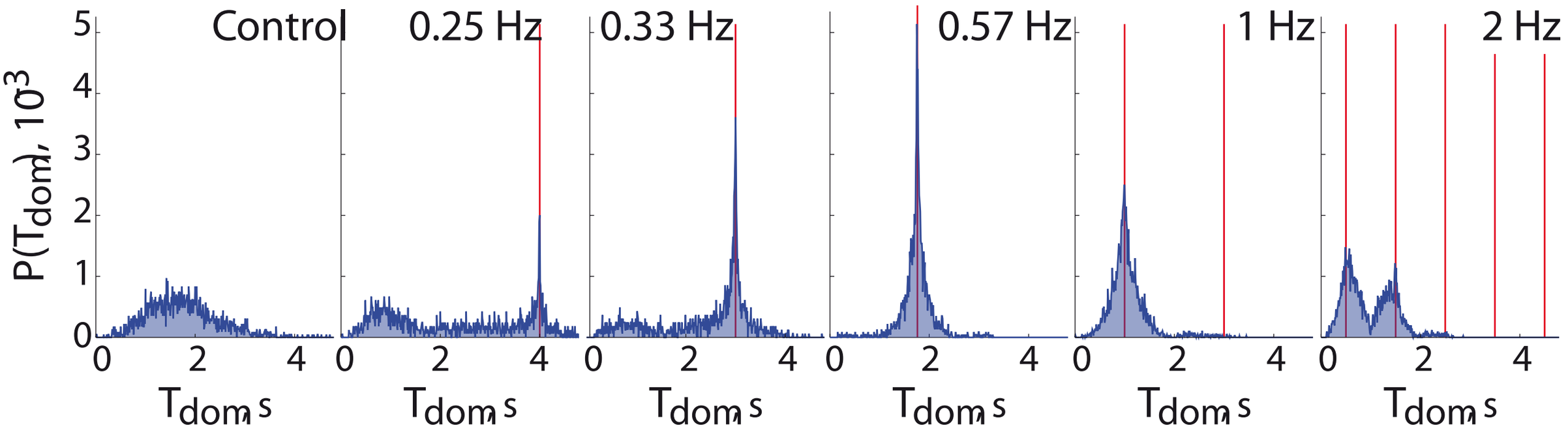
Why operate in a particular regime?

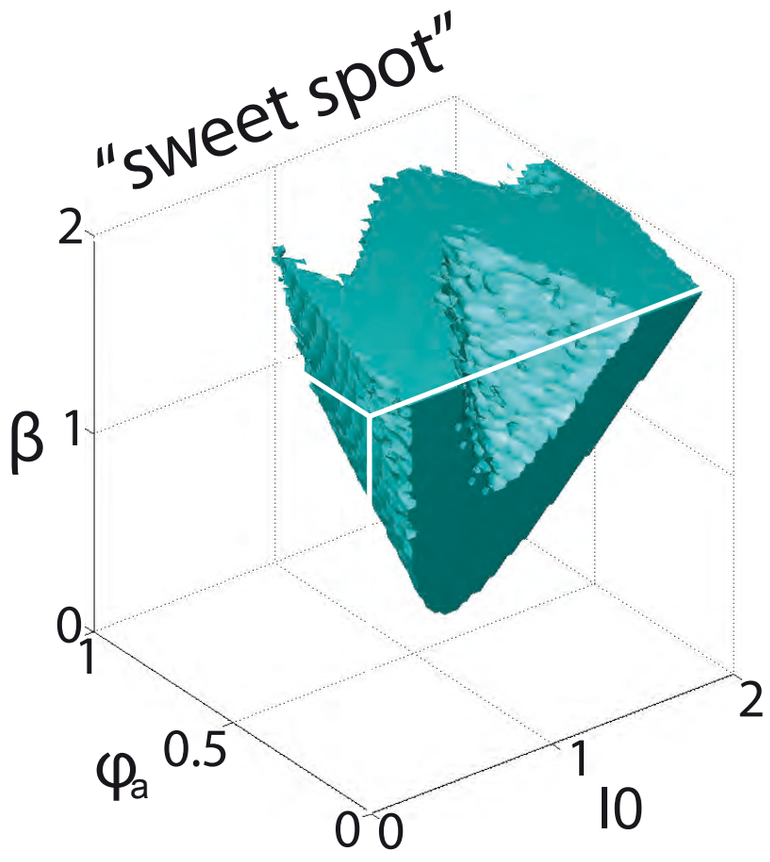






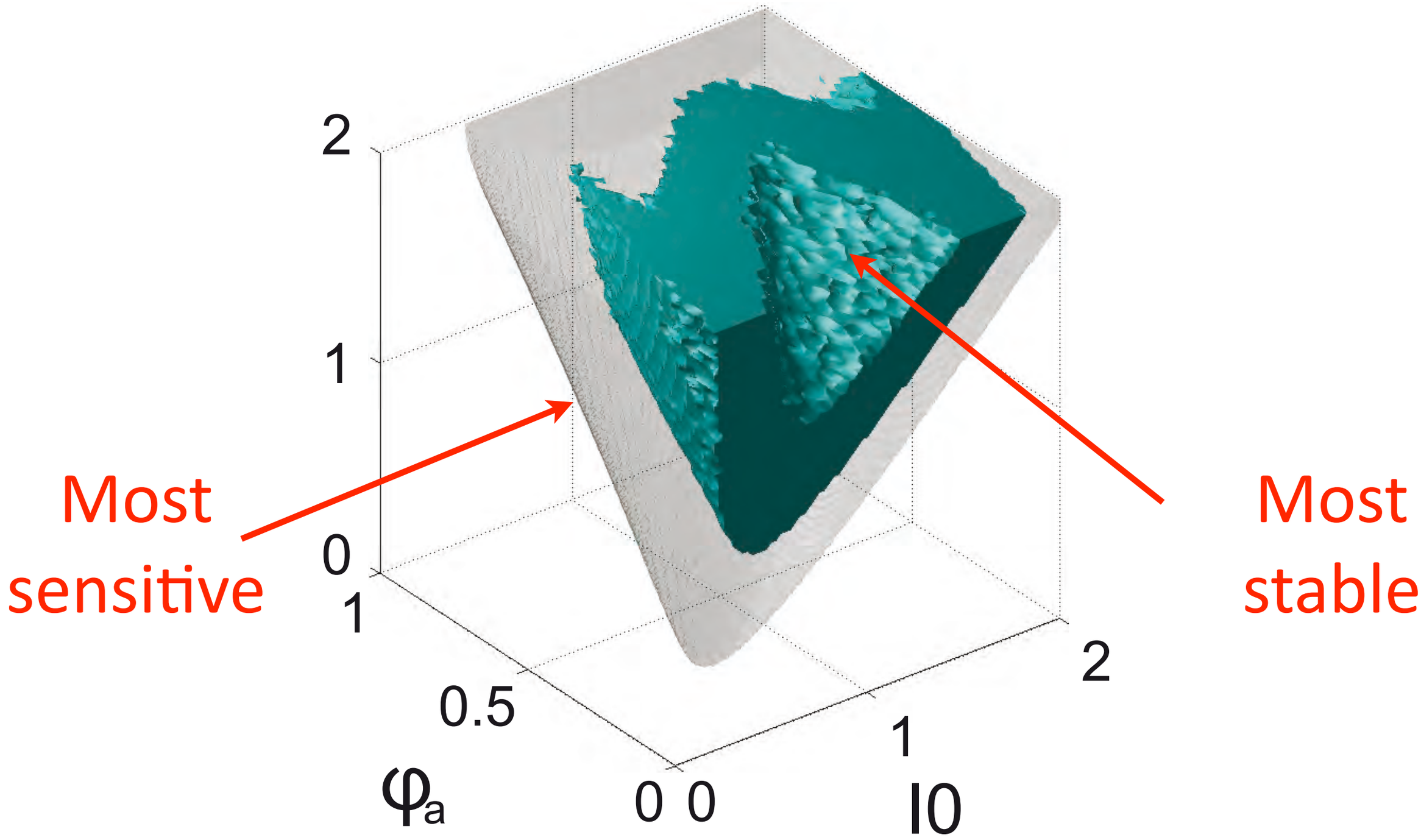
Functional 'sweet spot'





Theory predicts a functional 'sweet spot' which balances stability (dominance time) against sensitivity (here: frequency resonance).

Functional 'sweet spot'

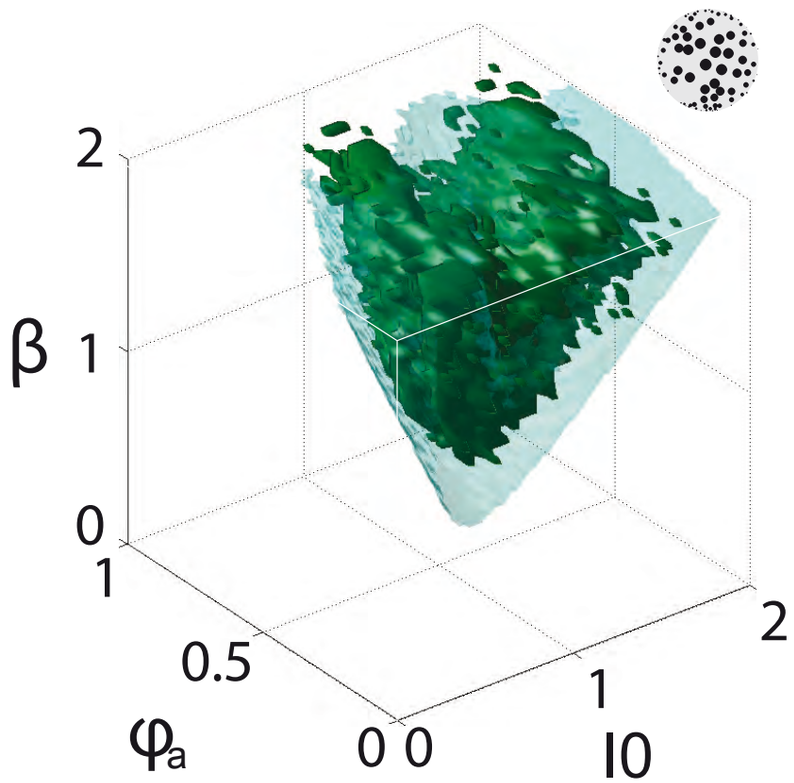


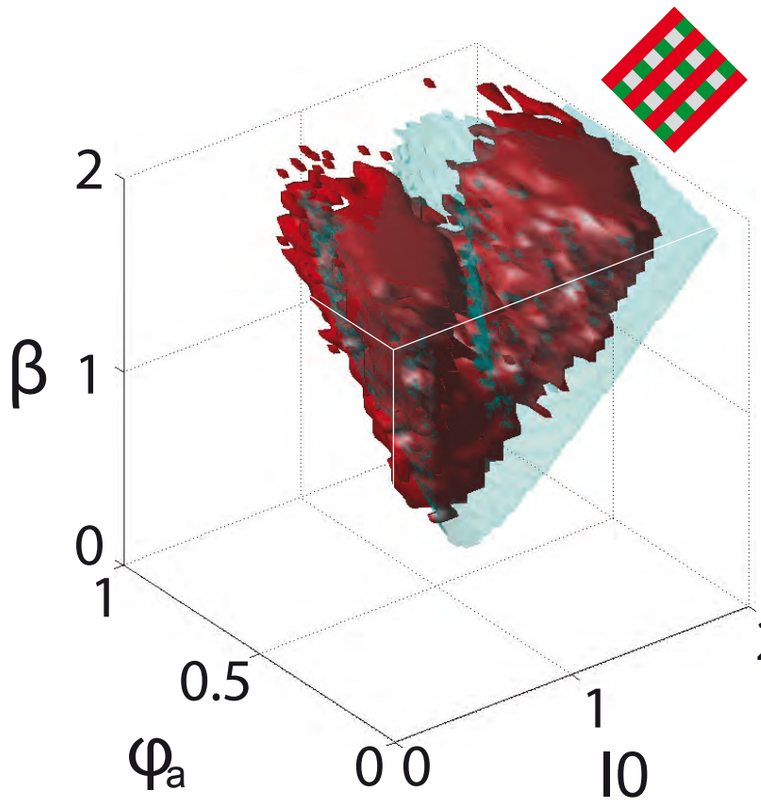
'Sweet spot' near, but not at, bifurcation surface

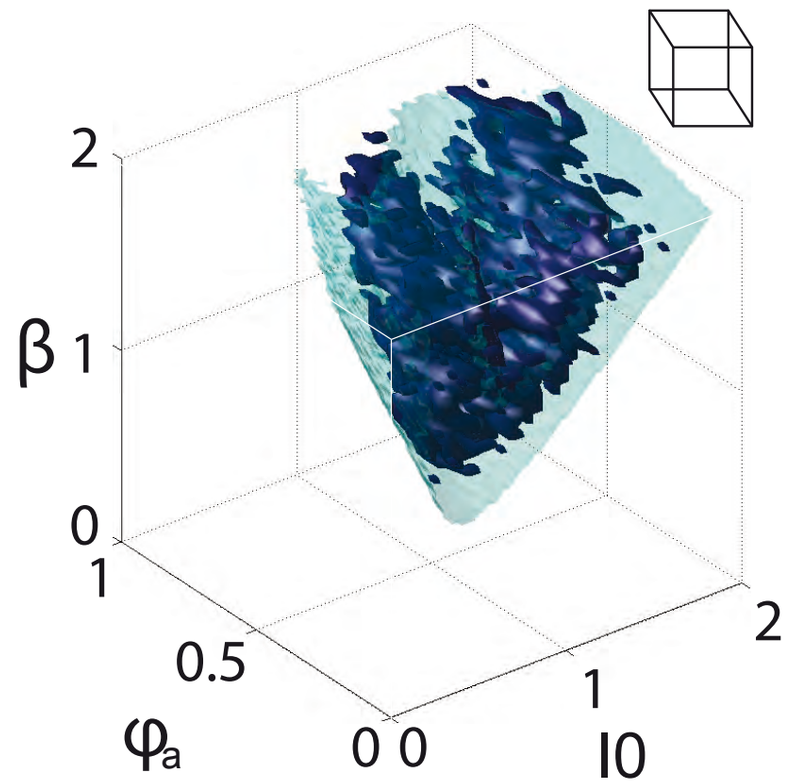
(= boundary between bistable and oscillatory regimes)

Balance of stability and sensitivity

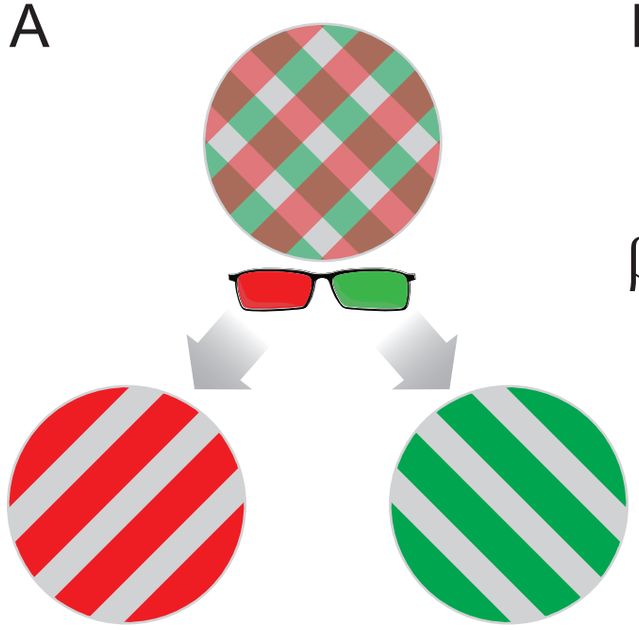
Humans operate in functional 'sweet spot' (cyan volume).

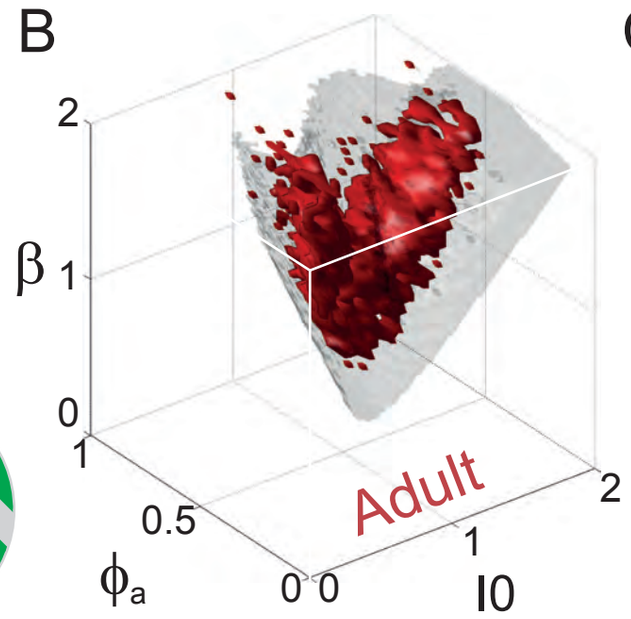


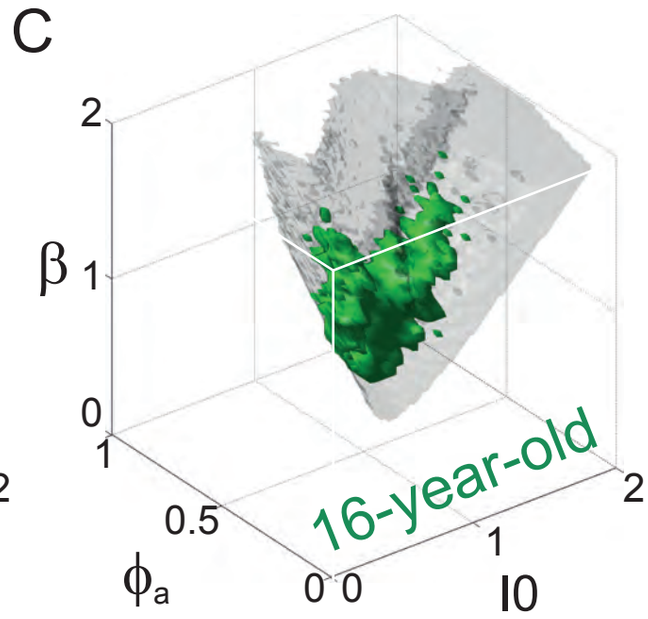


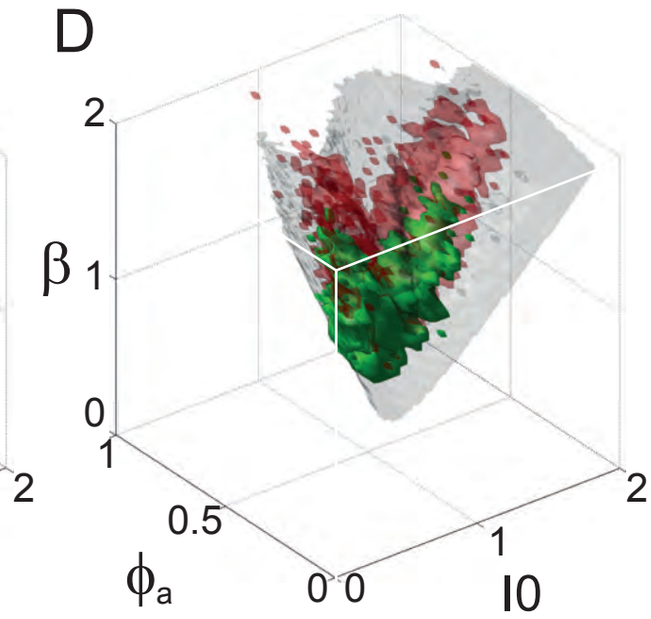


Comparing competition (vertical β-axis)



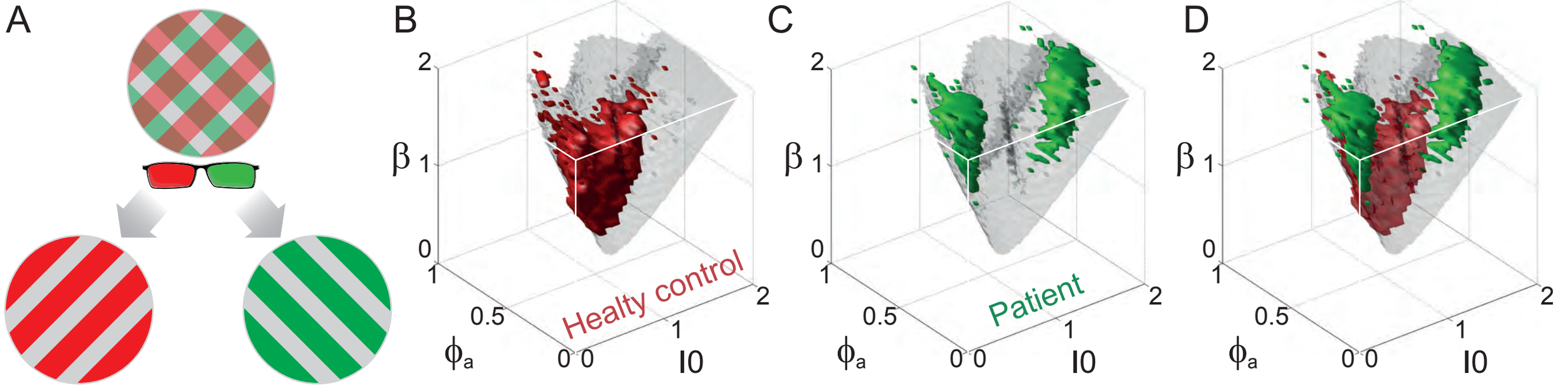






normal adults vs. 16-year olds
(with Ilona Kovacs, Budapest)

Comparing competition (vertical β-axis)



normal adults vs. anorexia nervosa
(with Ilona Kovacs, Budapest)

Two-level model

IPS

'limited capacity'

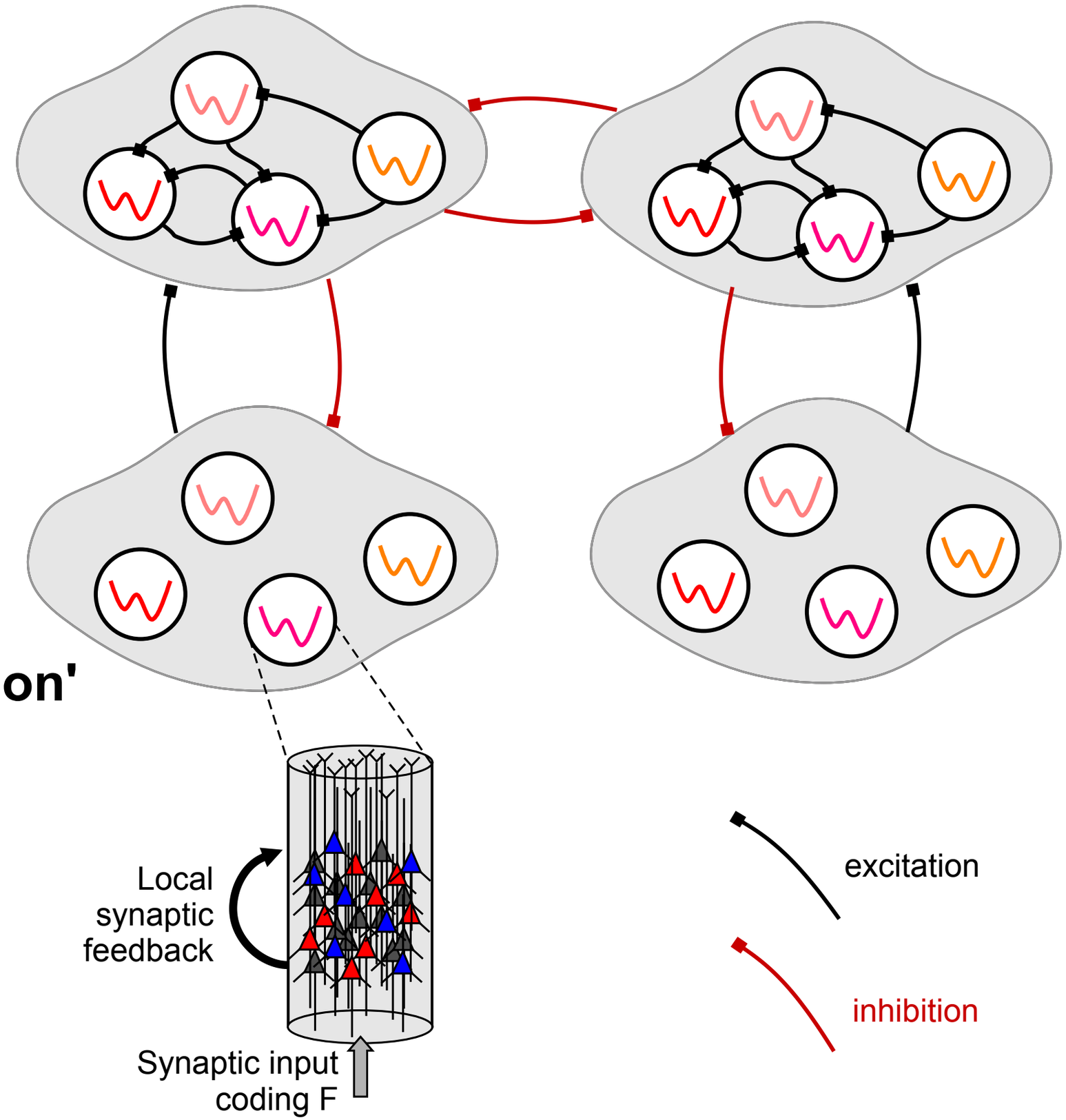
self excitation, competion

ff excitation
fb inhibition

VC

'evidence accumulation'

stochastic integration to bound



All interactions determined by psychophysics

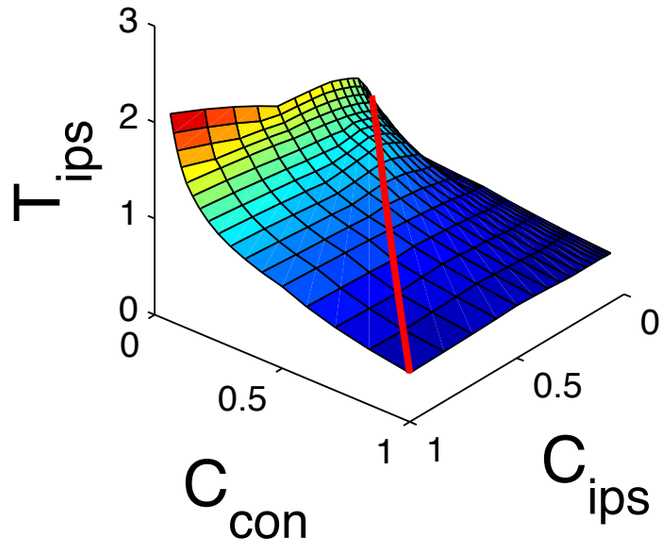
Levelt's propositions

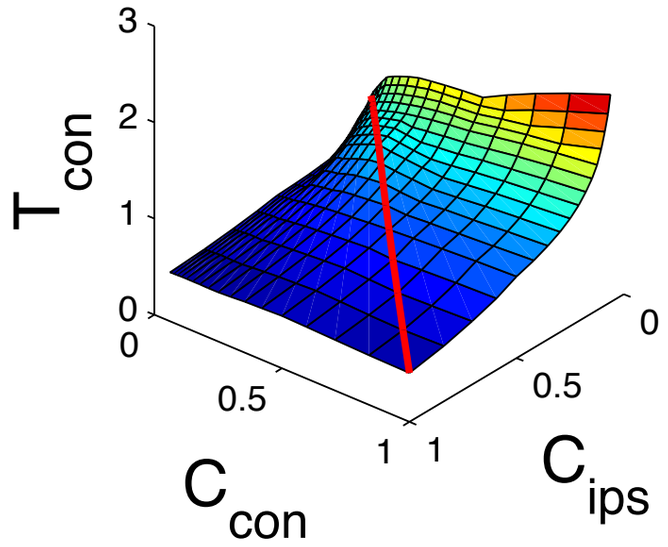
Scalar law

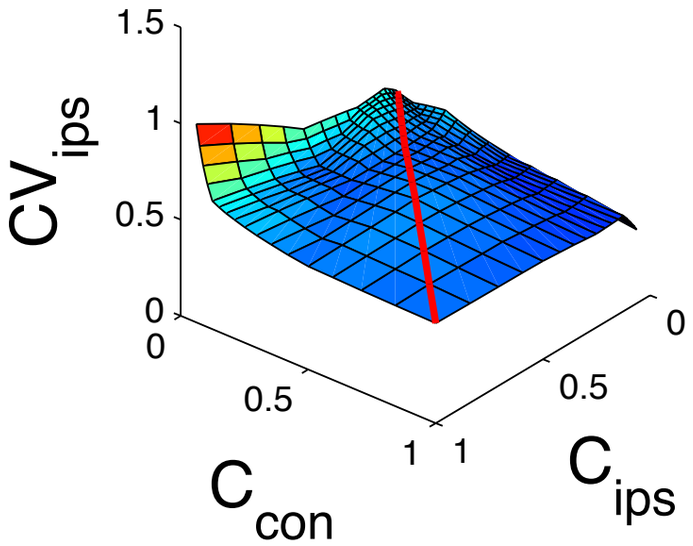
Perceptual adaptation

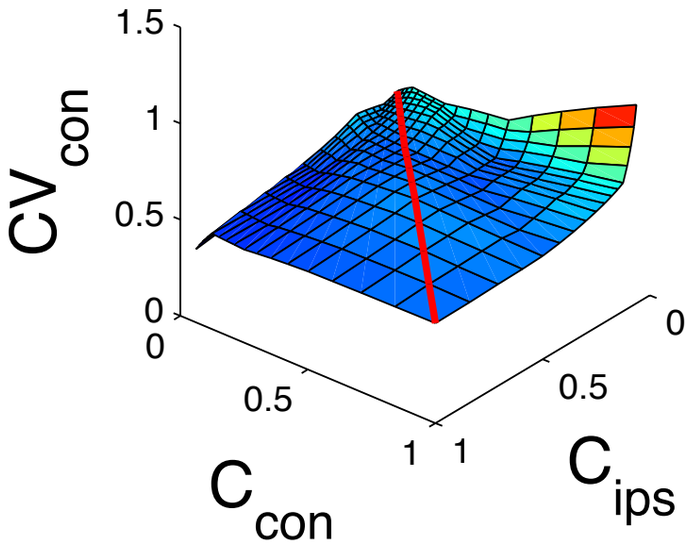
Flash suppression

Flash facilitation

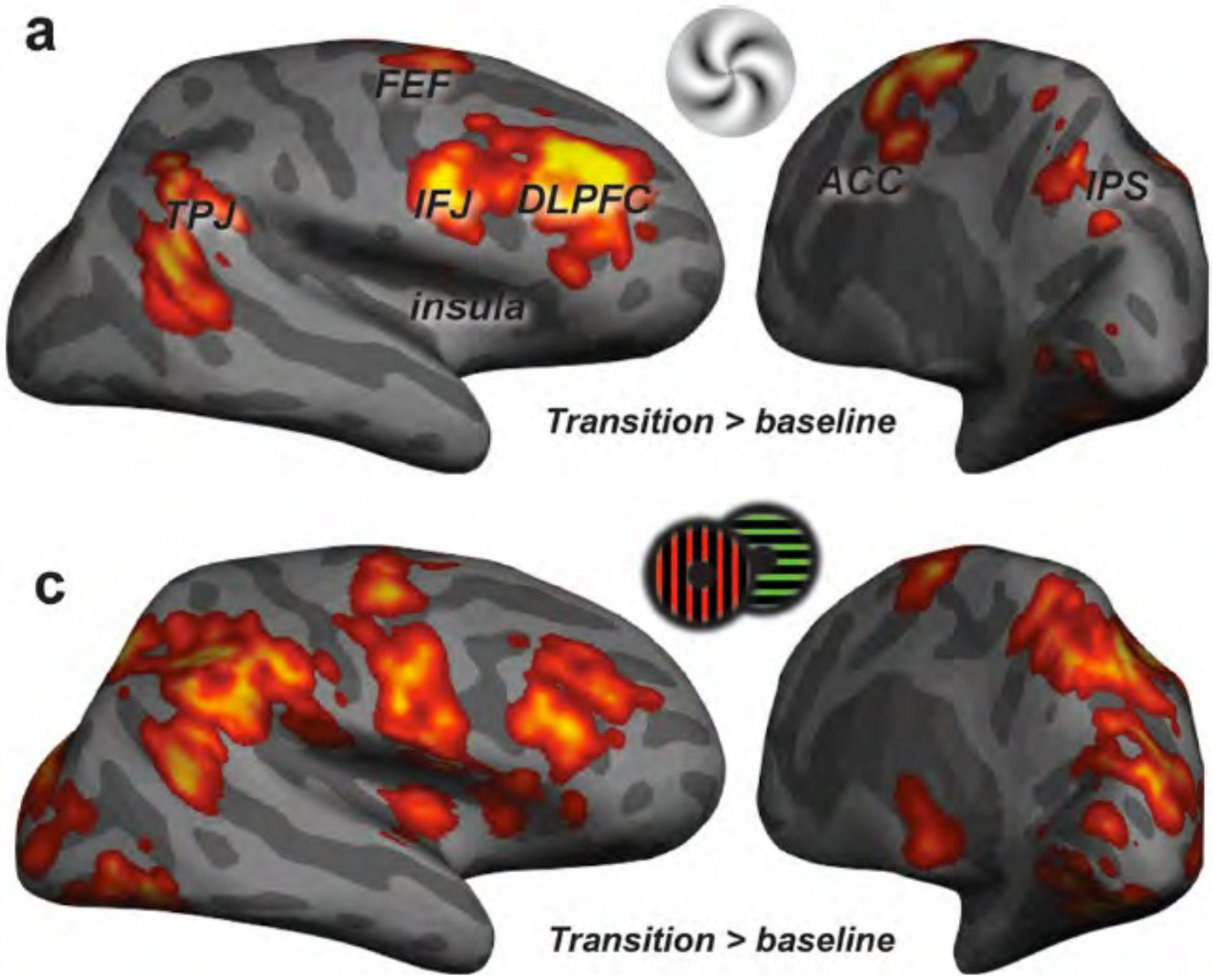








Transition-related activations



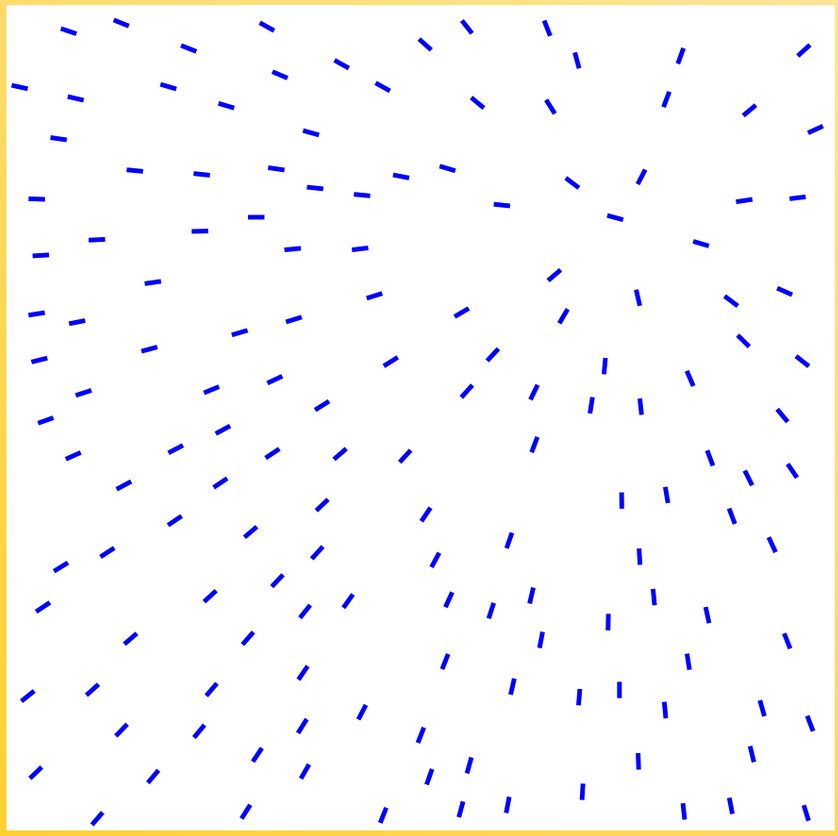
Knapen, Brascamp, et al. (2011) J Neurosci

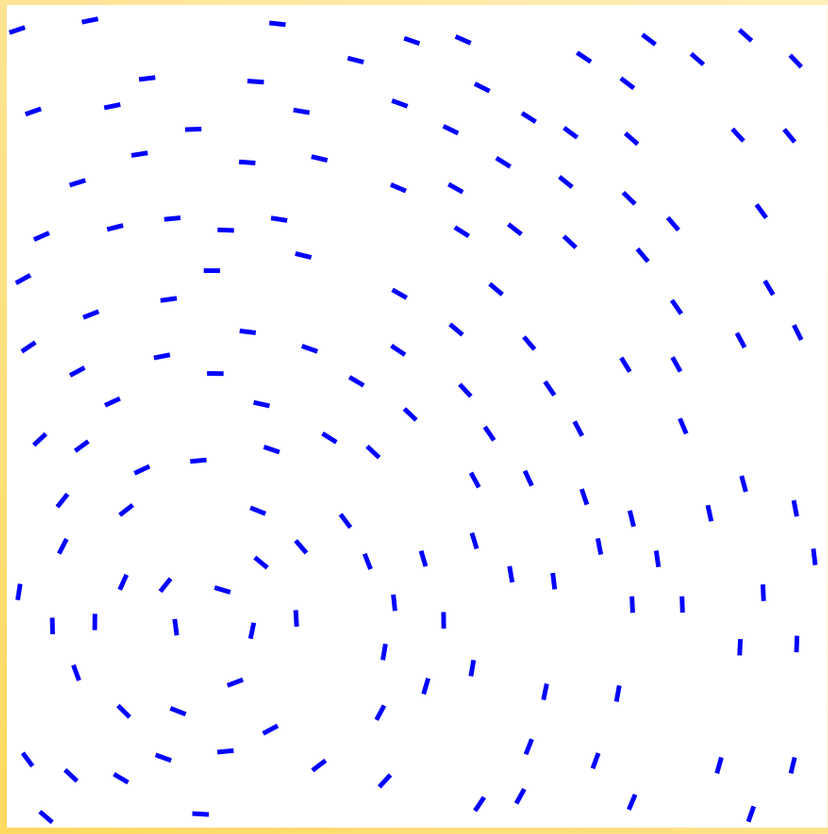
2b. Perceptual organization:

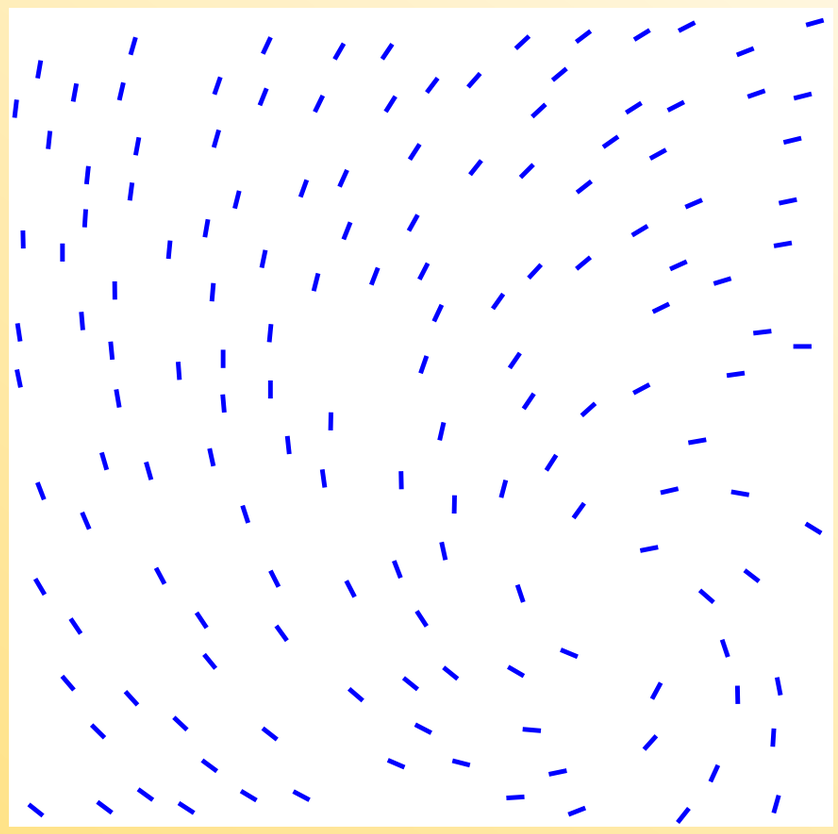
characterizing collective stable states

Aguilar, Mattia, Braun, in prep.

Perceptual organization is cooperative

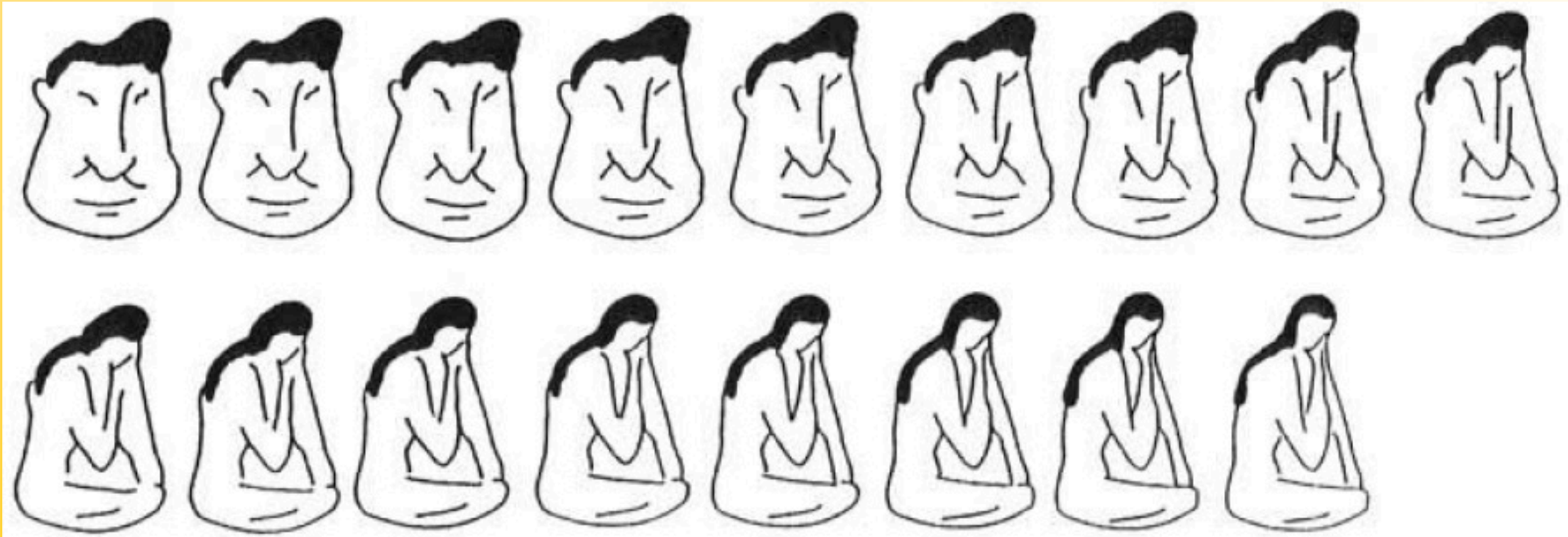




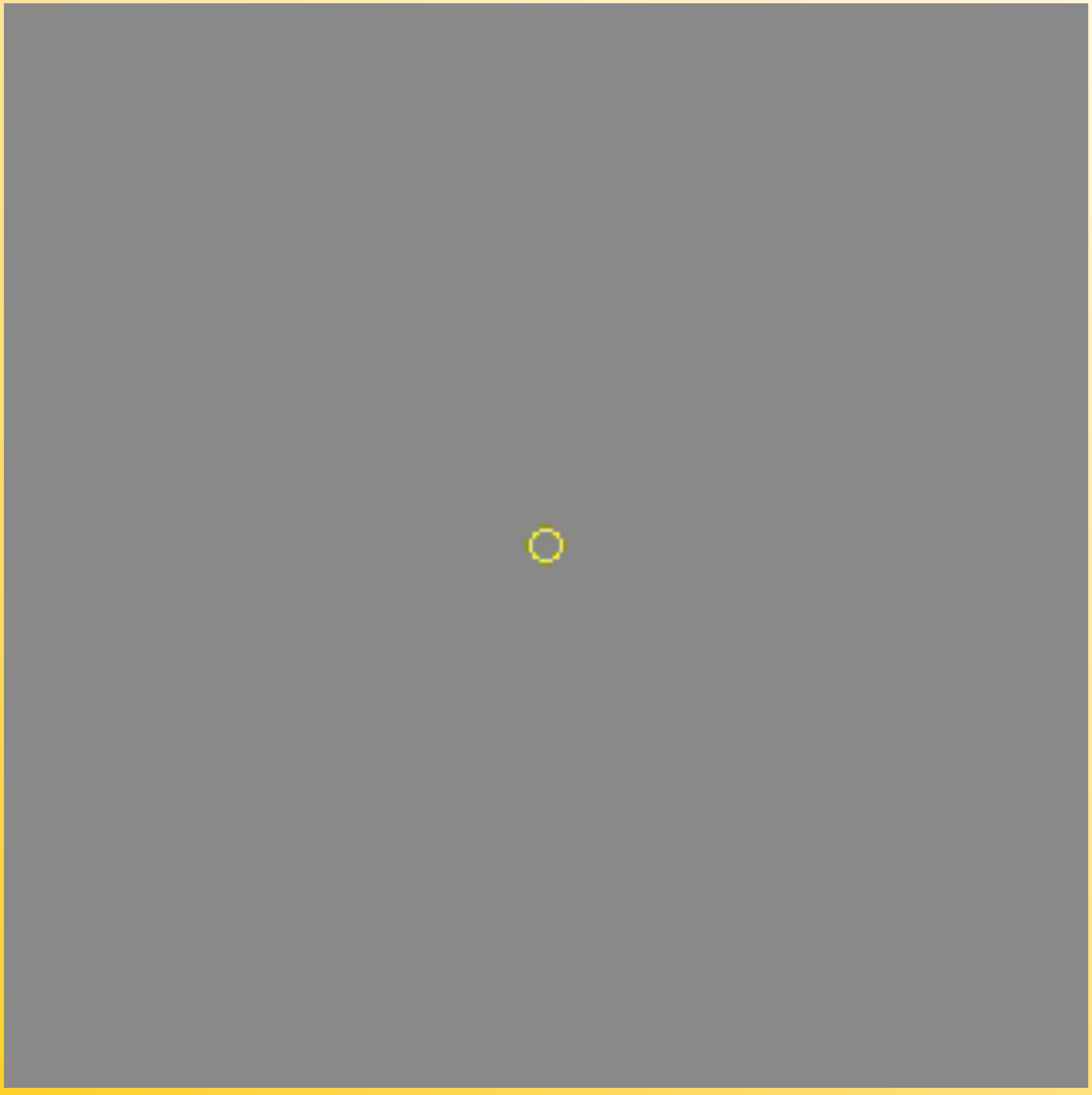


Perceptual organization exhibits hysteresis

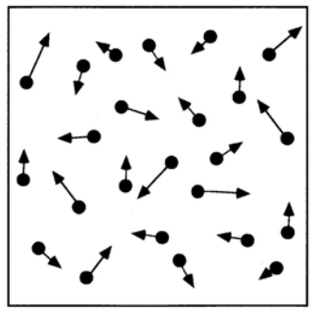
Chialvo, Apkarian, 1993



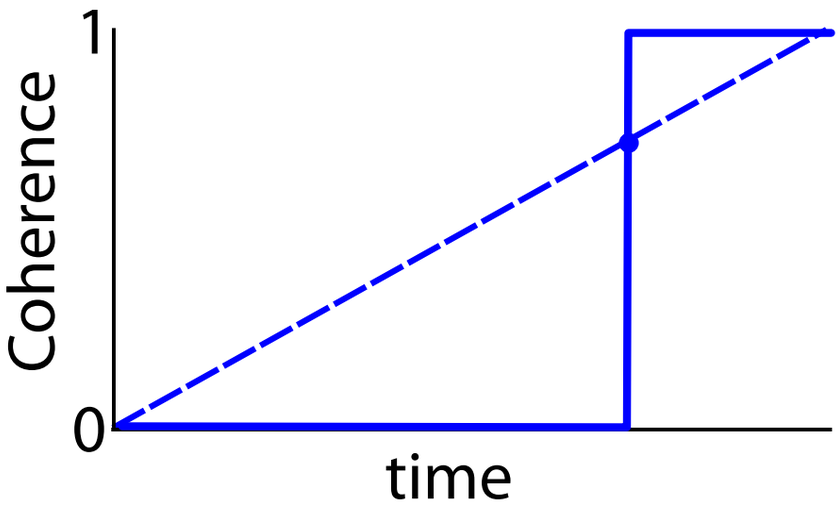
Motion-binding in RDK

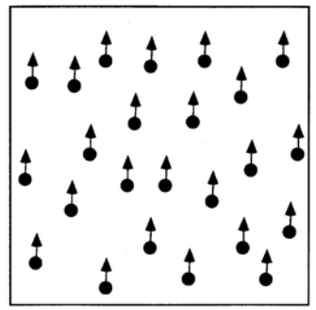


Ascending coherence

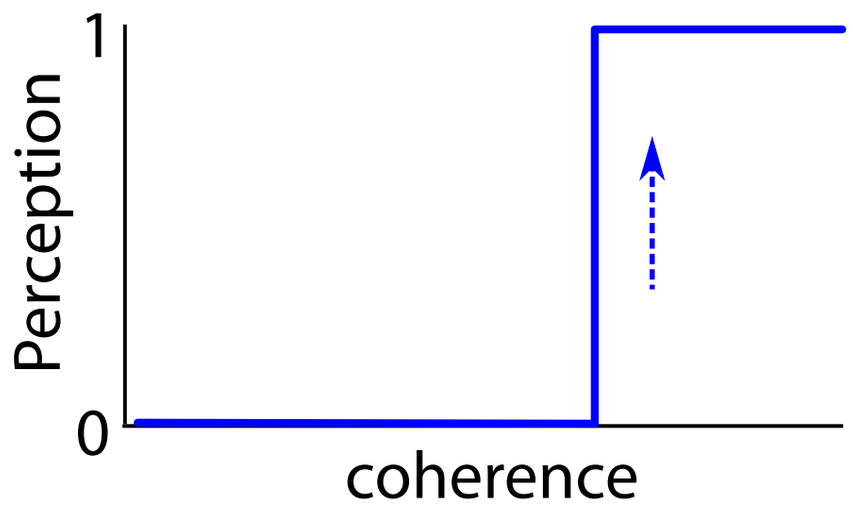


0% coherence

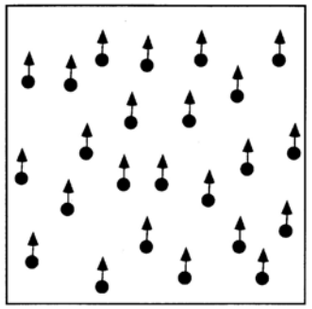




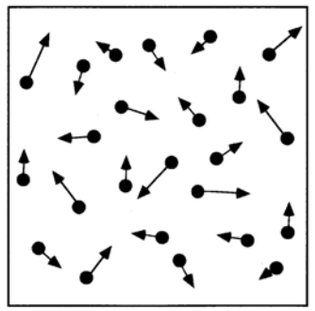
100% coherence



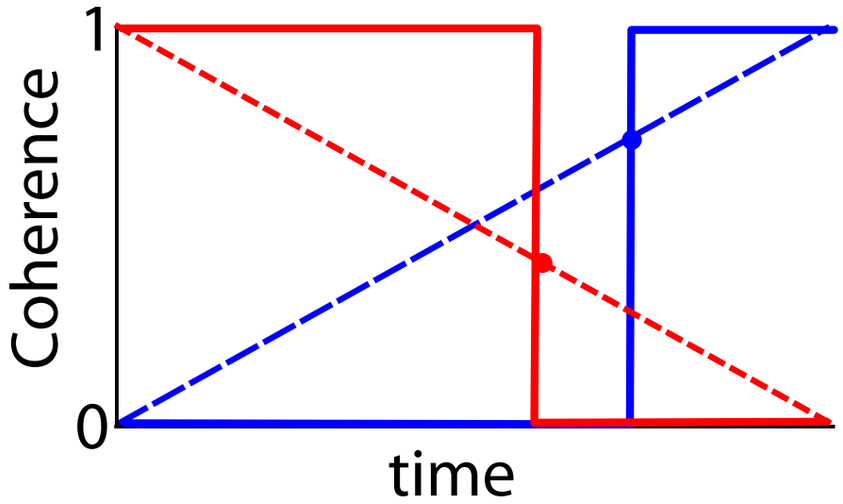
Descending coherence

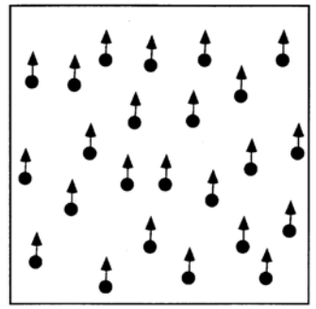


100% coherence

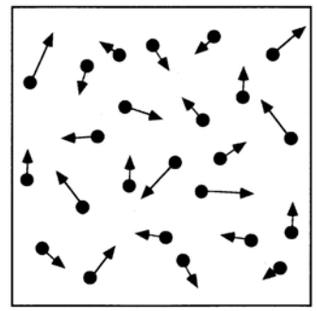


0% coherence

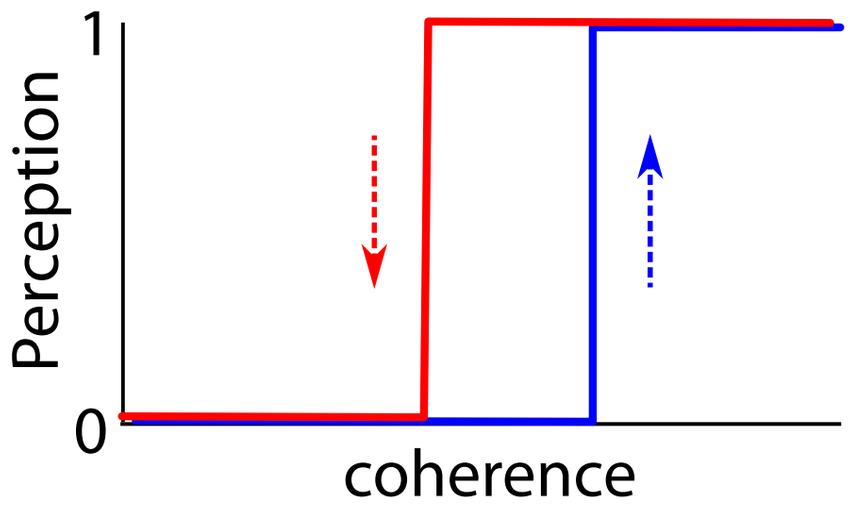




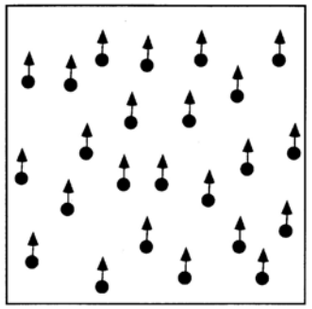
100% coherence



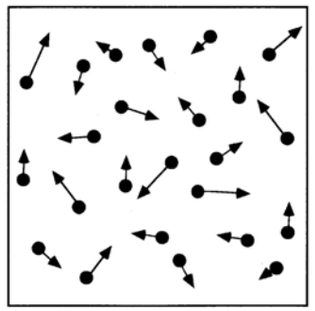
0% coherence



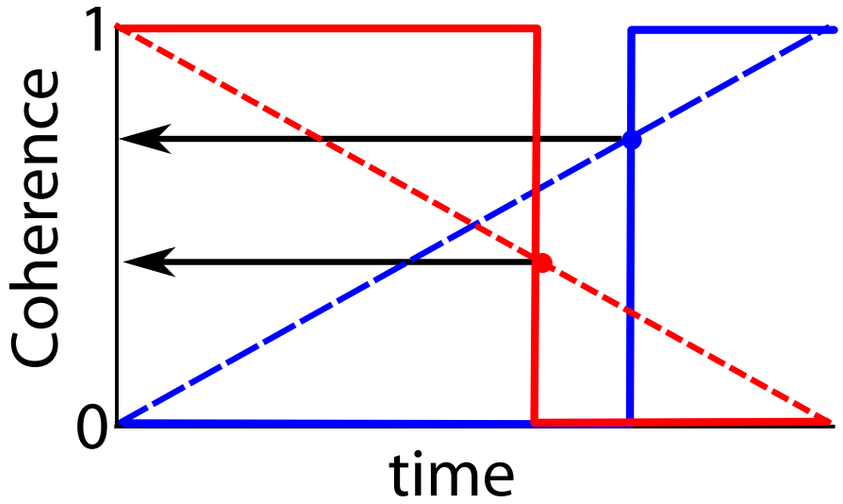
Hysteresis loop

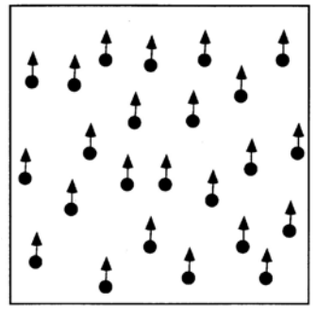


100% coherence

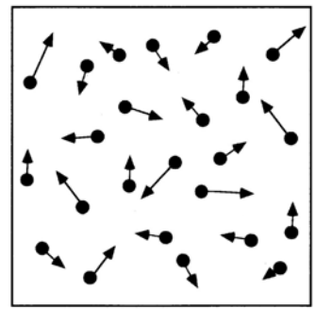


0% coherence

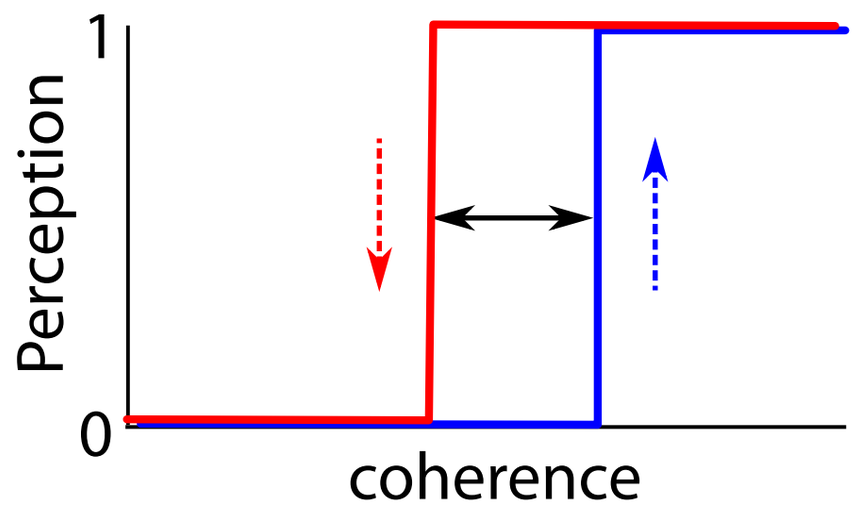




100% coherence



0% coherence

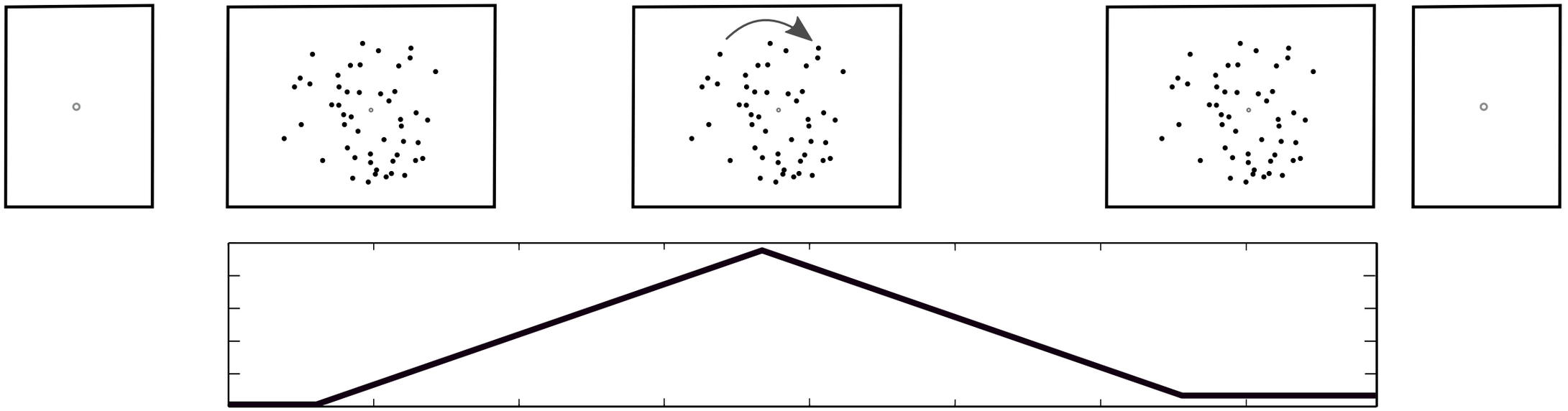


RDK

Fixation

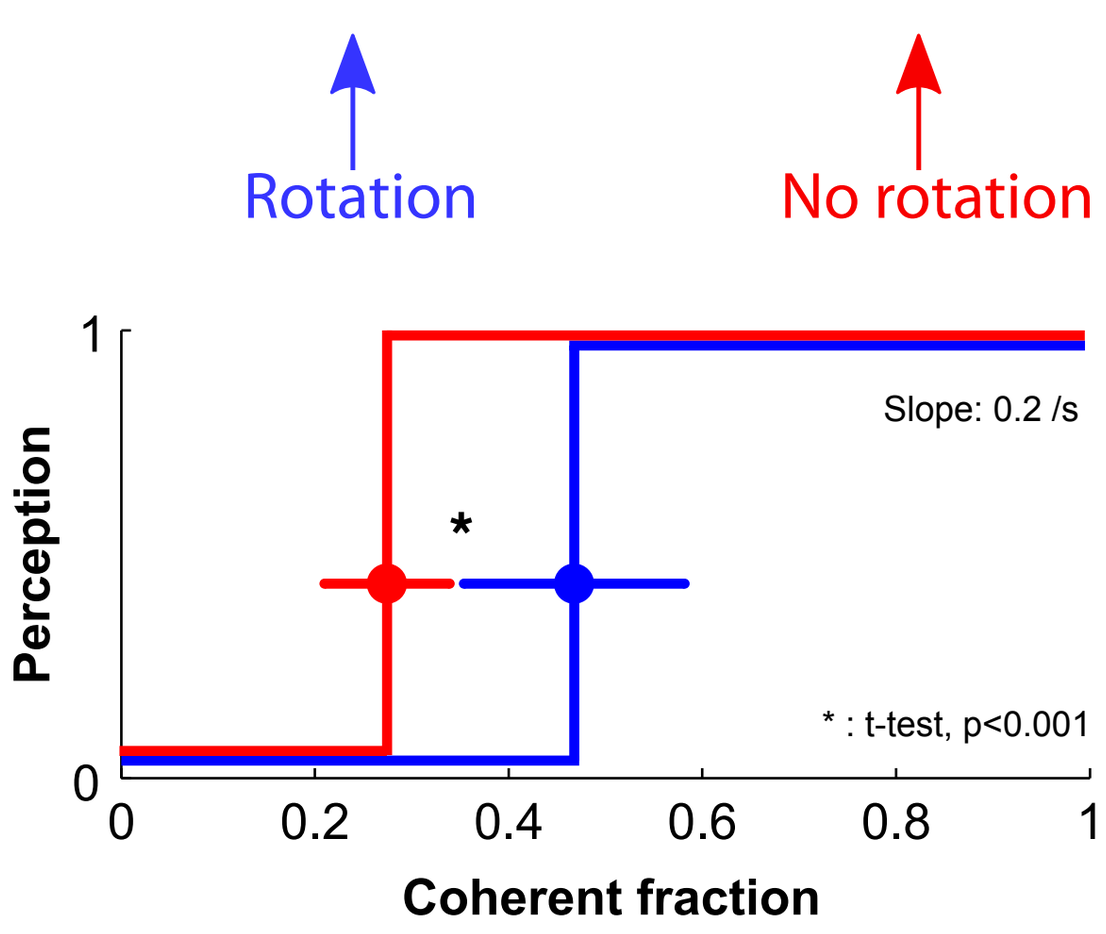
with ascending and descending coherence

Fixation



Report

Report



Hysteresis may reflect attractor dynamics of recurrently connected representation

- Evidence for cooperativity (Williams, Phillips, Sekuler, 1986).
- Evidence for stochastic dynamics (Chialvo, Apkarian, 1993).
- Stereopsis and binocular rivalry (Buckthought, Kim, Wilson,2008).
- Qualitative model (You, Meng, Huan, Wang, 2010).

Presumed cortical representation

MST

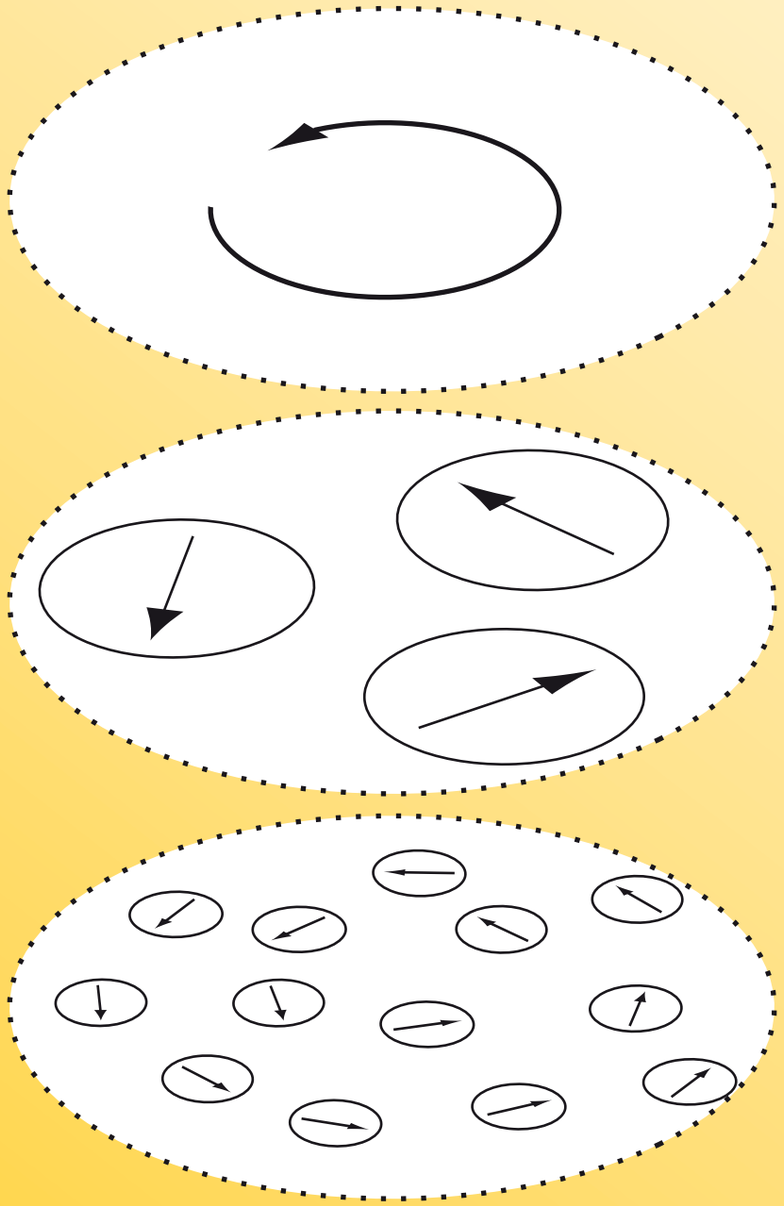
rotation

MT

pattern velocity

V1

component direction

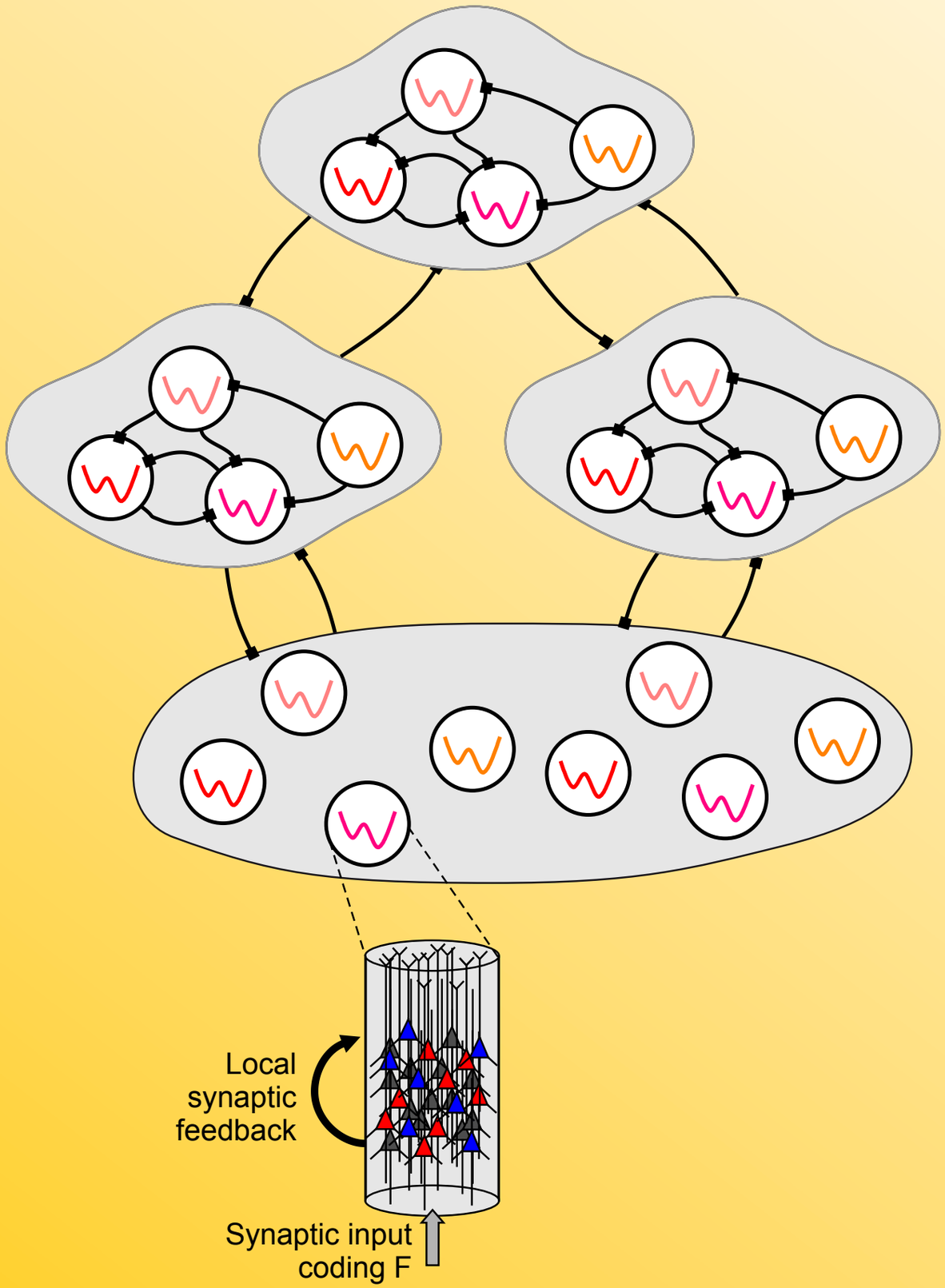


Hierarchy of recurrent networks

MST

MT

V1



rotation

pattern velocity

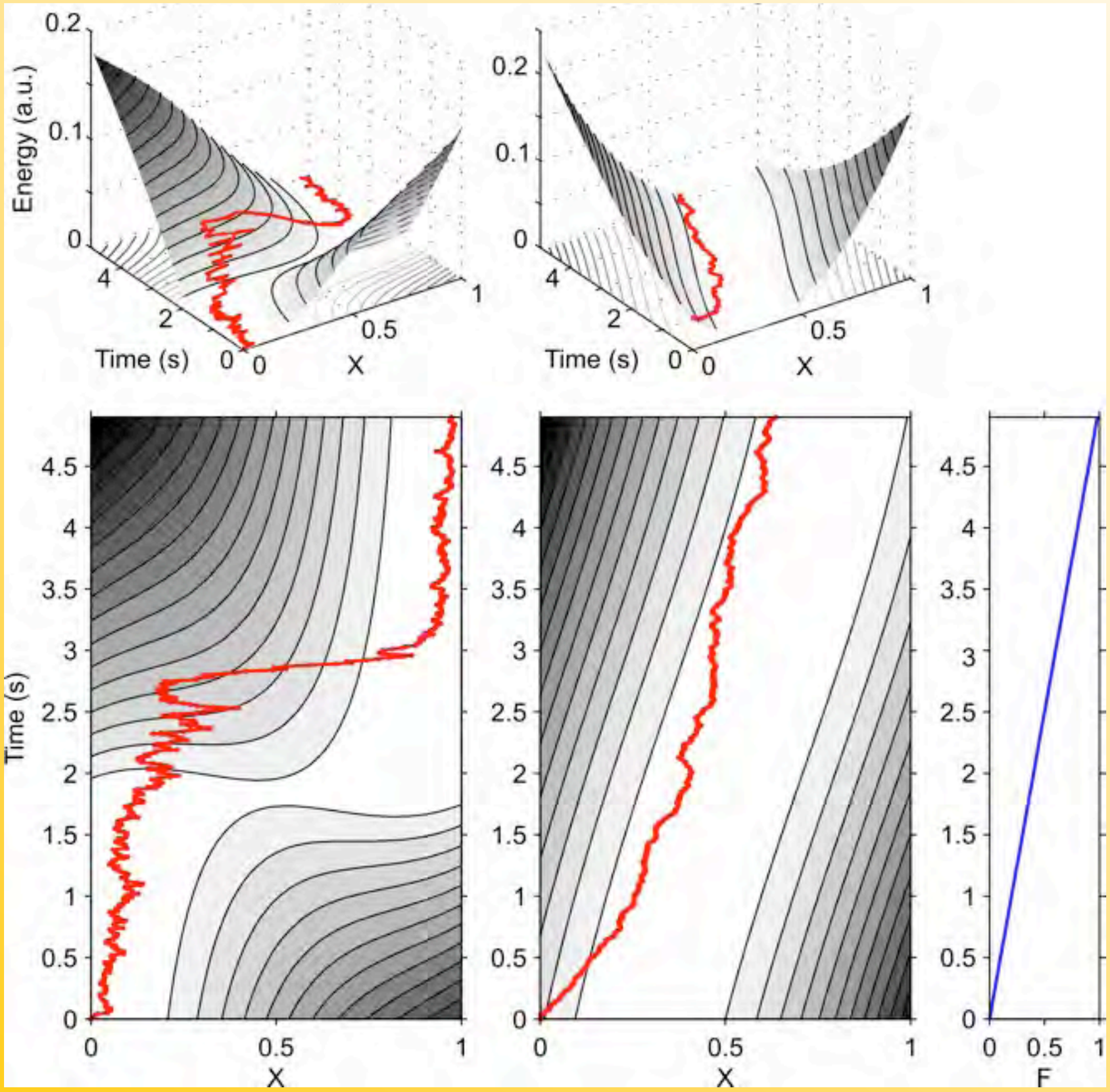
component direction

bgcn magdeburg

CORONET

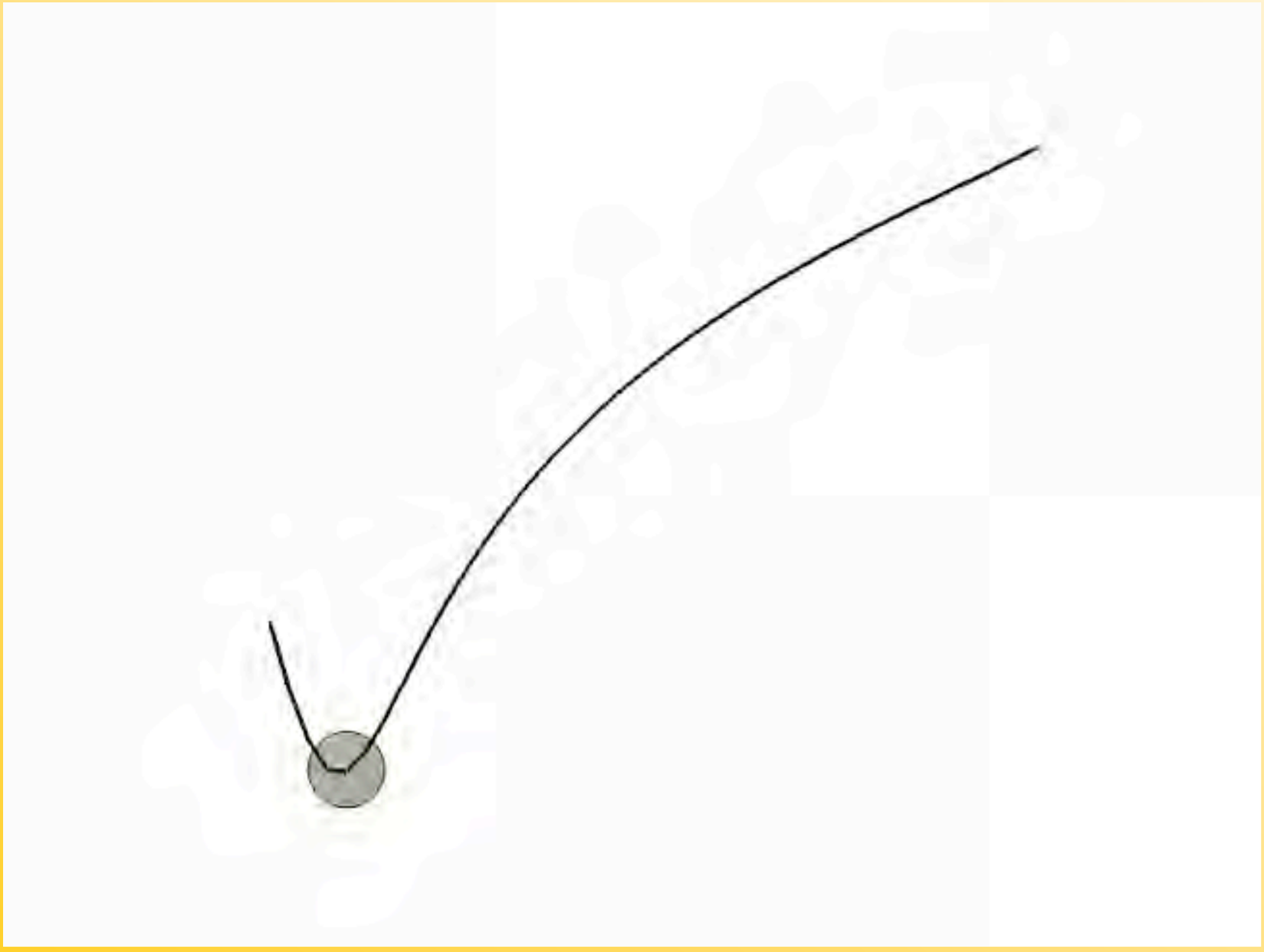
Possible sources of hysteresis

Attractor dynamics

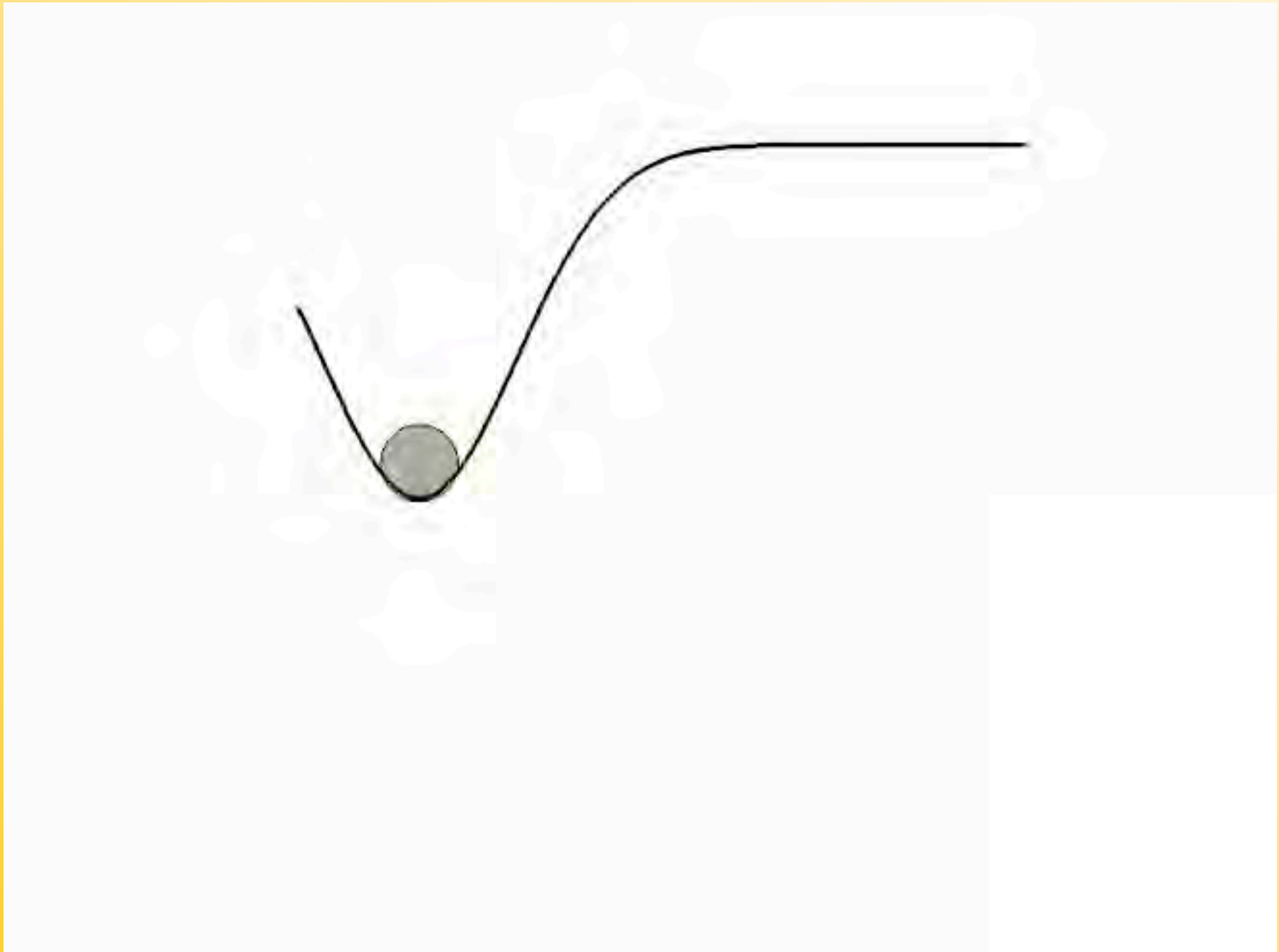


Inertial dynamics

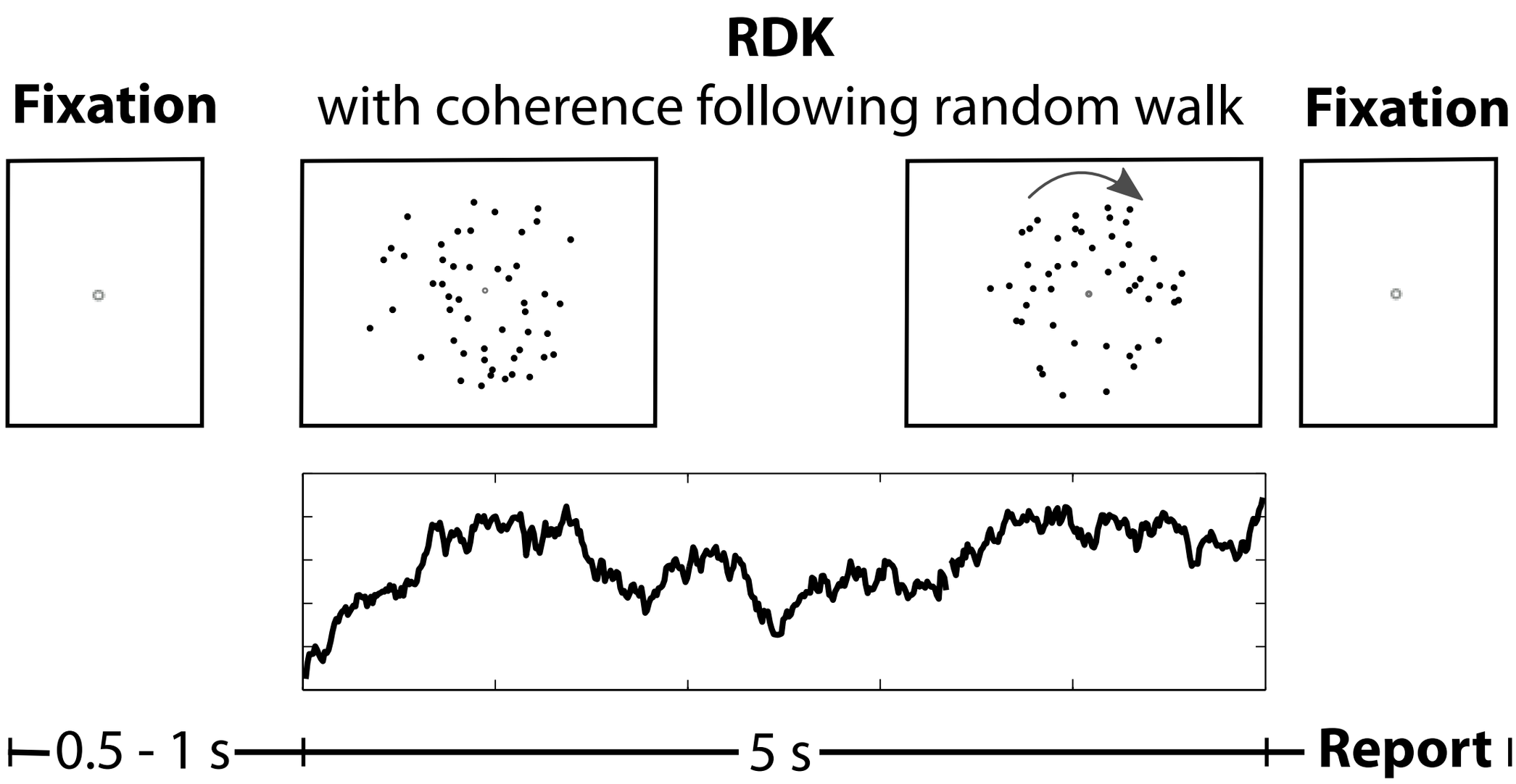
Inertial dynamics



Attractor dynamics

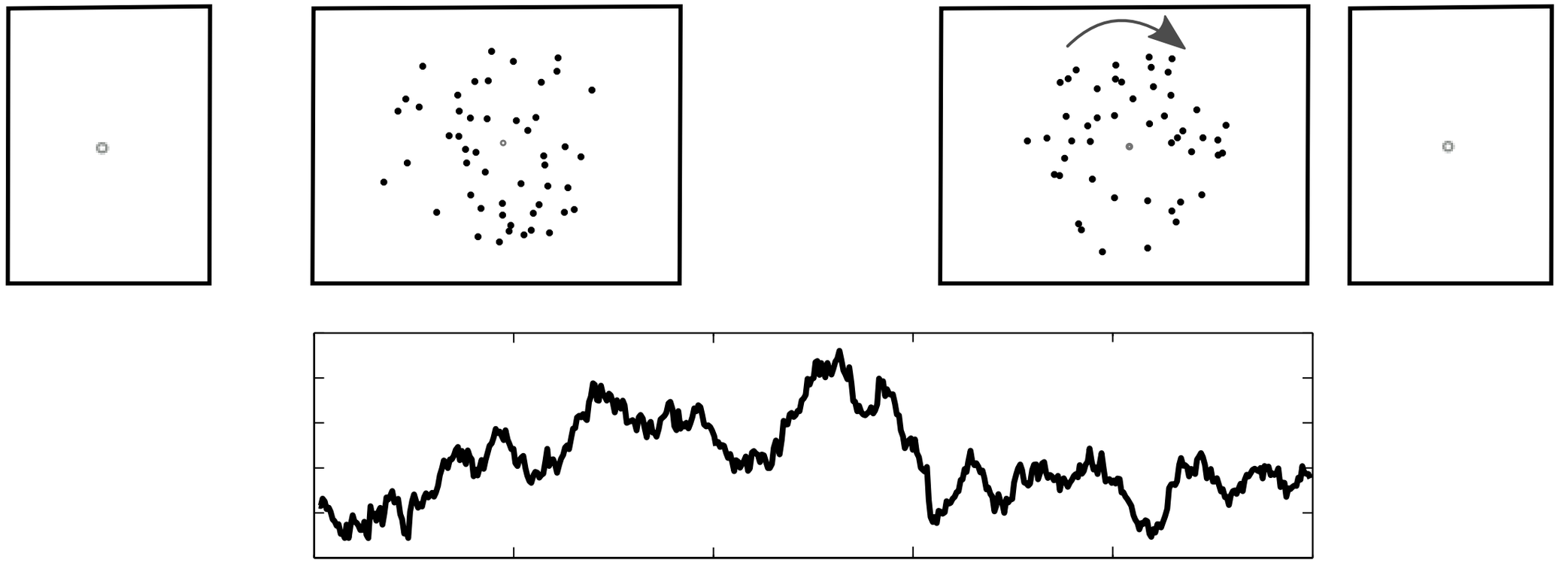


Coherence F follows random walk



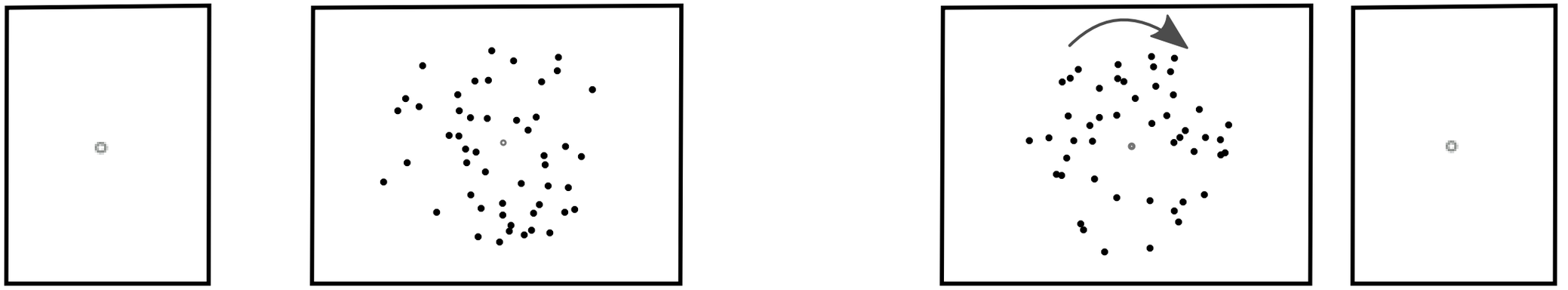
RDK

Fixation with coherence following random walk **Fixation**



RDK

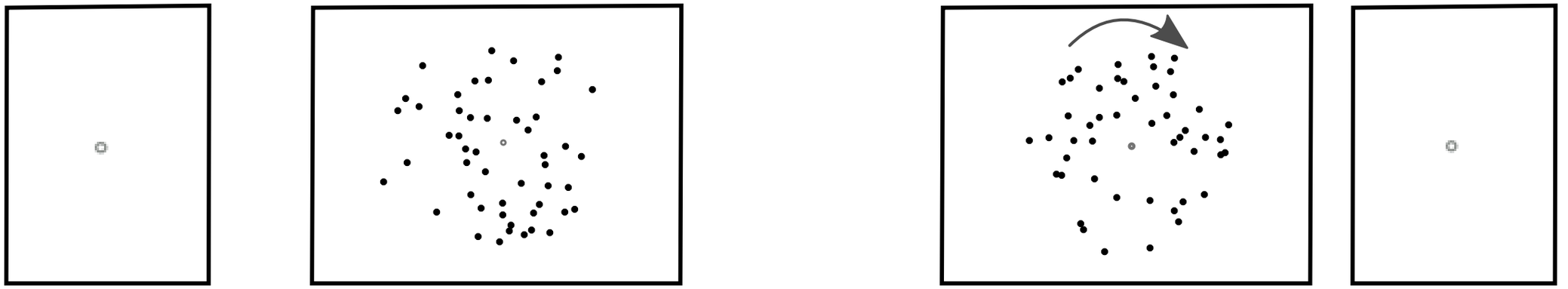
Fixation with coherence following random walk **Fixation**

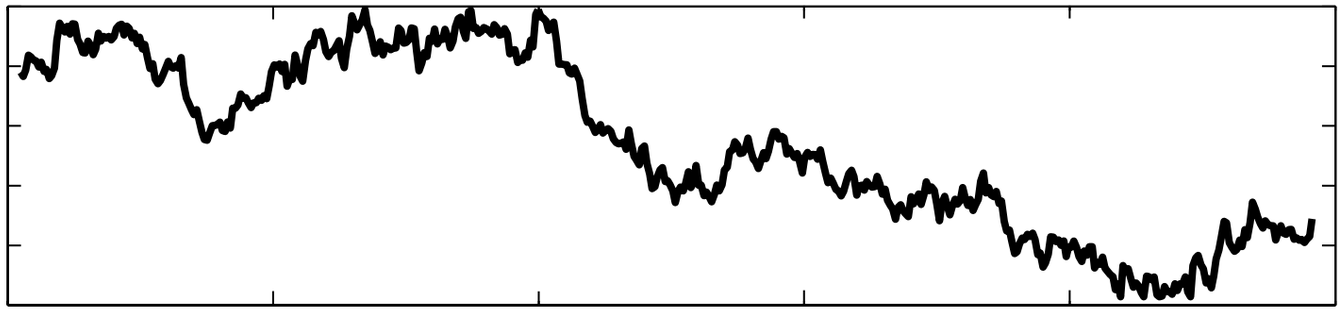


0.5 - 1 s — 5 s — **Report**

RDK

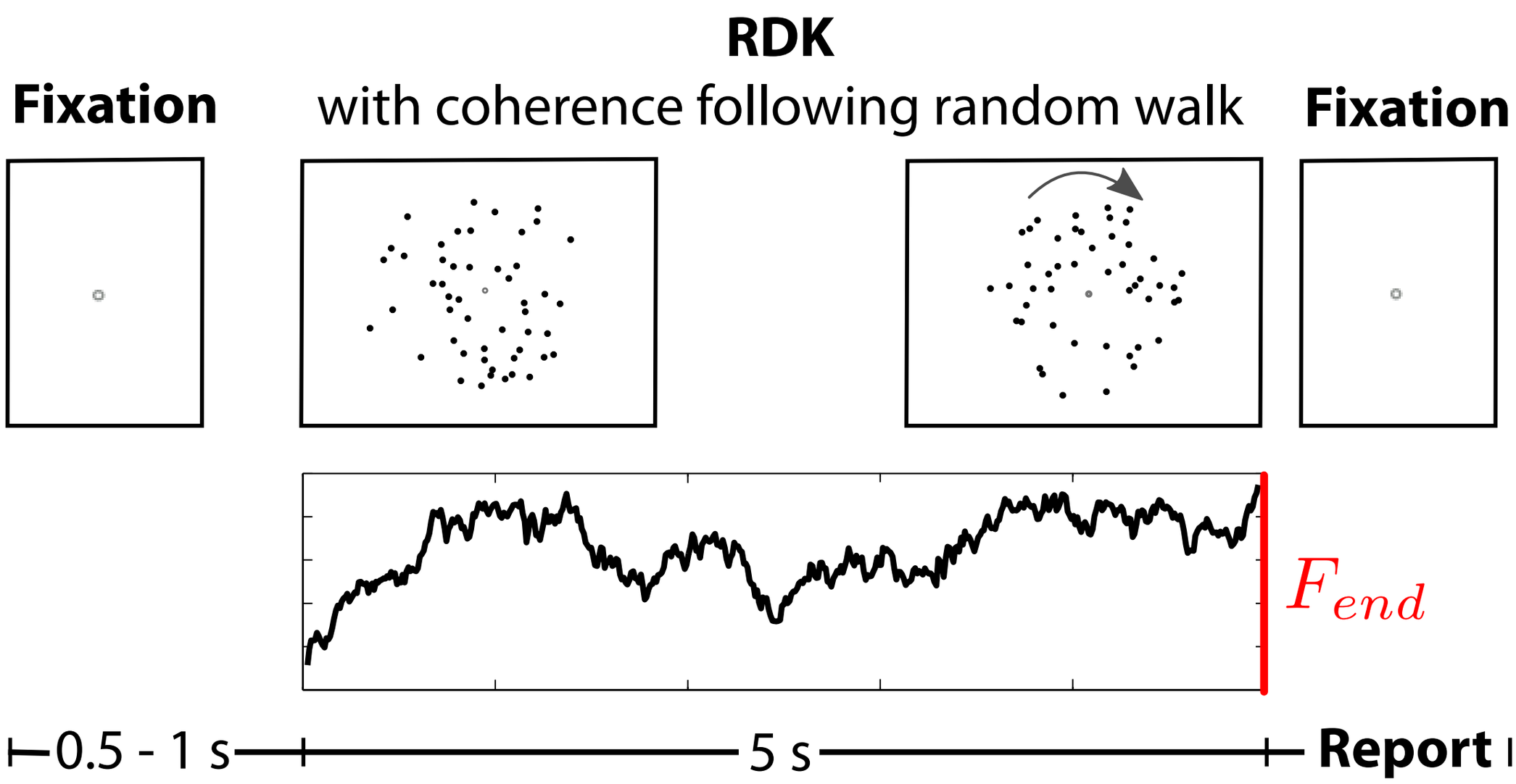
Fixation with coherence following random walk **Fixation**



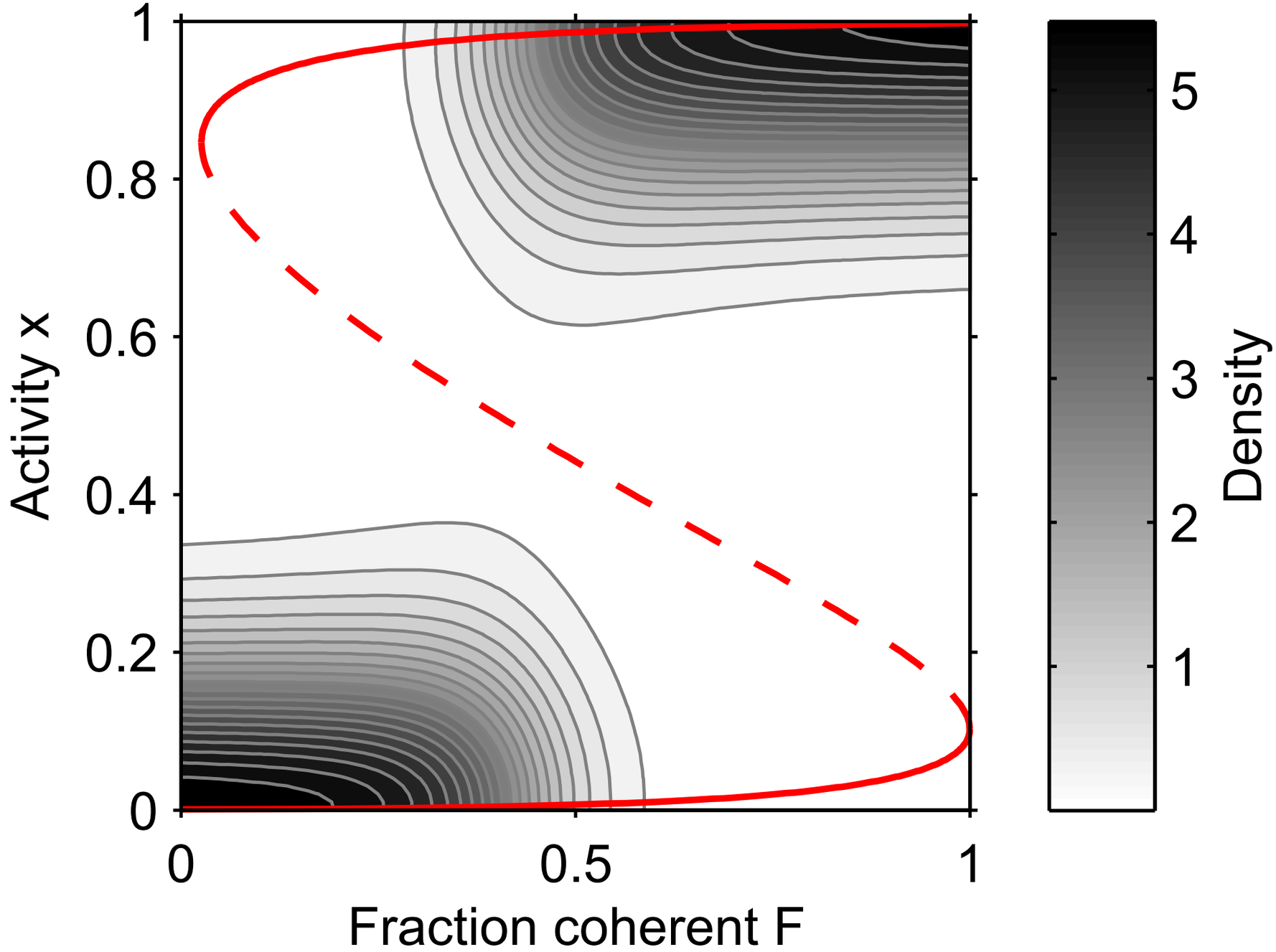


0.5 - 1 s — 5 s — **Report**

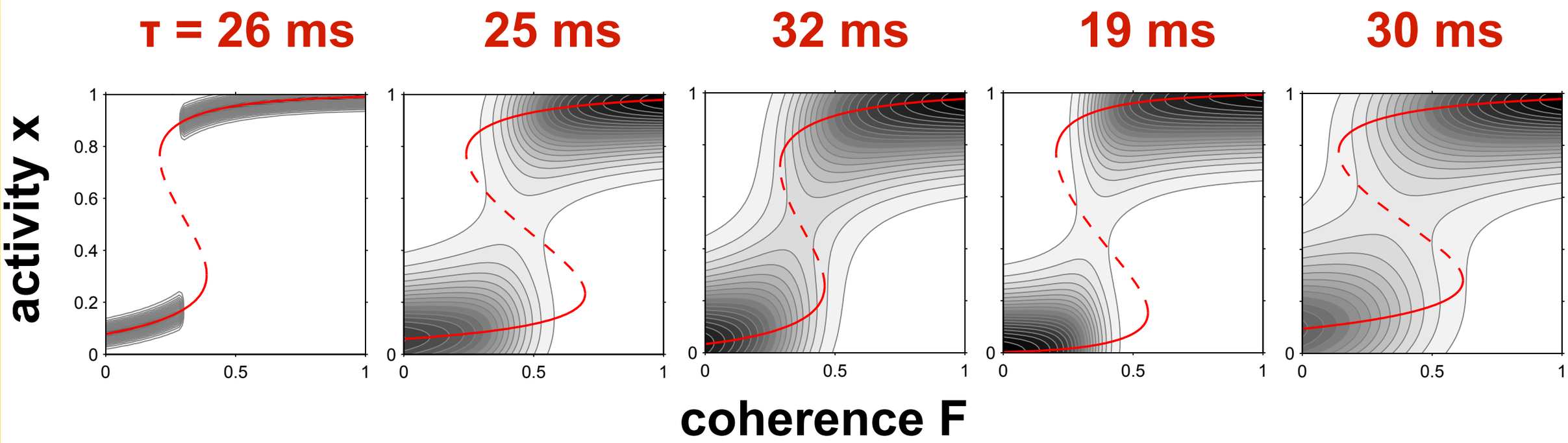
Observer reports final appearance



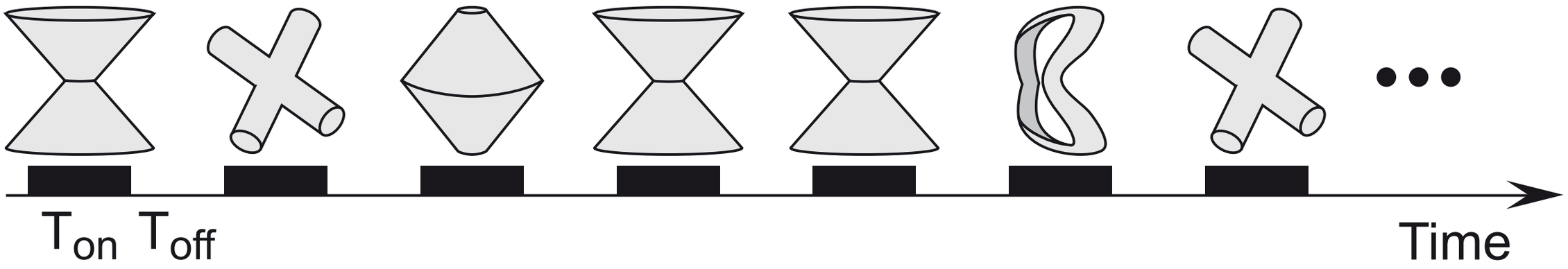
Fast attractor dynamics

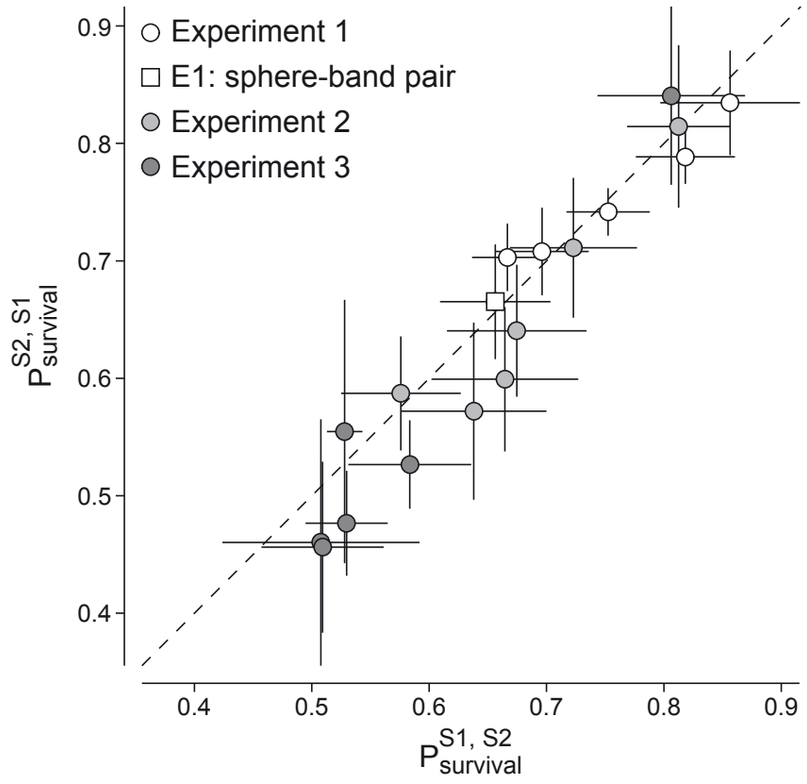


Fast attractor dynamics



Shape-specificity of sensory memory priming





Pastukhov, Braun, 2013
Pastukhov, Füllekrug, Braun, 2013
Pastukhov, Lissner, Füllekrug, Braun 2013
Pastukhov, Lissner, Braun, 2013

Three-level model (qualitative)

PFC

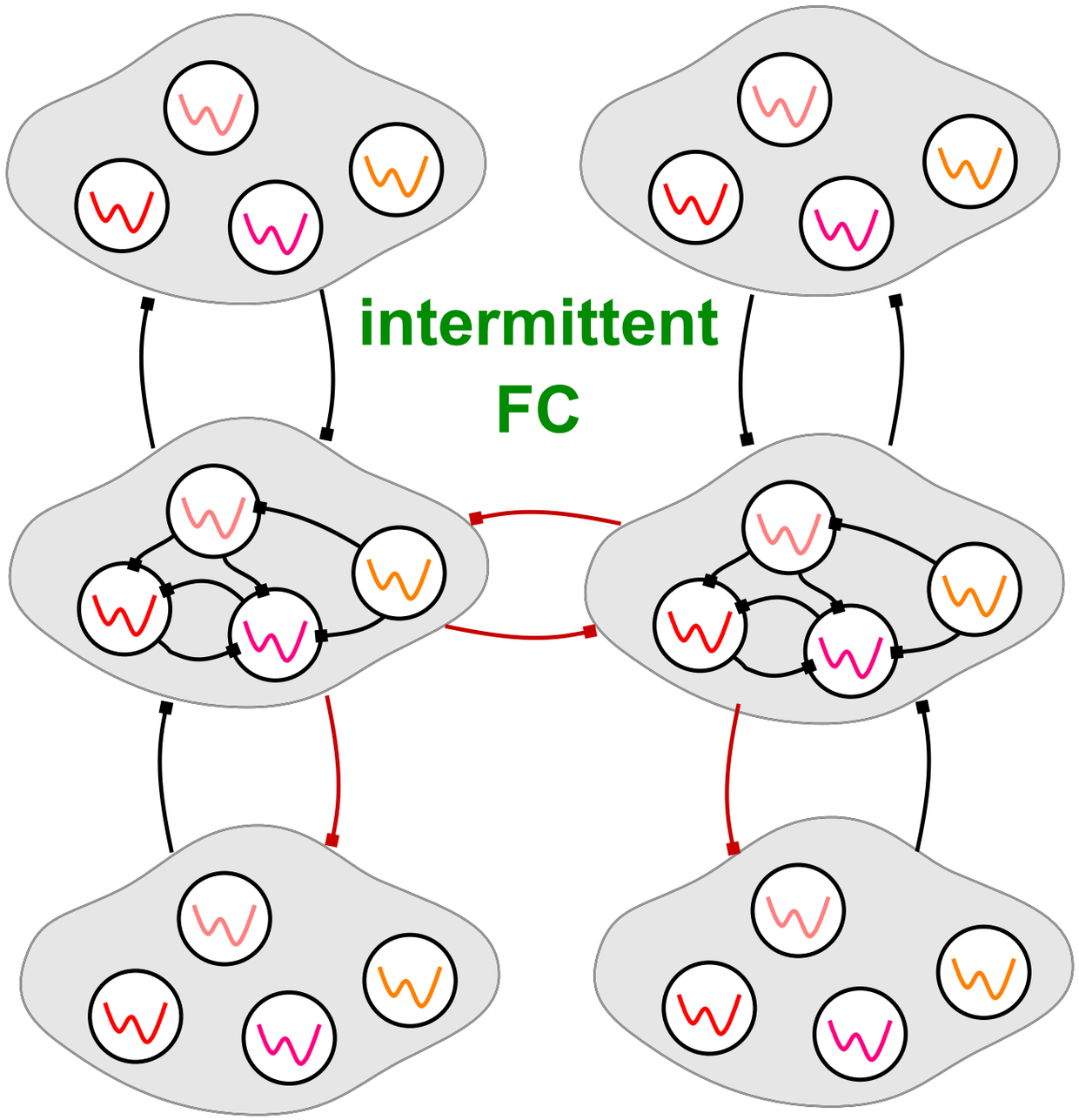
'sensory memory'

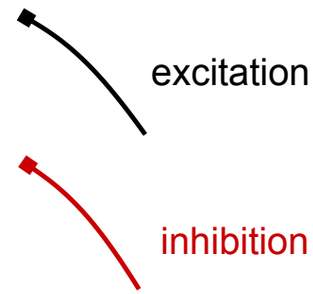
IPS

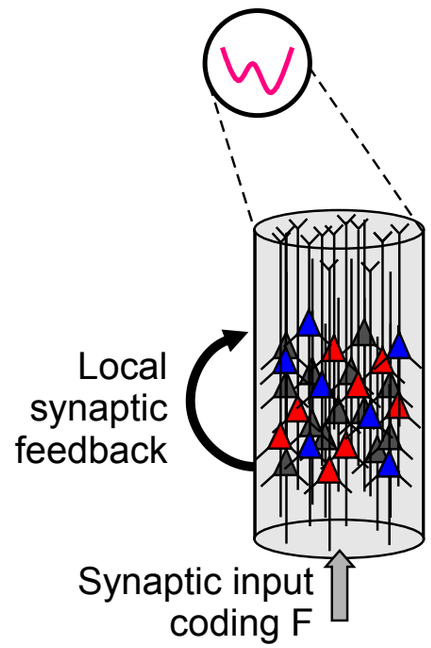
'limited capacity'

VC

'evidence accumulation'







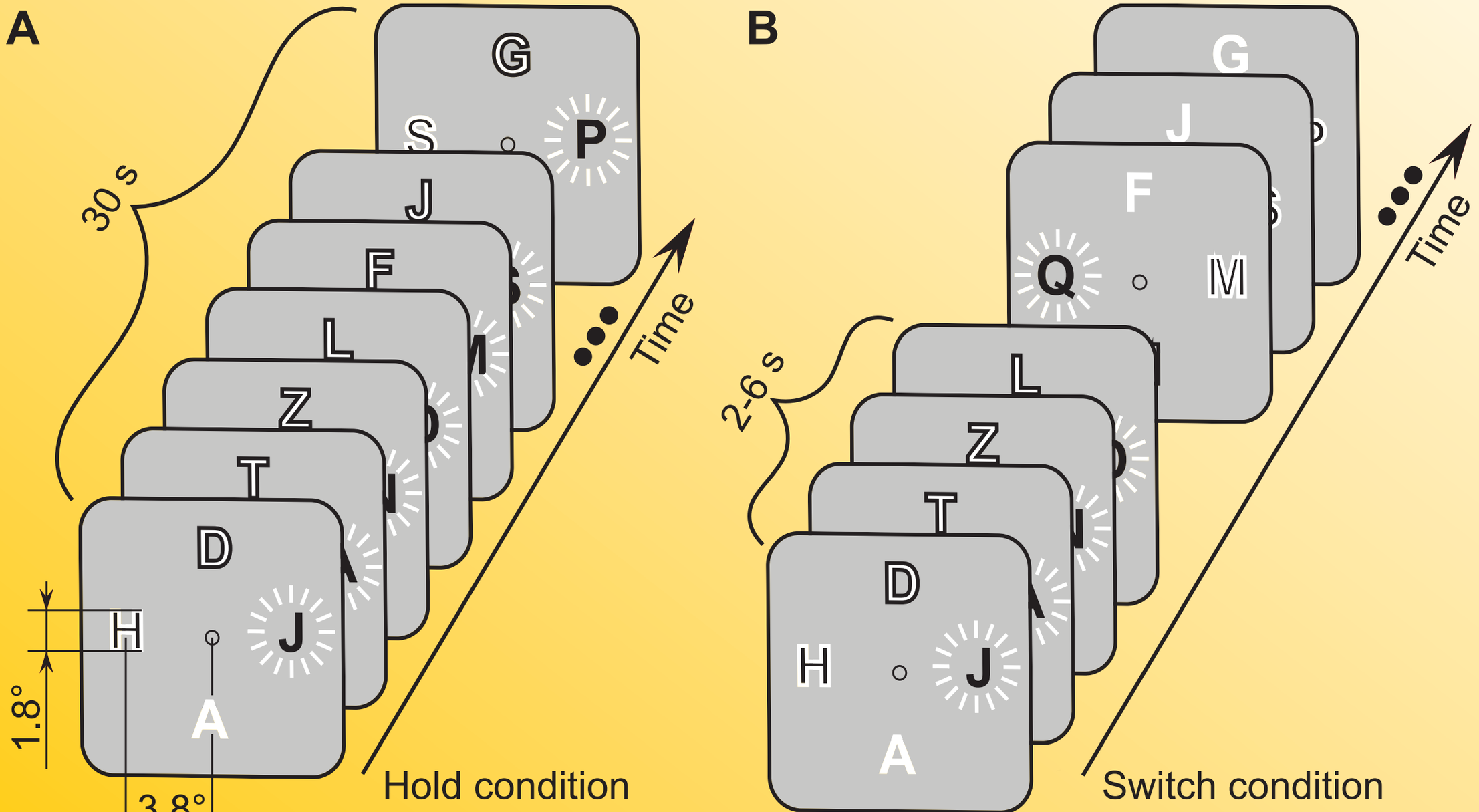
3. Spontaneous ongoing attention dynamics

Perceptual dynamics fixes large-scale interactions & flags intermittent attentional engagement

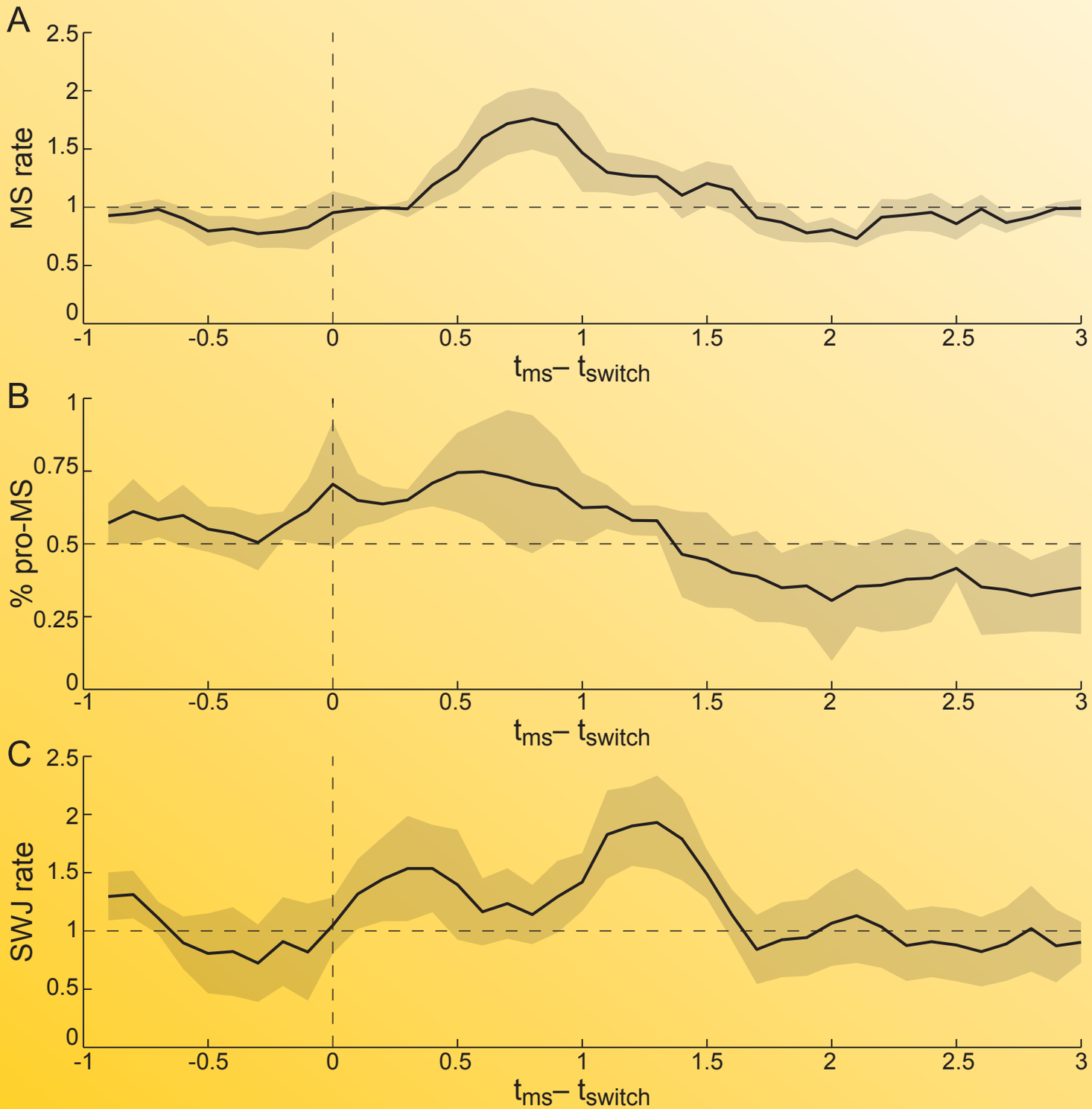
Functional connectivity (resting & task)

Structural connectivity (DSI)

Attentional engagement confirmed by microsaccades



Attentional engagement confirmed by microsaccades



Attentional engagement confirmed by task interference