FN-Wahrnehmung-Bistabil-EN-v0.1-2026-05-17

Research Note — Bistable Perception

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1. Thesis

L1 showed that the visual system does not measure lengths objectively; L2 and L3 provided mechanisms (lateral inhibition, opponent colours). L5 is the **strongest and most direct refutation** of the naive assumption “one stimulus produces one perception”: with bistable figures the stimulus is **completely constant**, but the perception **switches spontaneously** between two stable interpretations. The Necker cube flips between two 3D views, the Rubin vase between vase and two faces — without any change in the image. This proves: **the same stimulus produces different perceptions.** Perception is not a passive imaging of the stimulus but an **active hypothesis** of the brain — it chooses between possible interpretations, and when none wins unambiguously, it switches between them. This module is the culmination of the perception strand and the sharpest form of the cave-allegory core (Module 02): we do not see the world but our respectively most probable interpretation of it.

2. Assumptions

1. With bistable figures the physical stimulus is constant and ambiguous (it permits two equally good interpretations).
2. The two interpretations are represented by two competing neural populations.
3. The populations inhibit each other (winner-take-all): at any time one dominates.
4. The dominant population adapts (fatigues), which eventually triggers the switch.
5. Neural noise produces the stochastic variability of the switch times.

3. Mathematical model

M1 — “one stimulus produces one perception”: With a constant stimulus the perception is constant; the switch rate is zero.

Competition model (two populations r_1, r_2): $$\frac{dr_i}{dt} = -r_i + f\big(I - \beta\,r_j - \gamma\,a_i + \xi\big), \qquad \frac{da_i}{dt} = \frac{-a_i + r_i}{\tau_a},$$ with sigmoidal activation f, input I (constant!), mutual inhibition β, adaptation a_i with strength γ and time constant τ_a, and noise ξ. The dominant population suppresses the other, fatiguing in the process (rising a_i), until the suppressed population takes over — a spontaneous switch at constant I.

Prediction of the models: - **M2/M3** (Necker, ambiguous figure): spontaneous switches at constant stimulus. - **M4** (statistics): the dominance durations follow a gamma-like distribution (Levelt).

Symbol	Meaning	Unit
r_i	activity of population i	—
a_i	adaptation of population i	—
I	input (constant)	—
β	inhibition strength	—
γ	adaptation strength	—
τ_a	adaptation time	s

4. Parameters

Three scenarios:

Scenario	Setup
A Necker	$I=1.0$, $\beta=1.5$, $\gamma=0.5$, $\tau_a=2$, noise 0.15; $T=100$s
B ambiguous figure	adaptation strength varied (0.3, 0.5, 0.8)
C statistics	20 runs, $T=200$s, dominance-duration distribution

Tolerance: $\varepsilon = 0$ (a single switch already refutes M1).

5. Prediction

Scenario	Expectation
A	constant stimulus, but switches > 0
B	switch rate depends on adaptation, not on stimulus
C	gamma-like dominance-duration distribution, coefficient of variation ~0.5–0.9

6. Falsification criterion

M1 (“one stimulus = one perception”) is refuted as soon as a constant stimulus leads to more than zero perceptual switches. Since a single spontaneous switch already refutes M1, $\varepsilon = 0$.

7. Competing models

- **K1 — passive imaging (M1):** tested baseline model; predicts no switches.
- **K2 — competition with adaptation:** two populations, mutual inhibition, fatigue (the model used here).
- **K3 — pure noise models:** the switches are driven by noise alone (without adaptation) — explains the statistics less well.
- **K4 — top-down control:** attention and intention influence the switches (they can be partly controlled voluntarily).
- **K5 — predictive processing:** the brain tests competing hypotheses; the switch is a hypothesis change under ambiguous evidence.
- **K6 — Levelt's propositions:** quantitative laws on dominance duration and stimulus strength (for binocular rivalry).

8. Domain of failure

- **Generic parameters:** the model uses plausible values not fitted to specific data; the absolute times are illustrative.
- **Two populations:** multistable figures (more than two interpretations) need more populations.
- **Top-down ignored:** voluntary control and attention are not modelled; the model is purely bottom-up.
- **Stimulus ambiguity presupposed:** the model explains the dynamics of *given* ambiguity, not why a figure is ambiguous.
- **Individual differences:** the switch rate varies strongly between persons (and is partly heritable); the model gives a typical course.
- **Binocular rivalry vs. figure flipping:** different bistable phenomena have partly different mechanisms; the model is a common framework.

9. Simulation

Numerical evaluation in `bistabil_simulation.py`:

1. Competition model of two populations with inhibition, adaptation, noise; dominance with hysteresis (against noise flicker).
2. Scenario A: Necker cube; time series, switch count, time fractions.
3. Scenario B: ambiguous figure; switch rate for three adaptation strengths.
4. Scenario C: 20 runs; dominance-duration distribution, coefficient of variation, gamma fit.

Results in `bistabil_results.json`. Plot as `bistabil_szenen.svg` (four subplots: switch dynamics, dominance time series, dominance-duration distribution, Necker-cube schematic).

10. Result

10.1 A Necker cube

Quantity	Value
stimulus	constant (unchanged)
switches in 100 s	7
mean dominance duration	13.9 s
time fraction interpretation 1 / 2	0.56 / 0.44
Assessment M1	**refuted**

10.2 B ambiguous figure (adaptation dependence)

adaptation strength	switches	mean duration
0.3 (weak)	5	17.7 s
0.5 (medium)	5	14.3 s
0.8 (strong)	19	5.0 s
Assessment M1	**refuted**	

10.3 C dominance-duration distribution

Quantity	Value
number of dominance phases	(20 runs)
mean duration	2.3 s*
coefficient of variation	0.80
distribution	gamma-like
Assessment M1	**refuted**

*Across all runs incl. short phases; the coefficient of variation 0.80 lies in the empirical range.

Plot: `bistabil_szenen.svg`.

11. Assessment

M1 ("one stimulus = one perception") is refuted in all three scenarios — as directly and undeniably as in no other module of the strand.

Scenario A (Necker cube) is the classical example. A simple wire-frame image of a cube permits two 3D interpretations: either one looks at the cube slightly from above, or slightly from below. Both are equally plausible, and the image itself fixes neither. What happens: perception flips spontaneously between the two interpretations, every few seconds, without anything changing in the image. In the simulation: 7 switches in 100 seconds, mean dominance duration 14 seconds, time fraction 56% to 44%. **The decisive point for refuting M1:** the input is demonstrably constant (the same image), the output (the perception) is not. If perception were a passive imaging of the stimulus, this could not happen. But it does — so perception is not an imaging but an active interpretation.

Scenario B (ambiguous figure) shows *why* the switches happen. The Rubin vase (vase or two faces in profile) is a figure-ground ambiguous figure: sometimes the vase is the "figure" and the surround the "ground", sometimes vice versa. The simulation varies the adaptation strength and shows: the stronger the adaptation (fatigue of the dominant interpretation), the faster the switches (from 5 switches at weak to 19 at strong adaptation). **The switch rate depends on the internal dynamics, not on the stimulus** — which remains constant throughout. This localises the cause unambiguously in the perceiving system, not in the image. The mechanism is plausible: the active interpretation "exhausts" the responsible neurons until the competing interpretation becomes strong enough to take over — then this one exhausts itself, and it flips back.

Scenario C (dominance-duration statistics) provides the quantitative fingerprint. The times each interpretation dominates are not constant and not periodic but **stochastically distributed** — with a coefficient of variation of 0.80, which lies in the empirically observed range for bistable perception. The distribution is gamma-like, a finding known since Levelt (1968) for binocular rivalry and holding for many bistable phenomena. **This statistics is stimulus-**

independent — it arises from the interaction of adaptation and noise in the brain. Were perception stimulus-determined, there would be no such distribution of switches at a constant stimulus.

The central insight: Bistable perception is the crucial experiment for the nature of perception. In most situations the stimulus is unambiguous enough that we see the “correct” interpretation and do not notice the constructive character — perception feels like a direct look at the world. Bistable figures make the construction visible by offering two equally good interpretations: now we *see* how the brain chooses, and how it switches between the choices. **The stimulus underdetermines the perception; the brain supplies the rest.** This is the strongest confirmation of the basic idea of the whole perception strand (and of the cave allegory, Module 02): we do not perceive the stimulus but the most probable interpretation of the stimulus — and when there are two equally probable ones, we experience the construction process itself as flipping.

Connection to previous modules: - **Module 02 Cave Allegory:** the direct core. L5 is the most drastic evidence — here the “shadow interpretation” switches before our eyes, at a constant template. - **Module L1 Geometric Illusions:** there the misinterpretation was *unambiguous* (everyone sees the Müller-Lyer line equally wrongly); here the interpretation is *ambiguous* (it switches). Two sides of construction. - **Module L2/L3:** there adaptation (afterimages) and lateral inhibition provided mechanisms; here adaptation and inhibition drive the switches — the same building blocks, new dynamics.

12. Next test

Module L6 Gestalt Laws as a possible next step: the principles by which the brain orders ambiguous stimuli into gestalts (proximity, similarity, good continuation, closure) — the “rules” behind the interpretation that L5 saw flipping. Or **Module L4 Motion Illusions** (phi phenomenon, waterfall illusion).

Possible extension Module L5 v0.2: multistable figures (more than two interpretations); binocular rivalry separately; the role of attention and voluntary control; Levelt’s propositions quantitatively; impossible figures (Penrose) as a special case of permanent inconsistency.

Appendix A — Cross-references

- Practice explanation: `PRAXIS-Bistabil-EN.md` (follows)
- Companion paper: `BEGLEITPAPIER-Bistabil-EN.md` (follows)
- Tool: `AMBIGUA.html` (follows) — *Lat. ambiguus, ambiguous*
- Code: `bistabil_simulation.py`
- Plot: `bistabil_szenen.svg`
- Result data: `bistabil_results.json`
- Predecessor modules: Module 02 Cave Allegory, Module L1/L2/L3
- Follow-up modules (planned): L4 Motion, L6 Gestalt

Appendix B — External stocktaking

- **Necker (1832)** — the flipping cube.
- **Rubin (1915)** — figure-ground, the vase.
- **Levelt (1968)** *On Binocular Rivalry* — quantitative laws.
- **Blake & Logothetis (2002)** — neurophysiology of rivalry.
- **Laing & Chow (2002)** — competition model with adaptation.
- **Leopold & Logothetis (1999)** — multistable perception as a window into consciousness.

What the workshop note adds: three bistable phenomena in a unified falsification format; the explicit competition model (inhibition + adaptation + noise); the dominance-duration statistics as a quantitative fingerprint; the framing as the sharpest form of the cave-allegory core.

Appendix C — Sources

- Necker, L. A. (1832). Observations on some remarkable optical phaenomena. *London and Edinburgh Philosophical Magazine* 1:329–337.
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Word count: ca. 1830 · Pages: 8 · Version 0.1 · 2026-05-17