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

Research Note — Motion Illusions

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1. Thesis

The perception strand has shown: interpretation happens (L1), there are mechanisms for it (L2, L3), the interpretation can flip (L5), and it follows competing rules (L6). One factor was expressly missing in L6 — **common fate**, because it requires motion. This module closes the gap and in doing so examines motion perception itself.

The tested baseline model M1 reads: *“Motion is seen because something moves. Motion perception images physical motion — no stimulus, no motion.”*

This module’s claim: motion is **generated**, not imaged. It arises from still images (A), it arises without any stimulus from the observer’s state (B) — and it is at the same time the **strongest ordering factor** of perception (C).

2. Assumptions

1. Apparent motion occurs within a definable time window.
2. The optimal time interval depends on the spatial step distance (Korte).
3. Motion perception rests on direction-selective channels.
4. These channels adapt, and perceived motion follows their ratio.
5. Gestalt factors can be compared by weight (model from L6).

3. Mathematical model

M1 — “motion images motion”: Without physical motion no motion perception.

M2 — apparent motion. After Korte (1915) the optimal time interval grows with the step distance s: $$\text{SOA}_{\text{opt}} = 30\,\text{ms} + 15\,\frac{\text{ms}}{\text{degree}}\cdot s.$$ Motion strength falls log-normally on both sides; outside the window $[0.35\,\text{SOA}_{\text{opt}};\ 3.2\,\text{SOA}_{\text{opt}}]$ one sees simultaneity or succession.

M3 — motion aftereffect. Two direction-selective channels with baseline activity. Perceived motion follows the **ratio** (ratio model, Adelson & Bergen 1985): $$P = \frac{r_{\uparrow}-r_{\downarrow}}{r_{\uparrow}+r_{\downarrow}}.$$ Adaptation weakens the stimulated channel: $$a(t) = a_{\max}\left(1-e^{-t/\tau_a}\right), \qquad r_{\downarrow} = r_0\,(1-a).$$

M4 — common fate. Extension of the L6 model: $$p_{\text{columns}} = \frac{s(d_x)}{s(d_x)+s(d_y)\left(1+\beta w_{\text{sim}}+\gamma w_{\text{mot}}\right)}, \quad \beta=1.8,\ \gamma=6.0.$$

Symbol	Meaning	Unit
SOA	time interval between two stimuli	ms
s	step distance	degrees
a	adaptation depth	—
τ_a	adaptation time constant	s
P	perceived motion	—

4. Parameters

Scenario	Setup
A apparent motion	SOA 5–800 ms; step distance 2°; frame rates 12–120 fps at object speed 10 °/s
B aftereffect	adaptation 1–120 s, $\tau_a = 20$ s, $\tau_{\text{recovery}} = 12$ s, $a_{\max}=0.62$
C common fate	three aspect ratios; tipping points for similarity and motion

Tolerance: $\varepsilon = 0.02$ (perceptual threshold in B), otherwise $\varepsilon = 0$.

5. Prediction

Scenario	Expectation
A	motion only in the middle time window; common frame rates fall within it
B	exactly zero without adaptation; opposite direction after adaptation
C	motion overrides proximity at lower weight than similarity

6. Falsification criterion

M1 is refuted as soon as motion is perceived where physically there is none — whether from still images (A) or from the adaptation state alone (B).

7. Competing models

- **K1 — imaging theory (M1):** tested baseline.

- **K2 — phi and beta distinguished:** pure motion sensation without object (phi) versus object motion (beta) — Wertheimer (1912).
- **K3 — Korte's laws (1915):** the dependence on distance, time and intensity.
- **K4 — Reichardt detector / energy model (Adelson & Bergen 1985):** direction-selective filters as mechanism.
- **K5 — ratio model of the aftereffect:** the channel balance rather than absolute response.
- **K6 — ecological interpretation:** common motion as the most reliable cue to object membership.

8. Domain of failure

- **The model parameters are plausible orders of magnitude** from the literature (SOA window, \(\tau_a\), \(\gamma\)), not fitted to own data. The structure of the claims is robust, the numerical values are not.
- **The SOA model describes only the discrete case.** At very high frame rates (from about 120 Hz) the interval falls below the lower bound; this does **not** mean that no motion is seen, but that the transition to quasi-continuous motion occurs. There the model is at its limit.
- **Phi and beta are not separated.** Wertheimer distinguished pure motion sensation from object motion; the model treats both together.
- **Only two direction channels.** Real systems have many directions and speed channels.
- **No speed perception.** How fast something appears is not modelled.
- **Not treated:** motion parallax, biological motion, aperture problem, autokinesis, induced motion.
- **\(\gamma = 6.0\) was chosen** to represent the empirical dominance of common fate — not independently measured. The factor 3.3 relative to similarity follows from this choice.

9. Simulation

Numerical evaluation in `motus_simulation.py`:

1. Scenario A: motion strength across ten SOA values; regime determination; frame rates with step distance derived from object speed.
2. Scenario B: adaptation depth and perceived motion for seven durations; decay over 40 s; control case without adaptation.
3. Scenario C: tipping points for similarity and motion at three aspect ratios; extreme case of strong proximity against motion.

Results in `motus_results.json`, plot as `motus_szenen.svg`.

10. Result

10.1 A — apparent motion

Optimal SOA at 2° step distance: **60.0 ms**.

SOA	Regime	Motion strength
5 ms	simultaneity	0.000
30 ms	motion	0.652
60 ms	**motion**	**1.000**

120 ms	motion	0.652
400 ms	succession	0.000

Frame rates (object speed 10 °/s, step distance rate-dependent):

Rate	SOA	Step	Strength
flipbook 12 fps	83.3 ms	0.833°	0.668
cinema 24 fps	41.7 ms	0.417°	**0.983**
video 30 fps	33.3 ms	0.333°	**0.998**
monitor 60 Hz	16.7 ms	0.167°	0.673
120 Hz	8.3 ms	0.083°	model limit

Assessment M1: refuted.

10.2 B — motion aftereffect

Test stimulus **identical and static** in all cases.

Adaptation duration	adaptation depth	perceived motion	direction
0 s (control)	0.000	**0.0000**	**none**
1 s	0.030	+0.0154	below threshold
10 s	0.244	+0.1389	upwards
30 s	0.482	**+0.3172**	**upwards**
120 s	0.619	+0.4477	upwards

Assessment M1: refuted.

10.3 C — common fate

Weight required to override proximity:

Lattice	via similarity	via motion	Factor
$d_x/d_y = 0.5$	1.384	0.416	**3.33**
$d_x/d_y = 0.7$	0.621	0.187	**3.32**
$d_x/d_y = 0.9$	0.158	0.048	**3.29**

Extreme case: at very strong proximity ($d_x/d_y = 0.4$) with motion weight 1.0 the result is 0.390 — **rows win nonetheless**.

Assessment M1: refuted.

11. Assessment

M1 (“motion is seen because something moves”) is refuted in all three scenarios.

Scenario A shows motion out of stillness. Two alternately flashing lights produce the perception of *one* light that moves. Nothing moves — there are only two places and two moments.

Decisive is that this happens only within a **time window**. At 5 ms one sees two simultaneous lights, at 400 ms two in succession. In between, with a maximum at 60 ms for 2° separation, something arises that does not physically exist. Motion is not a property of the stimulus but an achievement performed only under particular temporal conditions.

The entire moving image rests on this. A film contains no motion, only single frames. The calculation reveals a finding I had not been looking for: **the historically chosen frame rates lie close to the optimum** — cinema 24 fps reaches 0.983, video 30 fps even 0.998. This is no coincidence but the result of empirical optimisation: the rates were chosen so that motion appears fluid, long before anyone knew the underlying psychophysics.

On the correction. The first version computed all frame rates with the same step distance (2°) and classified 60 Hz as “simultaneity” — which contradicts everyday experience at any screen. The error lay in the assumption: at a higher frame rate an object steps **less far** per frame, and by Korte’s law the optimal SOA falls accordingly. The step distance is now derived from object speed. The error is documented rather than silently fixed (workshop line) — and it was instructive, because the absurd result immediately revealed the modelling error.

Scenario B is the cleanest control case of the whole strand. The test stimulus is **identical and unmoving** in all conditions. Without prior adaptation the perceived motion is exactly **0.0000** — the stimulus appears still, as it is. After 30 seconds of adaptation to downward motion the **same** stimulus appears to move upwards at +0.3172.

There is no motion stimulus here that could be measured wrongly. **What changes is solely the observer’s state.** Motion perception is thereby demonstrably not a property of the stimulus.

The mechanism is the same as in L3: two opponent channels, adaptation weakens the stimulated one, the **ratio** tips. There it was red and green and the result a colour afterimage; here it is upwards and downwards and the result an apparent motion. And it is the same adaptation that drives the bistable alternations in L5. **Three modules, one mechanism** — the kind of connection the merge strand seeks systematically, occurring here within a single strand.

Scenario C closes the gestalt-factor family. In L6 common fate was expressly missing because it requires motion. The calculation shows why it is the strongest factor: to override the same proximity, common motion needs only about **one third** of the weight that similarity requires — consistently across all aspect ratios tested (factor 3.29 to 3.33).

This is **ecologically plausible**. Things that move together almost always really belong together in the natural world. Colour can deceive, proximity can be coincidence — common motion almost never. This is why a perfectly camouflaged animal becomes visible as soon as it moves: **no camouflage protects against common fate.** Camouflage can break up outlines and disrupt similarity, but it cannot prevent all parts of an animal from moving together.

The strand is complete. Six modules now form a closed arc:

Module	What it shows
02 cave allegory	the question: what is stimulus, what is interpretation?
L1 illusions	**distortion** — interpreted unambiguously wrongly
L2/L3 contrast, opponent colours	the **mechanisms** — inhibition and adaptation
	alternation — the interpretation

L5 bistability	flips
L6 gestalt laws	the **rules** — and that they compete
L4 motion	**generation** — motion too is constructed

And the modules connect mechanistically, not merely thematically: L3 supplied adaptation, L4 shows it in motion, L5 shows it as the driver of alternation. L6 supplied the weighting, L4 adds the strongest factor. **The cave-allegory core is thereby not merely illustrated but computed through:** we do not see the stimulus but the best interpretation according to weighted principles — and where several are equally good, we alternate between them.

12. Next test

The perception strand is complete. Continuations lie in other strands: the **quantum cluster** (groundwork laid by M2 and M3) or the **philosophy-of-science modules W1/W2**, which would draw the arc from perception to measurement theory.

Possible extension v0.2: phi and beta separated; aperture problem; biological motion (Johansson point lights); motion parallax as a depth cue; induced motion; speed perception.

Appendix A — Cross-references

- Practice explanation: `PRAXIS-Motus-EN.md` · Companion paper: `BEGLEITPAPIER-Motus-EN.md`
- Tool: `MOTUS.html`
- Code: `motus_simulation.py` · Plot: `motus_szenen.svg` · Data: `motus_results.json`
- **Strand modules:** 02 cave allegory, L1 illusions, L2 brightness contrast, L3 opponent colours, L5 bistability, L6 gestalt laws
- **Related merge modules:** M1 signal chain, N1/N2 (temporal resolution compared)

Appendix B — External stocktaking

- **Wertheimer (1912)** — the phi phenomenon, founding paper of gestalt psychology.
- **Korte (1915)** — the laws of apparent motion.
- **Purkinje (1820), Adams (1834)** — the waterfall illusion.
- **Adelson & Bergen (1985)** — energy model of motion perception.
- **Mather, Pavan et al. (2008)** — review of the motion aftereffect.
- **Johansson (1973)** — biological motion from point lights.

What the workshop note adds: the bringing together of apparent motion, aftereffect and common fate into one falsification; the demonstration that common frame rates lie close to the psychophysical optimum; the quantitative comparison of gestalt factors identifying common fate as threefold stronger; the mechanistic connection to L3 and L5 via the same adaptation.

Appendix C — Sources

- Wertheimer, M. (1912). Experimentelle Studien über das Sehen von Bewegung. *Zeitschrift für Psychologie* 61:161–265.

- Korte, A. (1915). Kinematoskopische Untersuchungen. *Zeitschrift für Psychologie* 72:193–296.
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- Mather, G.; Pavan, A.; Campana, G.; Casco, C. (2008). The motion aftereffect reloaded. *Trends in Cognitive Sciences* 12:481–487.

Word count: ca. 1980 · Pages: 9 · Version 0.1 · 2026-05-17