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Connectome Topology Under Embodied Perturbations

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Biological topology retains a short-horizon completion advantage under tested sensor / actuator perturbations, including with attention.

RESEARCH QUESTION

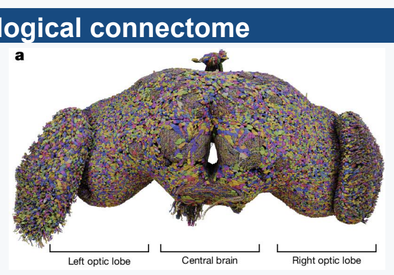
Does anatomical wiring retain an advantage when embodied control is perturbed?

- Anatomy supplies a structural prior.
- Robustness requires valid control.

The experiment: change topology, then perturb the body

1 BUILD POLICIES

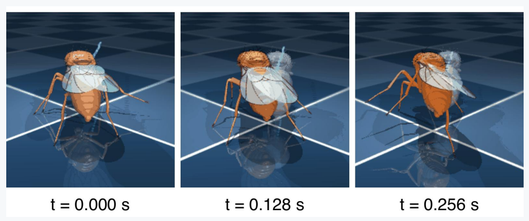
Biological connectome



Source anatomy [3], CC BY 4.0

5 rewired topology seeds

2 APPLY PERTURBATIONS



Sensor noise: α = 0 to .20
Actuator gain: g = 1.0 to .6
Ground friction: effect unverified

3 MEASURE

Completion
128 steps = 0.256 s

Progress
Reference-normalized displacement

Angle: orientation error

4 FUTURE BOUNDARY

Sustained control first

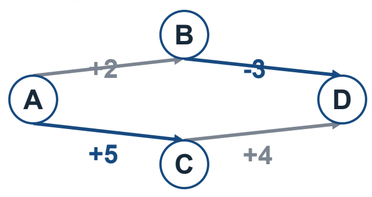
Current: short-horizon response profiles

Boundary not established

FlyGM-Lite IL • matched budget / interface • 100 / 15 / 15 split • epoch 5 / 500 updates • 1 biological graph, 5 graph seeds, 1 training seed, 15 shared references

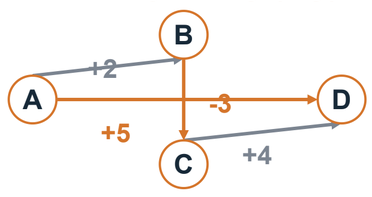
What rewiring changes — and what it preserves

Biological adjacency (toy)



shuffle targets

Rewired adjacency (toy)



PRESERVED

Nodes, directed in/out edge-row degrees, source-aligned signed weights

MODIFIED

Connection partners; incoming weighted strength

Gray: retained toy edges. Blue / orange: changed edges. Illustrative constraint example; exact historical repair selection is unavailable.

The completion gap persists across tested perturbation levels

BIOLOGICAL POLICY

14 / 15

93.3% • median progress .6643

REWIRED POLICIES

37 / 75

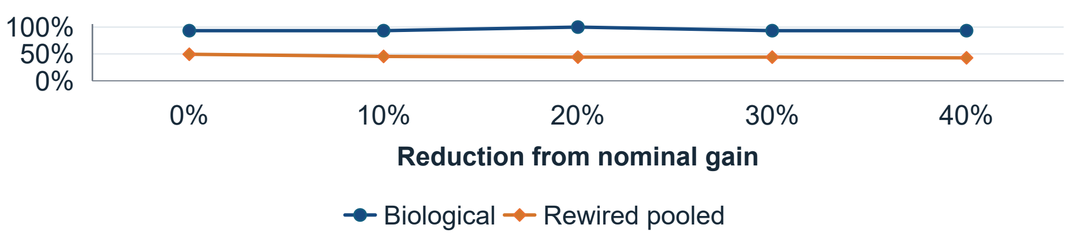
49.3% pooled • progress .1377–.2839

COMPLETION ≠ SUSTAINED WALKING

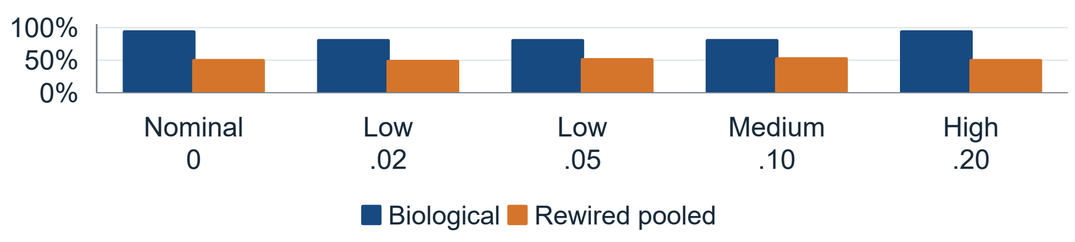
0.256 s

Canonical-zero 5/15 • train-mean 6/15

Actuator gain reduction



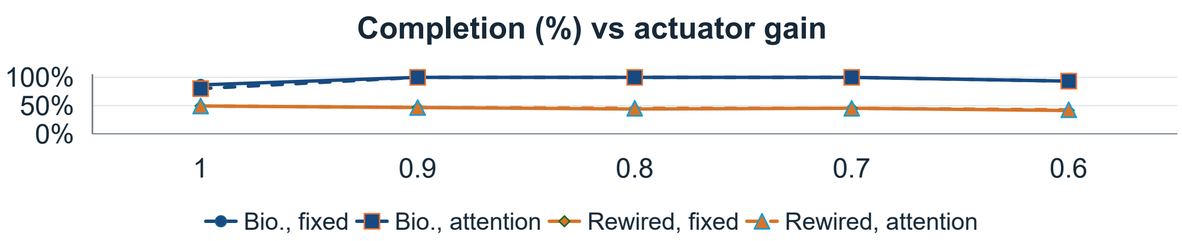
Sensor noise: all tested levels



128-step completion (%) • Original M1: 36-thread CPU, 1,350 repeated trials. Sensor draws change with severity. Progress is reference-normalized.

Attention changes aggregation, without consistently closing the gap

Completion (%) vs actuator gain



Same graph support, new neighbor weights

+64 parameters; edges, signs and incoming absolute weight mass stay fixed.

Policy-only CPU latency: 11.4 → 84.9 ms

Biological fixed → attention; shared-host load.
No 500 Hz real-time validation.

Attention batch: 900 paired trials, 4-thread CPU. Fixed nominal 13/15 vs original 14/15. New CPU vs historical GPU training limits attribution.

What we can conclude

1 Biological wiring completes more short rollouts at tested levels.
2 The gap persists with attention, without consistent attention gains.
3 Sustained control must precede a formal robustness boundary.

CONTACT

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KEY REFERENCES

[1] Jin et al., FlyGM (2026) [2] Vaxenburg et al., Flybody (2025)
[3] Dorkenwald et al., FlyWire (2024) [4] Velickovic et al., GAT (2018)

Original extension: 0/18 • Attention extension: 0/18 • Friction unverified • Shared references are not independent samples.