No-cloning constraints on quantum consciousness

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Inspiring Awe & Wonder

A common question at this conference:

Are there kinds of quantum systems or processes that **can** give rise to consciousness and cognition?

A question my colleagues* and I have asked:

Are there kinds of quantum systems or processes that **cannot** give rise to consciousness and cognition?

Our answer is yes—at least for two important cases:

Purely quantum systems cannot give rise to either **filled-in perception** or **deliberative agency**.

My question for today:

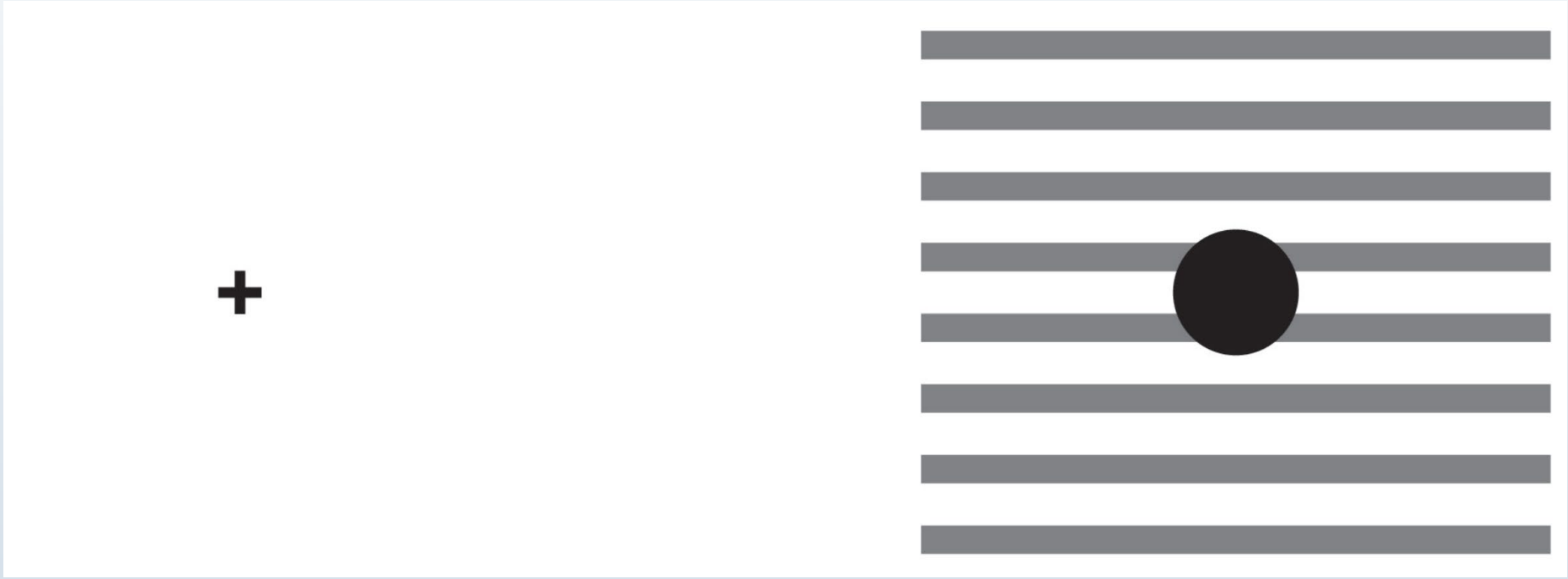
What challenge do the filling-in results pose for **Orch OR**?

*Adlam, E. C., McQueen, K. J., & Waegell, M. (2025). Agency cannot be a purely quantum phenomenon. *arXiv:2510.13247*.

Filled-in perception

A pervasive feature of human perception.

Perceptual content appears where there is no corresponding sensory input.



Find your blind spot: cover left eye and focus on + with right eye. Move forward until black dot vanishes. The void is *filled-in with the surround*: gray lines are perceived in place of the black dot.

Upshot: The surround content is *cloned* and then inserted into the blind spot. This raises serious problems for quantum accounts.

The no-cloning theorem

Intuitive idea: To copy a state, we determine what state it is and prepare another system in the same state. But in quantum mechanics, ***measurement typically disturbs the state being measured***.

Theorem

No unitary operation can perfectly copy an **arbitrary quantum state**.

Proof (from linearity). Assume a device that clones the computational basis:

$$|0\rangle |R\rangle \to |00\rangle , \qquad |1\rangle |R\rangle \to |11\rangle .$$

For a superposition $|\psi\rangle = \alpha |0\rangle + \beta |1\rangle$, linearity therefore gives

$$|\psi\rangle |R\rangle \to \alpha |00\rangle + \beta |11\rangle .$$

But perfect cloning would require

$$|\psi\rangle |\psi\rangle = \alpha^2 |00\rangle + \alpha\beta |01\rangle + \alpha\beta |10\rangle + \beta^2 |11\rangle .$$

So the device that copies the basis states does not copy a generic superposition.

Purely quantum systems

A physical system is purely quantum iff the information-bearing states it processes are:

i. **arbitrary:** not restricted to an orthogonal basis that the system can reliably distinguish and copy;

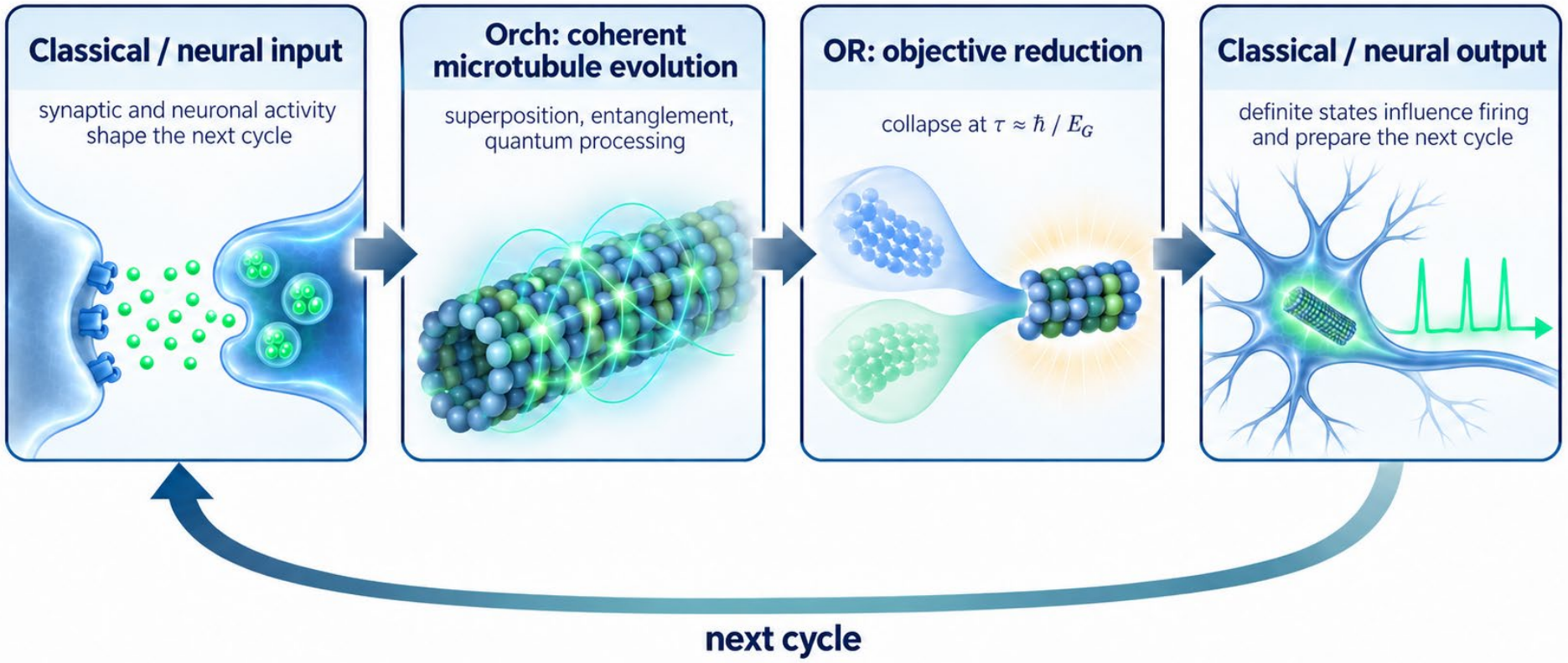
ii. **coherent:** processed only by unitary transformations.

How can a quantum system escape this regime?

Decoherence: selects an emergent preferred basis, typically coarse-grained position, which is copyable.

Collapse: selects a preferred collapse basis, often position or mass density, which is copyable.

Orch OR cycle



Key question:

Cloning is essential to filled-in perception.

So, in the Orch OR cycle, **where does cloning take place?**

Can the cloning happen during Orch?

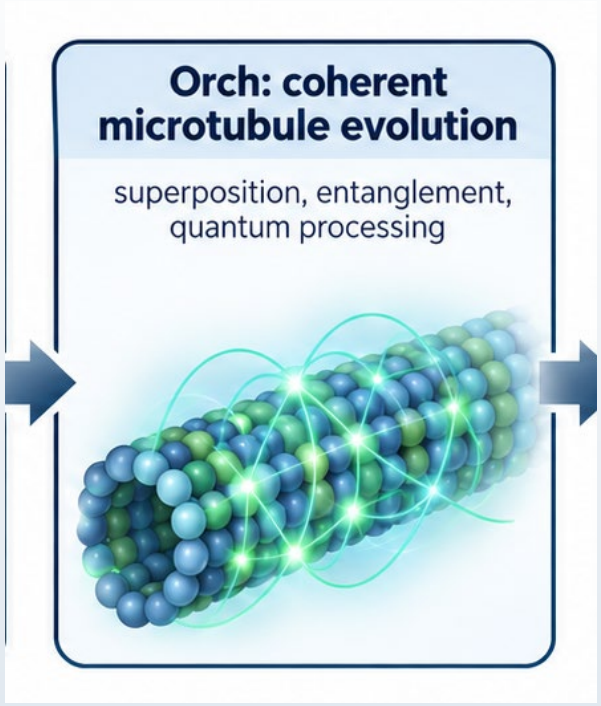
During Orch:

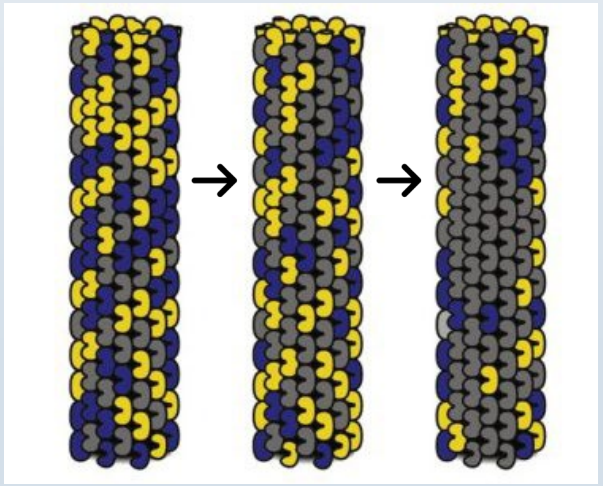
- **Coherence:** microtubule states evolve unitarily until OR.
- **Arbitrariness:** the information-bearing tubulin states include arbitrary superpositions.*

Dilemma: either Orch has access to independent information specifying which state/basis is present, or it does not.

If not: no-cloning blocks copying during Orch.
If so: what biological mechanism supplies and exploits this information?

Absent such a mechanism, cloning has to occur earlier, in the **classical** processing regime.

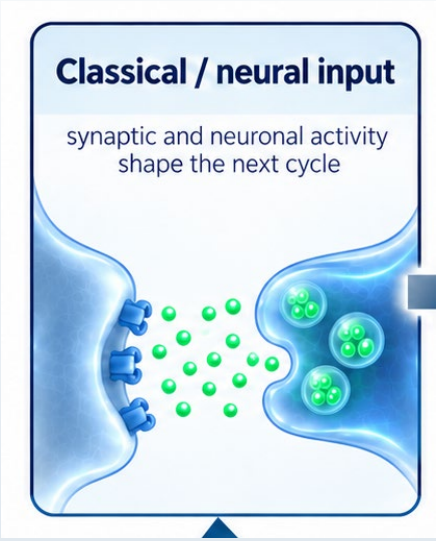




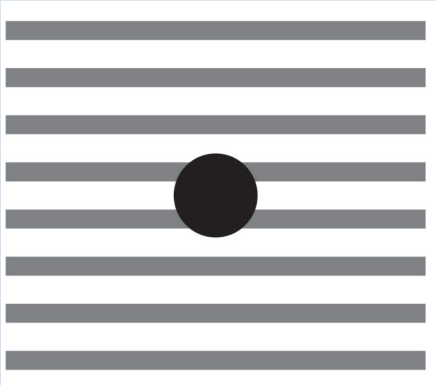
Yellow and blue: orthogonal tubulin states.
***Gray: superpositions of those states**
Hameroff and Penrose (2014)

Can the cloning happen prior to Orch?

Certainly, yes!
But this moves the copy-dependent processing into the ***classical*** regime.

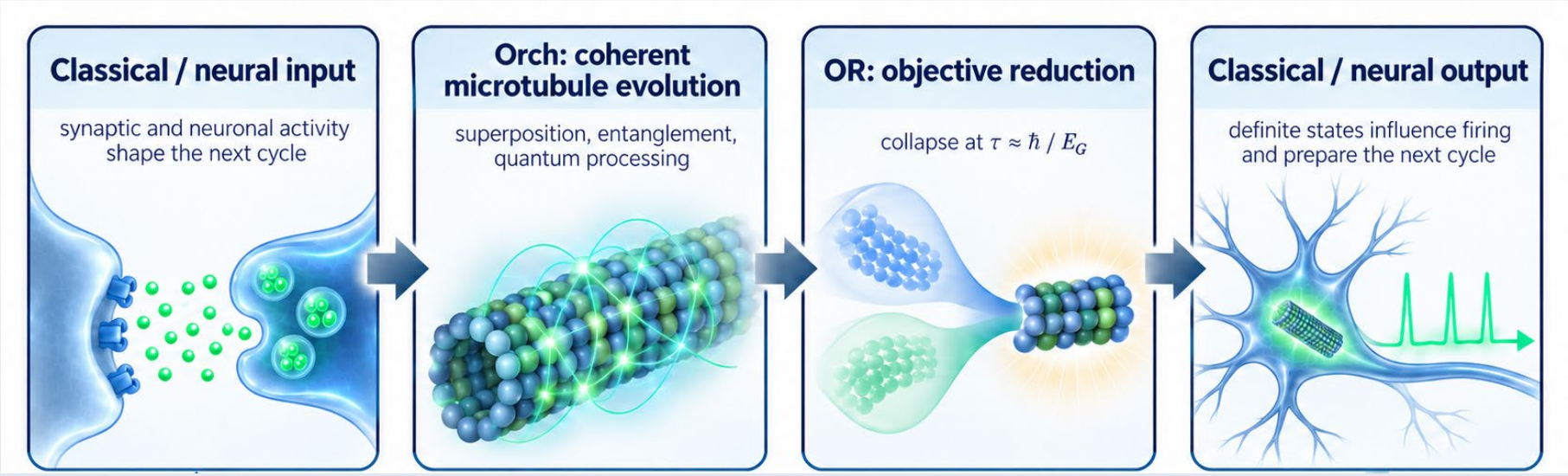


The resulting account of filled-in perception:
Classical neural processing copies the surround information, so the copy-dependent structure of the percept is determined *before* Orch.



Challenge:
What **indispensable explanatory work** is left for the microtubule quantum computations?

Two possible roles for Orch



1. Constructing perceptual contents

Quantum computations determine *what* we experience.

Problem: No-cloning appears to rule this out.

2. Providing phenomenal unity

Classical processing constructs the contents; entanglement during Orch helps *bind them* into a unified experience.

This second possibility is not ruled out by no-cloning.

A new challenge: how do perceptual contents *survive* the quantum computations in Orch?

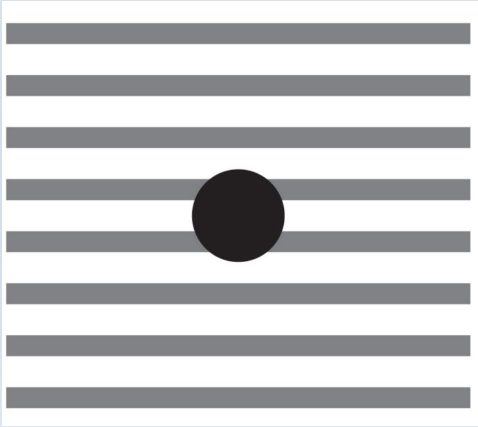
Suppose classical processing correctly determines that the blind spot should be filled with light gray.

$$|00\rangle.$$

What if the subsequent quantum evolution produces a superposition of light-gray and dark-gray contents?

$$|\Psi\rangle = \alpha|00\rangle + \beta|11\rangle.$$

OR could then collapse to the wrong shade!



Challenge: What ensures that the quantum evolution and subsequent collapse reliably preserve the correct perceptual contents?

Summary: a dilemma for Orch Or

Horn 1: Quantum processing during Orch constructs perceptual contents.
But no-cloning prevents the copying required for filling-in.

Horn 2: Classical processing constructs the contents; Orch supplies phenomenal unity.
But entanglement and OR can potentially alter those contents, producing incorrect percepts.

The challenge: How can purely quantum processes in Orch OR make an indispensable contribution to consciousness while reliably preserving the correct contents of experience?