Title: Between Order and Chaos: Exploring the Entropic Brain

Introduction

Ivan: Entropy is the physics of possibility - the measure of how structured or chaotic a system can be. But what happens when that concept is applied not to stars or molecules, but to the human mind?

In this episode, we are joined by Yicheng Su, co-president of Oxford University Cortex Club, to explore the Entropic Brain Hypothesis - a bold idea proposing that our conscious states arise from the brain's shifting balance between order and chaos. Drawing on research from Dr. Robin Carhart-Harris, the proponent of this framework, Yicheng explains how temporary increases in brain entropy can dissolve rigid patterns of thought and maybe even open new paths for healing. From the psychedelic state to everyday perception, we ask: when the brain's networks loosen their grip, what new realities emerge?

My name is Ivan, and *this* is CortexCast.

Interview

Ivan: Hello, Yicheng! Thank you for joining us today.

Yicheng: My pleasure to be here!

Ivan: So, could you tell us, how does entropy relate to brain function?

Yicheng: Great first question to kick things off. Most of us first encounter entropy in the context of the second law of thermodynamics - where systems drift from order to disorder over time, like how your room would go from neat to messy over time unless you actively try to tidy things up.

But when we talk about entropy in the brain, that picture needs some refinement. You have to think about it from an information theory perspective here.

Ivan: Right, so, there's a dual meaning here - it's not just chaos, but something closer to informational richness as well?

Yicheng: Exactly. So it measures two things at once. First, it measures uncertainty: how unpredictable the brain's next state is. And second, it measures its information content.

Think about a deck of cards sorted by suit and number from ace to king. It is highly ordered. If I tell you the first card is the Ace of Spades, you know the next is the Two of Spades – high predictability.

A high entropy setting is analogous to shuffling the deck. Now the order is random; if I see the first card, I have no idea what the next one is – high surprise and uncertainty.

Now, before we move on, it's worth saying a little about how we actually measure brain entropy in the first place. Most people think of brain imaging as just pictures, but for entropy we look at the time series - how the signal fluctuates moment to moment. For example, with functional magnetic resonance imaging, or fMRI, you're tracking slow waves of activity across the cortex. You can treat each region's signal like a sequence, almost like a heartbeat trace, and then ask: how predictable is this sequence? How compressible is it? Does it keep repeating, or does it keep surprising you?

That's what gives us the entropy score. So when we talk about brain entropy increasing, we don't mean noise or chaos - we mean the brain's activity is becoming richer, less stereotyped, and more flexible.

And that's the bridge. It's taking a hard physical number from brain scans and connecting it to subjective experience - to qualia. And the EBH states that consciousness is not in some perfectly stable ordered system. It puts it in a dynamic sweet spot between exploration and exploitation.

Ivan: So, it appears there is a critical zone of a sort that is most conducive to emergence of consciousness?

Yicheng: Precisely. Yeah. The idea is consciousness emerges when the brain is operating right at this edge, the edge of chaos. It's this balance point between total order, where things are just rigid, repetitive; and complete disorder, which is just random noise.

Normal waking consciousness sits inside this zone, often sort of towards the upper end, the more complex side. We kind of know what happens when things go downwards from that zone, like with sedation or anaesthesia: the brain's activity shifts down, becomes subcritical, low entropy, and consciousness fades or the content disappears. The system gets too ordered, too simple – predictable unconsciousness.

But the really counterintuitive finding, the one that EBH really brings out, is what happens when you push upwards. Classic psychedelics seem to reliably push brain entropy above the level of even normal waking consciousness. They shift the brain towards the super critical end of that zone which favours flexibility, adaptability, and emotional change.

Ivan: Hold on, so you say that this critical zone is the ideal spot for consciousness, if so then why would normal waking consciousness sit slightly below it? I mean, you'd think maximum flexibility would always be best, surely? Is that slight subcriticality actually useful for everyday life?

Yicheng: Yeah, that's a great point. The hypothesis is that Normal Waking Consciousness is slightly subcritical for a reason. It favours stability, efficiency, and basically sticking with what we already know that works - what psychologists call exploitation of known information. It helps us navigate a mostly predictable world without constantly re-evaluating everything.

It's like taking the familiar route to work - you stick to it because exploring every possible alternative route every day would be exhausting and pointless. Normal waking consciousness makes the same trade-off: it relies on known patterns because exploring all possibilities would be massively inefficient in a mostly predictable world.

Ivan: Yeah, makes sense.

Yicheng: Yeah. The psychedelic state on the other hand, is much more exploratory. It breaks those assumptions down. So finding this state where entropy is robustly higher than normal waking consciousness was really significant. It suggests we found a way the brain can actually expand the richness, the complexity of conscious experience beyond its usual baseline, which brings us now to the evidence - because when EBH first came out, it was more theoretical. But the sources we looked at confirmed there's been a flood of empirical support since 2014. Multiple independent studies are finding these entropy increases using different techniques and different drugs. Scientists have used some fairly complex math tools on brain imaging data. Things like Lempel-Ziv complexity.

Ivan: Right, we're getting quite technical now. Could you tell us more about this Lempel-Ziv complexity?

Yicheng: Sure. Think zip files on computers. Imagine you record the brain's activity like a long string of symbols and then ask a computer programme, "How much can I zip this down?"

If the brain is stuck in simple, repetitive patterns, you can shrink that file a lot – so the complexity score is low. If the brain is exploring lots of different patterns and is very unpredictable, the file barely compresses – high complexity.

So Lempel–Ziv lets us measure how surprising and varied the brain's activity is in a really concrete way. And multiple studies using this on MEG data or fMRI data, consistently show higher scores, higher entropy in the psychedelic state, LSD, psilocybin, ketamine, even DMT infusions. And the really compelling bit isn't just that the number goes up, but that how much it goes up matters. The degree of entropy increase strongly correlates with how people describe their subjective experience.

Ivan: So it's the magnitude of the increase in entropy that correlates with the intensity of psychedelic experience?

Yicheng: Yeah, exactly. If the entropy measure shoots way up, subjects tend to report a much more profound, complex, maybe overwhelming experience. It really strengthens that link between the objective measure and the subjective report.

Ivan: I see. And so, as far as I understand, beyond entropy itself, there is also this idea of enhanced criticality. What is that all about?

Yicheng: Right. Criticality, as we said, is that sweet spot between order and disorder. Functionally, being near critical is thought to maximize how well the brain processes information, its capacity, its efficiency.

And recent fMRI work, specifically with LSD, found that psychedelics don't just increase entropy, they tune the brain closer to that critical point, even pushing it slightly beyond critical into supercritical territory.

Ivan: So if being slightly subcritical in everyday life confers stability and lets us exploit what we already know, then what does moving toward supercriticality actually do? Does the brain just become chaotic?

Yicheng: It seems to lead to what you might call structured flexibility. And it's not just random noise. The supercritical state favours exploration. It makes the system maximally sensitive to changes. In a more ordered state, it's like a ball resting in a deeper bowl – you have to push it quite a bit to move it. In the supercritical state, it's like moving that ball onto a steeper slope – now the slightest push can send it rolling down many possible paths.

Normal waking consciousness is tuned for reliable performance. The super critical state is tuned for maximum responsiveness to any input. Highly sensitive, highly flexible.

Ivan: And so does this heightened sensitivity – maximal responsiveness – explain why the mindset and environment are both so crucial in psychedelic experiences?

Yicheng: Absolutely. Your mindset, expectations, emotional state, and the environment, the music, whom you are with, will drastically shape the experience's quality and outcome.

The source material even mentions studies where music that fits the patients emotional journey enhances therapy while jarring music hinders it because the brain's just soaking it all up in that state.

Ivan: And I suppose in many ways this reinforces the original meaning of the word psychedelic.

Yicheng: It really does. Humphry Osmond coined the term from the Greek word *psyche*, meaning mind or soul, and *deloun*, meaning to reveal or make manifest.

The idea wasn't just about altered perception, but about revealing something deeper, facilitating emotional insight, helping people gain new perspectives on themselves, their assumptions, and their behaviours.

Ivan: Right, now if the experience itself is this high-entropy cascade of thoughts and sensations, how does that turn into something useful afterwards? Surely it's more than just chaos?

Yicheng: Yeah, that's a crucial question. The EBH suggests it's probably a two-step dynamic process. First, you have that high entropy state, the exploration, the flexibility where old patterns and assumptions get relaxed, shaken up.

But that needs to be followed by a second phase - integration. And this integration phase is thought to involve a return towards baseline, maybe even a temporary dip below normal entropy levels as the brain works to make sense of the experience. It's like the crystallisation of that initial chaotic download into something coherent and insightful you can actually use.

Ivan: So the high-entropy phase is like brainstorming I suppose, generating ideas, breaking moulds, and the low-entropy phase is the editing, the consolidation.

Yicheng: Exactly. You need the disruption to create the opening, but you need the consolidation to make it stick. It reminds me of that Alan Alda quote:

"Your assumptions are your window on the world. Scrub them off every once in a while, or the light won't come in."

The psychedelic state might be like that scrubbing brush, relaxing the grime of fixed assumptions.

Ivan: Interesting. So, thinking about this from a clinical perspective now, if this supercritical flexibility is the mechanism, what does that mean for treating conditions that are… well, rigid?

Yicheng: It has direct implications. Many psychiatric conditions, especially things like chronic depression, OCD, addiction - they often involve very rigid, repetitive pathological thought patterns. Rumination is a classic example in depression. This kind of cognitive rigidity might reflect a brain state in subcriticality - too much order, not enough flexibility. So, the temporary shift towards supercriticality induced by a psychedelic could in theory loosen those rigid patterns, relax those entrenched assumptions, and allow for therapeutic change. It fits well with the promising results we're seeing in trials.

Ivan: Okay. So that’s for conditions with excessive order - low entropy. But the Entropic Brain Hypothesis also points towards the opposite problem, right? Disorders of consciousness or DoCs.

Yicheng: Yes. And this is a really novel implication. If brain entropy is a reliable marker of conscious level and we know it's significantly reduced in patients with vegetative state or minimally conscious state, then the EBH naturally leads to a compelling question and testable hypothesis. If psychedelics reliably increase brain entropy, could they potentially be used to elevate conscious content even slightly in these patients?

Ivan: And these complexity measures are already being used diagnostically for DoCs, aren't they?

Yicheng: They are. Measures like the Perturbational Complexity Index, or PCI, are proving quite valuable. They help differentiate patients who have some level of consciousness from those who are truly unresponsive.

Ivan: How does that PCI work exactly? It sounds a bit more involved than just recording brain waves.

Yicheng: It is more involved, yeah. PCI measures the brain's capacity for complex interactions via actively probing. Researchers use transcranial magnetic stimulation, or TMS, to deliver a brief magnetic pulse to a specific part of the cortex.

Then they use high-density EEG to map out how that pulse propagates, how the electrical activity echoes through the brain network. In a fully conscious brain, that pulse triggers a complex, widespread, long-lasting chain reaction - high complexity, high PCI score.

In unconscious states like deep sleep or Disorders of Consciousness, the response is much simpler, localised, and fades quickly - low PCI score.

Ivan: So EBH suggests psychedelics might artificially boost that complexity response, boost the PCI score, and potentially improve the patient's conscious state?

Yicheng: Precisely. It's hypothetical at this stage, but the logic is sound. The logical first steps would be, say, testing if psychedelics can raise entropy and conscious markers from a deeply sedated state in healthy volunteers or perhaps seeing if they could induce a shift from low entropy, non-REM sleep into the more complex high entropy REM sleep state. These are initial avenues to explore.

Ivan: All right, we've talked a lot about this shift in entropy being key for flexibility for clinical potential. But what's actually driving it at the neurochemical level? What's the trigger?

Yicheng: It appears serotonin is central, specifically its action at the 5-HT_2A receptor. That's the main target for classic psychedelics like LSD and psilocybin. And there's some really fascinating recent research suggesting what serotonin systems particularly, from the dorsal raphe nucleus, are actually encoding.

It seems serotonin might not be about simple reward or punishment. Instead, it might be encoding value neutral surprise, unexpected outcomes, things that violate predictions.

Ivan: Surprise! Unexpectedness. That sounds a lot like uncertainty and entropy, right?

Yicheng: Yeah, exactly. They're formally linked. In information theory, average surprise mathematically is equivalent to uncertainty, which is equivalent to entropy. So, the proposed mechanism is that activating these serotonin 2A receptors effectively signals a high degree of environmental uncertainty or unpredictability. This signalling is thought to act like a kind of system reset, relaxing the hold of prior beliefs or assumptions. It essentially flattens the brain's energy landscape.

Ivan: What do you mean by that?

Yicheng: Well, think of the normal brain state having deep valleys representing strong habits or beliefs, paths of least resistance for thought. Flattening the landscape means making those valleys shallower. It makes it easier for the system to escape those engrained patterns and explore new configurations, new ways of thinking. It's often compared to annealing in metal moulding.

Ivan: Annealing - how so?

Yicheng: Annealing is when you heat a metal up really hot, which allows its atoms to rearrange and then cool it slowly. This process removes internal stresses and makes the metal softer, less brittle, more workable. The idea is that serotonin 2A signalling does something similar for cognition. It heats up the system, allows rigid cognitive structures, those prior assumptions to loosen up, making the mind more adaptable, ready for new learning. Especially useful when the world feels unpredictable around you.

Ivan: So, it's like the brain's built-in mechanism for hitting reset when faced with too much surprise, allowing it to adapt. That fits perfectly with the need for flexibility we discussed, right?

Yicheng: Exactly. A potential mechanism for enabling exploration and breaking free from those fixed mental states.

Ivan: Okay, earlier you also hinted at limits. If high entropy equals rich consciousness, what happens if you push it too far, go right off the top end of that critical zone?

Yicheng: Yeah, that's the big remaining question, and the researchers themselves point this out. The EBH probably only holds true within certain boundaries. If high entropy equals maximal richness, the really provocative thought is, is there a point where the brain becomes too disordered, too critical, so complex that it can't actually integrate information into a coherent self or experience anymore?

Could extreme entropy lead to a breakdown, a fragmentation, maybe even a complete loss of awareness, albeit perhaps rarely reported? Exploring those upper limits where complexity might tip into incoherence, that's still a frontier. What's the absolute key complexity the brain can sustain before the conscious self just dissolves? I think that it’s likely constrained by the physical hardware - the wiring, biochemistry, and biophysical properties of the brain.

In other words, the zone where consciousness can exist might differ across species, or even from person to person, because the underlying architecture sets how much entropy the system can tolerate before breaking down.

That's not something the paper directly discusses, but it follows naturally from its logic: the software of mind can only stretch as far as the hardware allows. It's a good hypothesis to throw out there for listeners — to think about whether the limits of your conscious experience are, in some sense, written into the material fabric of your brain.

Ivan: Yicheng, this has been a truly invigorating discussion, quite abstract at times, but definitely exciting. Thank you very much indeed for sharing your thoughts and expertise!

Yicheng: Thank you, Ivan. See you next time!

Conclusion

Ivan: So that concludes our exploration of the Entropic Brain Hypothesis. We've moved from physics to psychedelics, from information theory to the fragile architecture of consciousness. Whether or not entropy turns out to be the key that unlocks these mysteries, it offers a powerful way of thinking about how the brain balances order and possibility. It's a reminder that the mind is not static, but dynamic - always shifting, exploring, reorganising. Thank you for being with us. To keep up to date with all the recent breakthroughs in neuroscience, make sure to tune in to CortexCast.

Take care, all the best, cheerio.