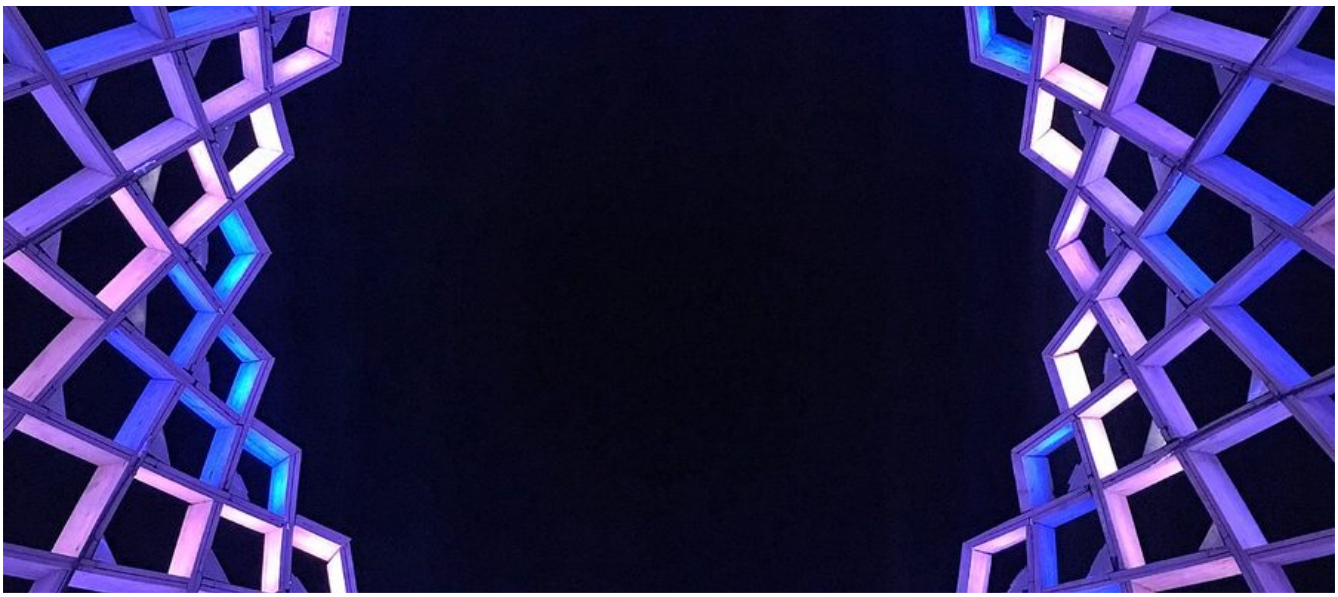
MIND FOUNDATION

Entropy as more than chaos in the brain

DATE PUBLISHED

10 June 2018



The Entropic Brain Hypothesis, put forward by Robin Carhart-Harris et al. in 2014, is a model of consciousness based on recent brain imaging research with psilocybin. Psilocybin is the main psychoactive ingredient in non-muscarinic hallucinogenic mushrooms. This chemical is well known for inducing changes in the very nature of consciousness, and according to Carhart-Harris, this is due to a fundamental, temporary change in the function of the brain itself — from what he refers to as “secondary” (the conscious agent that reasons, plans, and structures things) to “primary” (the ancient, chaotic consciousness that is analogous to dream states) consciousness1. According to Carhart-Harris, just as matter becomes less or more ordered as it changes states, so do mind states undergo changes based on the brain’s overall structure, with both ends of the entropic spectrum being unstable in the long term — like a popping or deflating balloon.

What Is Entropy

Entropy is a word generally associated with physics, specifically the second law of thermodynamics, which states that in a closed system (in which no matter or energy leaves) structures will gradually become more disorganized until equilibrium is reached. For our purposes, we can say that entropy is essentially a measure of structure: if the Great Pyramid of Giza represents a state of low entropy, then a pile of rocks would be an example of high entropy. Stacking those rocks into a pyramid would decrease the entropy of the rocks, but in the greater system of the world, entropy would increase because of energy expended as heat in the process of stacking. This is why entropy often has a negative connotation: according to the laws of physics, everything will eventually become undone, and chaos will “win”. This is a bummer — but it’s not the whole story.

The Entropic Brain Model

The entropic brain hypothesis is a model of brain function that posits a relationship between total entropy in the brain and long-term psychological states, particularly pathological conditions such as schizophrenia and obsessive-compulsive disorder (OCD). The human brain, at baseline, tends to operate just below a state of criticality. Criticality is a state of complex behavior in a system between pure order and pure random states2. In other words, our minds are ordered just enough to do the things we regularly need to (in everyday life, this usually manifests as our habits) while being flexible enough to reality test. That is to say, they maintain responsiveness to new, novel situations via feedback from the external world.

Small fluctuations in brain entropy are natural, but according to Carhart-Harris' model, many conscious states can be classified as either "low entropy" or "high entropy". Results from fMRI neuroimaging suggest that psilocybin increases overall connections in high-level association cortices, thereby disorganizing brain activity. Many states that affect the medial temporal cortex in a similar manner — from REM sleep to acute psychosis — likely achieve their subjective characteristics in the same way. Likewise, one could argue that states exhibiting lower cortical connection would be associated with more rigid thoughts and behavior, something that we can see in conditions like clinical depression, addiction, and OCD.

The Repercussions

These conditions are characterized by repetitive, conditioned behavior that the sufferer feels powerless to change. Whether this behavior is regular rumination on the hopelessness of existence, abusing drugs, or compulsive hand washing, it is conditioned, inflexible, and rigid. It is no wonder, then, that a temporary and extreme increase in brain entropy might be helpful for people suffering from these conditions, allowing them to form new associations.

This is consistent with recent research suggesting that psychedelics are effective at treating these conditions3,4. They also tend to have a profound impact on the personality trait of "openness", though dramatic personality change is normally rare in adults5. Caffeine has also been found to increase entropy in the brain to a lesser degree6**,** perhaps hinting at reasons why some might seek out coffee for forming new habits or brainstorming. In contrast, drugs that tend to lower brain entropy, such as alcohol and nicotine7, have a much higher incidence of abuse in people suffering from schizophrenia8, a disorder that shares many features with high-entropy states and primary consciousness.

Can we use brain entropy as a marker to determine the likelihood of developing certain syndromes or behavior patterns, and adjust the subject's criticality accordingly? What about non-pharmacological methods of entering altered states, such as meditation or kundalini yoga, both of which anecdotally trigger psychedelic states? How might people harness these techniques for therapeutic purposes? The science is still out!

Entropy in The Brain

But how does all this happen? Neuroscientists have isolated two main networks in the brain: the task-positive network (TPN), associated (as the name suggests) with activity and action, and the default mode network (DMN), associated with resting states and maintaining a coherent ego, or sense of "self", while not engaged in active tasks. These networks are comprised of many different areas of the brain, but are inversely coupled: the more one is active, the less the activity in the other.

The medial temporal cortex, which contributes to the function of the DMN, seems to be crucial for maintaining the sense of self and the continuity that these networks usually impart. When its function is disturbed, which seems to happen under the influence of most classical psychedelics, the networks decouple, causing

disruptions in subjective interpretations of external and internal phenomena. This seems likely to be the mechanism behind what is commonly known as “ego death” or “ego dissolution”— the feeling of “oneness with the universe” or “loss of self” that many people report experiencing under the influence of psychedelics and some other psychoactive drugs9,10.

Figure 1, “Spectrum of Cognitive States”. Carhart-Harris, 2014.

Conclusion

> “Entropy is the price of structure” – Ilya Prigogine

If the amount of flexibility and connectivity in the brain are indeed associated with the ability to make or break new habits, then we clearly have a framework for why psychoactive substances tend to affect human psychology in predictable ways. Entropy is more than just “disorder” or “chaos”. While these are useful metaphors that capture some of the aspects of entropy (such as the breakdown of structures and rigidity), they have negative, normative connotations that take away what entropy generally means in mathematics and physics: an increase in possibilities. Matter changing from a solid to a gas represents an increase in entropy because as the particles expand, they can be found in more possible positions.

Do people feel the need to self-medicate with substances, such as alcohol and cigarettes in the case of schizophrenia or hallucinogens in the case of depression and addiction, in order to unconsciously enable changes within their own brain entropy? Can we replicate the entropy-inducing qualities of psychedelic drugs and reap their benefits with non-pharmacological, non-invasive methods? Could we even do the opposite, and treat schizophrenia by reducing entropy? At the very least, within this model we gain an understanding of how adjusting maladaptive states in the opposite direction might be therapeutic, and how the brain can and does change.

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