MIND FOUNDATION

The Rebus model

DATE PUBLISHED

1 February 2020



> *"Maybe psilocybin will work at least as well, that's my prediction," Carhart-Harris says. "but imagine that psilocybin is more effective? That's really quite…" he trails off. "that would be something." –Carhart-Harrison a comparative study of psilocybin and an anti-depressant.*

Our understanding of the brain's neurobiology has evolved rapidly since the development of imaging techniques such as PET, MEG, and perhaps most notably (f)MRI. Based on the findings and ideas that these techniques have generated, the conception of the brain as an interpretation machine has gradually shifted to a view in which it is seen more as a prediction machine. The theoretical framework for this is called predictive coding.1 Predictive coding is one leading paradigm by which the brain is currently understood and studied, as it is able to explain many perceptual curiosities3 and aspects of experience and behavior.

Another hot topic within neurobiology, especially in relation to psychotherapy and psychiatry, is the second wave of psychedelic research — a.k.a. the Psychedelic Renaissance.4 With a growing scientific basis and FDA 'breakthrough therapy' status already designated to specific treatment models in the United States, it may be only a matter of time before psychedelic therapy is incorporated into the psychotherapists' toolkit. Until recently, however, no one ventured to integrate predictive coding with the impressive results obtained by psychedelic research. We lacked an overarching theoretical model explaining the effects of psychedelic therapy on the brain beyond the level of structures and receptors — until now.

REBUS & the anarchic brain

Robin Carhart-Harris and Karl Friston, two leading neuroscientists from England, have attempted to formulate such an overarching model, integrating their own theories of the entropic brain5 and the free-energy principle6 within the framework of predictive coding.1 They name this model: *RE*laxed *B*eliefs *U*nder p*S*ychedelics and the anarchic brain, or REBUS for short.7 This blog post will start by outlining the main theoretical

underpinnings of this model, then connect these concepts in order to give a description of the REBUS model that enables us to formulate some critical views and thoughts.

The building blocks

Hierarchical predictive coding

I stated in the introduction that our view of the brain is shifting, namely from interpretation to prediction "machines". Scientists often use machine analogies – particularly computer analogies – to visualize function when they talk about different parts of the body. Brains are clearly not "machines", particularly not trivial ones. But even for something as complex as the brain, the analogy makes heuristic sense: Neurons, simply put, are either 'on' or 'off'. Machines are usually based on mathematics, so how does one translate the biology of the brain into such abstract language? In other words, what does it mean to "methodically" see the brain as a prediction machine?

The more we learn about the brain, the more we realize that our perceived reality is constructed from estimation and error, based on input.3 Predictive coding is exactly that: As we get older, we become more familiar with the way the world works, and we gain more relative certainty that specific events have specific results which are consistent over time. After years of 'data-gathering' and model formation, our brain constantly generates explanatory models about expected input, predicting the causes and origins of our surroundings and experiences and testing this against actual input. The higher-order models are what we may call our "worldviews" or "beliefs", and they are updated in a Bayesian8 manner depending on the measure of our surprise when something unexpected occurs.

In mathematical models of brain activity, surprise is conceptualized as prediction error, i.e. the difference between what the brain predicted would happen and the incoming sensory information. The hierarchical aspect is that this prediction process is happening at multiple 'levels' of brain organization simultaneously. During model formation and testing at the different cortical levels, the higher level (or top-down9) beliefs or predictions can influence our bottom-up9 perceptions by explaining away or rationalizing part of the experienced surprise (a.k.a. prediction error).

It is important to note that existing models have a certain 'weight', which could be rephrased as its strength or certainty. The larger the weight of the belief, the more likely it will be able to explain away any surprise. As an example, most people are familiar with the 'chair-with-clothes' effect: in your dark bedroom, for a split second, your chair may look like a person standing in the room. After a moment, this perception instantly reverts back to just a chair with clothing on it. This instant flip is hierarchical predictive coding at work: Your higher-order cortex is telling your perceptual system that it must be wrong. The incoming prediction error is explained away, updating your perception with existing knowledge of what is really in your room.

The free-energy principle

Friston expanded the theory of predictive coding by hypothesizing that organisms try to reduce the amount of uncertainty or surprise, herein called free-energy, that they experience throughout life.6 Since a biological organism can change the input it receives through acting on its environment, it is possible to avoid states in which it would experience such uncertainty or surprise. Said uncertainty would force the organism to change its models about the world, and it prefers to avoid this because updating models is an energetically costly and uncomfortable undertaking. When applied to humans, a person can limit her- or himself to an environment which is most congruent with the beliefs he or she holds about the world, thus avoiding large surprises (or,

to relate back to predictive coding, prediction-error). Note that this limiting can be external, but also internal, e.g. changing the narrative.

The entropic brain hypothesis

Carhart-Harris, based on data from his research with psilocybin, proposed a theory of how different states of consciousness relate to each other. His idea was that the experienced quality of subjective experience — or information richness — is directly related to the measure of entropy in the brain5. Put simply, entropy means the measure of random activity or disorder. Applied to the brain, one ought to mention that it shows both synchronous activity but also random or asynchronous activity. Following this basic notion of synchrony and asynchrony, the measure of brain entropy is the degree to which the brain's activity is unpredictable, i.e. how much random or spontaneous activity it has.

In short, Carhart-Harris's entropic brain hypothesis states that rigid states of consciousness such as depression and obsessive-compulsive disorder, which are partially defined by rigid thought loops and rumination, are on the low end of the spectrum of brain entropy. Vibrant states of consciousness, such as early psychosis and the psychedelic state, are on the high end of the spectrum. As an example, in order to be able to think of a strategy for dealing with a new problem, one requires some creative thinking and the ability to think outside of one's normal frame of reference. If the brain completely lacked entropy, it would be hard to have an original thought beyond what already existed to solve the new problem. However, on the other end of the spectrum, a maximally entropic brain would have no cohesion of thought, making it impossible to constructively act on all the creative and bizarre ideas floating through the mind.

Carhart-Harris's hypothesis is that the adult human brain normally pushes down its measure of entropy, away from a point known as criticality,11 into sub-criticality. Criticality can be seen as the 'perfect balance' between order and disorder in the brain at which information processing is maximally efficient – exactly the point between the two examples given above. Using data obtained from participants in psilocybin trials, Carhart-Harris demonstrates that psychedelics have the potential to push the brain from sub-criticality into a state closer to actual criticality.5,11,12

Recap

To summarize, hierarchical predictive coding explains how higher-order beliefs can, depending on their 'weight', modulate or constrain the interpretation of sensory data. Moreover, according to the free-energy principle, organisms aim to minimize their subjective uncertainty, acting on their environment to further minimize their free-energy (a.k.a. exposure to uncertainty) during their lifetime. Lastly, Carhart-Harris's entropic brain hypothesis states that neuronal entropy is directly related to the 'richness' of subjective experience, and that psychedelics increase entropy, pushing the brain closer to criticality.

Building with blocks

So, how does this all fit together? Carhart-Harris and Friston propose that a key neural mechanism to which psychedelic therapy owes its therapeutic effect is a weakening of higher-order beliefs.4 By increasing entropy and thereby stimulating creative thought, entrenched patterns of thought become weakened, and the brain is able to communicate more freely within itself, letting more information 'flow upstream'. Therein, the free-energy principle temporarily breaks down; people are released from their energy-efficient world-view. Through this, one's world-view can be reweighted to find a new optimum from which to operate instead of being limited to an overly rigid predictive model.

Imagine that a person experiences a violent traumatic event during their youth. The shock is so profound that the belief '*people are inherently good*' is destroyed. Thereafter, the new belief that '*people usually have bad intentions*' becomes a guiding principle. Years pass and this belief strengthens more and more because any contrary evidence is explained away; another large shift in worldview would be too demanding. Often enough, the belief is also confirmed. At 45, the person notices that it is hard to get close to people and build relationships, since mistrust in other has become so entrenched that it blocks the way. Upon realizing this the person tries to work on it, but since it is rooted in a childhood event and years of 'practice', this proves difficult.

This example illustrated several aforementioned concepts. The hierarchical predictive coding model describes the sudden updating of beliefs after the traumatic event. For years after, the free-energy principle is at work, taking away uncertainty about who is 'good' and who is 'bad' to employ a (short-term) energy efficient strategy, namely categorizing everyone as bad. Over time — back to predictive coding — this belief becomes stronger and even starts to explain away positive things that people do. Now what?

Now, psychedelic therapy comes into play. By its proposed action on higher order belief systems and general rigidity of mind, our person is able to 'take a step back' and observe this belief and its underpinnings from a distanced perspective; from an altered state of consciousness. In its weakened state, the belief is able to be updated or, better said, 're-weighted'. It is as if the fingers of an overprotective parent are pried loose because their fears have been assuaged. The belief has been relaxed under psychedelics, granting the opportunity for other beliefs to be considered and other perceptual information to enter consciousness without the strict compression and control of the debilitating belief.

Patient reports can provide nice real-world examples. After treatment with psilocybin during one of Carhart-Harris's own studies, one person said:12

> *"I felt so much lighter, like something had been released, it was an emotional purging, the weight and anxiety and depression had been lifted."*

Note the description of the 'release', and coincidentally the 'weight'. When seen in light of REBUS, this corresponds quite well to the weakened weighting of a limiting belief.

A critical review

Intuitively, the model certainly seems compelling. However, it is still young and it will remain to be seen if it stands the test of empirical science. I intentionally use the term 'intuitively', since the model itself entails quite a bit more neurobiological argumentation, whilst the links between the biological constructs and the mind are in some degree speculative. The arguments have a slight tendency to rest upon how they 'would make sense' instead of concrete scientific evidence. Moreover, since REBUS is set up as a global and unified model for brain function and mental states, the claim that it explain all changes and phenomena which occur in personality and psychiatry is quite bold – and overly general. This is something to be appreciated, though, as the model is the first of its kind and meant to serve a specific scientific purpose which invites attempts at falsification.

The model recognizes the fact that the link between large scale cognitive/heuristic changes (e.g. personality changes, changes in political views) must have some biological underpinnings, but that these have not been elucidated so far. This fact in itself perhaps shows that the model is a starting point and not yet an exhaustive model for what exactly happens in the brain related to the mind, both from an experiential and simultaneously from a neurobiological perspective.

It remains to be seen what merits the model will have for guiding research and practice. It is certainly exciting to see leading neurobiological theories being used to explain possible mechanisms of psychedelic therapy. An ever increasing amount of scientific evidence suggests that psychedelics may be effective instruments which, if properly applied in a controlled therapeutic setting, can help treat numerous psychopathologies and facilitate personal development. A unifying model that can structure and inform the avenues of scientific inquiry is therefore a valuable asset in the current academic climate.

With REBUS being the first of such unifying models, and having only been out a few months, the reaction of other leading neurobiological research centers is something to look forward to. How will a theoretical model support or advance psychotherapists who have to work with individuals suffering from very distinct (and not just general) problems? Is there value in this model for understanding oneself, or for self-knowledge? If we apply this framework to broader society, what are the implications?

References

1. Huang, Y., & Rao, R.P.N. (2011). Predictive Coding. Wiley Interdisciplinary Reviews: Cognitive Science 2, 580-593.

2. Briggs, S. (2018). How Predictive Coding Is Changing Our Understanding of the Brain. MIND Foundation Blog.

3.Hohwy, J., Roepstorff, A., Friston, K. (2008). Predictive Coding Explains Binocular Rivalry: An Epistemological Review. Cognition 108, 687-701.

4. Pollan, M. (2018). How to Change Your Mind. The New Science of Psychedelics. Penguin Press.

5. Carhart-Harris, R.L, Leech, R., Hellyer, P.J., Shanahan, M., Feilding, A., Tagliazucchi, E., Chialvo, D.R., Nutt, D. (2014). The Entropic Brain: A Theory of Conscious States Informed by Neuroimaging Research with Psychedelic Drugs. Frontiers in Human Neuroscience 8.

6. Friston, K. (2010). The Free-Energy Principle: A Unified Brain Theory? Nature Reviews Neuroscience 11, 127–138.

7. Carhart-Harris, R.L. & Friston, K.J. (2019). REBUS and the Anarchic Brain: Towards a Unified Model of the Brain Action of Psychedelics. Pharmacological Reviews 71, 316-344.

8. Spiegelhalter, D. & Rice, K. (2009). Bayesian Statistics. Retrieved from: http://www.scholarpedia.org/article/Bayesian_statistics.

9. OpenPsyc. (2015). Bottom-up vs. Top-down Processing. Retrieved from: http://openpsyc.blogspot.com/2014/06/bottom-up-vs-top-down-processing.html?m=0.

10. Osborne, S. (2018). Entropy as More than Chaos in the Brain: Expanding Field, Expanding Minds. MIND Foundation Blog.

11. Tagliazucchi, E., Carhart-Harris, R., Leech, R., Nutt, D., Chialvo, D.R. (2014). Enhanced Repertoire of Brain Dynamical States During the Psychedelic Experience. Human Brain Mapping 35, 5442-5456.

12. Roseman, L., Demetriou, L., Wall, M.B., Nutt, D.J., Carhart-Harris, R.L. (2018). Increased Amygdala Responses to Emotional Faces After Psilocybin for Treatment-Resistant Depression. Neuropharmacology 142, 263-269.