Qeios

Peer Review

# Review of: "Integrating Biological Principles into Observational Entropy"

**Joseph Schindler**[1]

1. Universitat Autònoma de Barcelona, Barcelona, Spain

In this paper, the author discusses several ways in which entropy, insofar as it is observer-dependent, could more directly include information about the biological and epistemological state of observers. The aim of the article seems to be mainly philosophical/suggestive, and in this light, I think the article raises some interesting points that can stimulate further discussion. On the other hand, I think that the paper could benefit from more technical development, such as examples, as well as from being more precise.

Due to the discursive or philosophical nature of the article, as a physicist, I find it somewhat hard to judge its merits. However, I can nonetheless comment on certain aspects.

In relation to the author's discussion around the section: "For example, if I receive a message from a source written in a foreign language using a non-Greco-Roman alphabet....", the author may find it useful to consider the following.

The information in a message depends on the decoding mechanism!

This is an often overlooked (but extremely important) part of Shannon's information theory. The most beautiful introduction to it is Shannon's own paper "Prediction and Entropy of Written English" (DOI:10.1002/j.1538-7305.1951.tb01366.x).

Given a book, how much information is in it? Well, obviously, the information (entropy) comes from H=-sum p_i log p_i. But what distribution p_i was this book drawn from?

One way to interpret the book is as a string of English characters. Each character is considered drawn according to its English frequency. You can also interpret the book as a string of 2-grams (a sequence of 2 characters), drawn according to the English 2-gram frequencies. Or as a string of English words, drawn from English word frequencies. Shannon's paper studies how the entropy changes under n-gram and word decodings.

You can also interpret the book as a sequence of Spanish n-grams, in which case it has a very different entropy. Or English paragraphs, words, or concepts. Or as a sequence of atom positions: again, very different entropy.

So with regard to the alien alphabet message—what is the final decoding alphabet? One entropy (the one you refer to) describes the transmission of alien symbols from one end of a transmission channel to another. However, it is just as valid to consider the initial and final messages as some kind of knowledge graph like in Fig 1. If you go through the effort of modeling this, you will find that the total channel transmitting the alien's knowledge graph to your knowledge graph is very noisy. The transmission of the symbols was only one intermediate part of this process. But the full channel consists of encoding -> transmission -> decoding, and the decoding introduces this huge amount of noise. If you consider the initial/final alphabet as the knowledge states, these three steps get lumped together into a single super CHANNEL = (-> encoding -> transmission -> decoding ->), which describes the more complicated communication problem.

So this part: "The same message with the same Shannon information and same uncertainty of transmission..." is true only of the intermediate transmission step. This is *not* a property of the Shannon entropy; it is a property of a communication model to which the entropy is applied.

That is to say, this is all within completely standard Shannon theory. The hard part here is not deciding the entropy definition; the hard part is modeling the decoding channel, which decodes physical information into brain states or knowledge graphs.

Observational entropy is relevant here mainly insofar as it is really a relative entropy, which allows you to incorporate some prior information into the V_i. This comes from prior information about the physical state in the OE definition. But you can also incorporate the above into the OE model. To do so, you apply the above-discussed "decoding channel" to the data obtained from the original coarse-graining. Now you have a mathematical model of a measurement whose "outcome set" is knowledge graphs or brain states.

It would be interesting to see how far one could go in quantifying such channels (transmission of knowledge graphs or brain states) based on biological/epistemic/etc. models; maybe it's been tried before in some mathematical field or another.


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In summary, it's an interesting problem, and solving it involves somehow modeling the observer's decoding channel. But solving it doesn't require changing Shannon/relative/observational entropy definitions; they are already equipped to handle such a model.

I'll just add a few other comments about the paper:

- I find the question of how much information a *specific* observer has (in the sense you describe) intriguing. However, from the physics/observational entropy side, it is not really necessary to describe the physics. There, generic statements are more important, like: any observer who can only measure energies up to precision dE will observe entropy increase. It's these generic kinds of statements that have to do with things like "heat flows from hot to cold bodies." So in that sense, I actually find this more interesting as a Shannon communication problem than as an OE problem.

- Missing minus sign in the observational entropy definition. (Note that V_i is not normalized, which is why the sign differs from the relative entropy definition.)

- I feel that the equation having to do with the information dynamics of populations with different fitnesses had very little to do with the main point of the article. If there is more than one completely separate "biological principle" you are discussing, it would be better to clearly separate them. That said, I'm not sure I understood the intended insight of these information population dynamics, so maybe I'm missing something.

## Declarations

**Potential competing interests:** No potential competing interests to declare.