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PENULTIMATE DRAFT

On the 'transmission sense of information'

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Philosophers of biology tend to believe that biological information is not adequately captured by Shannon's mathematical theory of communication. In their recent paper, Bergstrom and Rosvall (2011a) object to this trend and propose a 'transmission view of information', which is intended to retain and employ Shannon's insights. In their response to commentaries (Godfrey-Smith, 2011; Maclaurin, 2011; Shea, 2011), Bergstrom and Rosvall offer the following formulation of the transmission view:

> [**TMV**]: "An object X conveys information if the function of X is to reduce, by virtue of its combinatorial properties, uncertainty on the part of an agent who observes X" (Bergstrom & Rosvall, 2011b, p. 198, this is the refined version, in which 'combinatorial' properties replace the 'sequential' properties of the original version)

Bergstrom and Rosvall often write about genes or DNA, observing that "[in] biology genetic transmission occurs vertically (from parent to offspring to grandoffspring). It is upon this axis that the transmission sense of information focuses" (Bergstrom & Rosvall, 2011a, legend to fig. 2, p. 165). Framing the transmission view around genes and intergenerational relations suggests that its primary target are the genetic (and non-genetic) factors of inheritance. Yet Bergstrom and Rosvall's wider goal appears to be that the transmission view should apply to all kinds of biological information. For instance, TMV makes no explicit reference to inheritance factors, referring generically to "an object X" instead. Furthermore, Bergstrom and Rosvall (2011a) hope that by focusing on intergenerational transmission, they "can make sense of a large fraction of the use of information language in biology" (p. 165). Bergstrom and Rosvall also emphasise, in their response to commentaries, that we should think of the transmission view as a diagnostic tool rather than an account of (a certain kind of) information. The view is intended to determine the presence of information by offering a set of criteria for identifying information carriers, while bracketing potentially thorny issues about its content. Both these points are summarised in the

remark that the transmission view “simply offers the tools to diagnose biological information where ever it can be found [...]” (Bergstrom & Rosvall, 2011b, p. 197).
This note focuses on the two components of the transmission view, the reduction in uncertainty and the appeal to function.

(1) *Reduction in uncertainty*. It is natural to interpret uncertainty reduction as being somehow connected to Shannon’s mathematical theory of communication, especially to mutual information. After all, Bergman and Rosvall (2011a) wish to employ Shannon’s theory, and mutual information is the key quantity for present purposes (we can exclude psychological states, like feelings of uncertainty, because ‘agents’ are meant to include objects like cells). Bergman and Rosvall say little about how TMV is meant to integrate uncertainty with Shannon’s theory, thus inviting a number of possible concretisations. One is to cash out uncertainty reduction in terms of non-zero mutual information, as has been done before (Halliday, 1983):

> [**TMV***]: An object X conveys information if the function of X is to have, by virtue of its combinatorial properties, non-zero mutual information with an agent who observes X.
> (the reference to combinatorial properties introduces unnecessary restrictions, but is retained here in order to remain close to TMV)

This would amount to something close to Wiley’s (1983) ‘transmitted information’. Note that X’s satisfying these criteria would establish that X has the function to influence the agent’s behaviour, but not that this happened because semantic information was transmitted (cf. Slater, 1983).
Another way to make the connection explicit is to add mutual information to TMV:

> [**TMV****]: An object X conveys information if the function of X is to reduce, by virtue of its combinatorial properties and non-zero mutual information with some feature Y, uncertainty on the part of an agent who observes X

This elaboration of TMV may be closer to Bergstrom and Rosvall’s intentions, because it appears to fit with their example of a practical application of the transinformation view. In the example (Bergstrom & Rosvall, 2011a, p. 170), neuronal spike trains were measured to have non-zero mutual information with stimuli and it is plausible to assume that Bergstrom and Rosvall take spike trains to have the function to reduce the uncertainty of higher-level brain regions. Note, however, that on this interpretation the reduction in uncertainty is not operationalised and remains essentially metaphoric. This may well reduce the usefulness of the transmission view as an effective diagnostic tool. Both elaborations of TMV are subject to some general difficulties with applying Shannon's measures in biological contexts (Pfeifer, 2007).

Another point worth emphasising is that TMV allows an altogether different approach to cash out uncertainty, one which is gaining ground in animal behaviour studies: statistical decision theory (SDT). Animals routinely need to make decisions about how to act, often based on incomplete information about relevant states of the world. The challenge is solved partly by attending to the environment and gathering knowledge about the probability of certain events. In particular, animals can use current perceptions to update their background knowledge about events. Background knowledge stems from earlier experiences and/or evolutionary history. SDT employs Bayes' theorem to derive posterior probabilities, and the difference between posterior and prior probabilities is understood as measuring the animal's uncertainty reduction about the state whose probability is being updated (e.g. Bradbury & Vehrencamp, 1998; 2011; see also Danchin *et al.*, 2004; McNamara & Dall, 2010; Skyrms, 2010). On this approach, TMV could be refined as follows:

> [**TMV*****]: An object X conveys information if the function of X is to change, by virtue of its combinatorial properties, an agent's probability estimate of some state Y

Bergstrom is open to this take on uncertainty (pers. comm.). Keeping the two approaches apart is important, not least because applying them as diagnostic tools requires different methods. For instance, choosing a Shannon approach will require measuring the relative frequencies of signals and some other states (as in the neurobiology example). Choosing the SDT approach will require developing quantitative models in order to generate predictions about probabilities (among other things).

(2) *Functions*. Bergstrom and Rosvall (2011a) exclude from the remit of the transmission view instances in which X lacks the etiological function to reduce uncertainty. The underlying rationale here seems to be a contrast between the transmission view and the "causal sense of information" (p. 168). Bergstrom and Rosvall characterise causal information in terms of mutual information, where mutual information is merely a "descriptive statistics for correlations" (legend to fig. 1, p. 161). To the extent Shannon's theory is deployed simply as a measure of correlations, it fails to

address what they regard as its original task: to address the “packaging of information for transport” (p. 162) from senders to receivers across time and/or space. Bergstrom and Rosvall’s move of supplementing Shannon’s theory with an appeal to X’s etiological function is their attempt to equip the theory for this task. But if the overall goal is to develop a tracking tool for “biological information where ever it can be found” (Bergstrom & Rosvall, 2011b, p. 197), then the inclusion of function is both unnecessary and unduly restrictive. In animal behaviour studies, for example, attending to inadvertent cues and ‘eavesdropping’ are widely recognised as instances of reducing uncertainty in receivers without X having the function to reduce receiver uncertainty (e.g. European starlings learn about patch quality by observing the foraging success of their flock members; vervet monkeys gather information about the presence of eagles by eavesdropping on the calls of superb starlings). These important sources of biological information systematically escape the transmission view. Note also that, while Bergstrom and Rosvall (2011a) make a strong case for specific evolutionary functions of DNA, in general it is difficult to establish evolutionary functions. Impracticality is a reason for some to reject historical function concepts (e.g. Reeve & Sherman, 1993). This may well go too far when the task is metaphysical. But when the task is epistemic, as in TMV, impracticality is a cause for concern.

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