The Informed Neuron: Issues in the Use of Information Theory in the Behavioral Sciences

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"Blood courses through our veins, and information through our central nervous system".
- A Neuropsychology Textbook.

Abstract. The concept of "information" is virtually ubiquitous in contemporary cognitive science. It is claimed to be "processed" (in cognitivist theories of perception and comprehension), "stored" (in cognitivist theories of memory and recognition), and otherwise manipulated and transformed by the human central nervous system. Fred Dretske's extensive philosophical defense of a theory of informational content ("semantic" information) based upon the Shannon-Weaver formal theory of information is subjected to critical scrutiny. A major difficulty is identified in Dretske's equivocations in the use of the concept of a "signal" bearing informational content. Gibson's alternative conception of information (construed as analog by Dretske), while avoiding many of the problems located in the conventional use of "signal", raises different but equally serious questions. It is proposed that, taken literally, the human CNS does not extract or process information at all; rather, whatever "information" is construed as locatable in the CNS is information only for an observer-theorist and only for certain purposes.

Key words. Cognition computation, information-processing, information-extraction, knowledge, belief, vision, signal, intelligibility.

Introduction

In one form or another, the idea that our nervous systems extract and/or process 'information' from our environments (physical/material and social/symbolic) has become a centrally important assumption in most areas of the behavioral sciences, from neurophysiologically-informed psychology to ecological perceptual theory. Various analyses of 'information' are available in the many extensive discussions of this topic, but few can surpass the comprehensive and lucid treatment proposed by Fred Dretske in his book, Knowledge and the Flow of Information. Indeed, this work has become something of a standard reference for those who deal with information-theoretic concepts in their research enterprises without specifically wishing to defend their use philosophically at every turn.

From its inception in communications theory and computer science, the technical concept of 'information' has had a powerful attraction for biologists, neurophysiologists and cognitive scientists as a fundamentally 'materialist' category for unifying the physical and biological descriptions of human CNS functioning, the physical description of the environments of human beings and...
other organisms, and the apparently supra-physical, ‘psychological’ or ‘mental’ attributes and capacities with which human beings are apparently endowed. A central theme in the reductionist programs of materialist psychophysiology has been the theoretical derivation of human cognition from pre- or non-cognitive phenomena. As Dretske sees it, “In the beginning there was information. The word came later.”3 If we agree to distinguish between information and meaning, then, in Dretske’s terms, “one is free to think about information (though not meaning) as an objective commodity, something whose generation, transmission, and reception do not require or in any way presuppose interpretive processes. One is therefore given a framework for understanding ... how genuine cognitive systems—those with the resources for interpreting signals, holding beliefs, and acquiring knowledge—can develop out of lower-order, purely physical information-processing mechanisms.”4 The pacification of the general problem of the emergence of mind and cognition in higher forms of intelligent life can only be approached in terms consistent with evolutionary fact and theory if we are prepared to treat the phenomena of meaning, belief, knowledge and related ‘mental’ attributes and capacities as dependent upon “progressively more efficient ways of handling and coding information ... The raw material (for these higher-order accomplishments of human beings—JC) is information.”5

**Information Theory and Human Cognition**

The chief reason for selecting information theory for application in the service of efforts to analyse human cognition has traditionally been the awareness of a commonality of (formal) structure between channels of electronic communication and nerve circuitry in the CNS. Both operate with pulse trains amenable to specification in terms of binary digits (0s and 1s). Both are inter-related in connected arrays facilitating the transmission (and transformation) of pulses. And both operate on ‘input’ from sources suitably digitized for such transmission. Since both electrical wiring systems and nervous systems comprise channels, and pulses transmitted according to binary digitalization principles can convey information encoded according to such principles, it was thought (both by Alan Turing, the founder of computational theory and by Claude Shannon, the founder of the mathematical theory of communication,6 and by many of their successors) that a purely materialist (biological, physical) science of CNS functioning might be constructed that could connect physical processes with our knowledge of and perception of the world (our ‘information’ about it). Given that neurophysiological investigations of the neuron (e.g., by Ramon y Cajal) had determined that it operated in a (largely) binary fashion, formerly metaphorical talk about neurons receiving and transmitting ‘messages’ might be encashed by an appropriate application of information-theoretic ideas originally developed in the domains of electronic-communications and computational engineering.

Conventional information theory, since the original formulations of Shannon