

## Seeing, doing and knowing

Mohan Matthan (2005). *Seeing, Doing and Knowing: A Philosophical Theory of Sense Perception*. Clarendon Press, Oxford. Hardback. 362 pp. \$74.00. ISBN 0-19-926850-9

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This is a philosopher's serious attempt to give a coherent account of perception and its role in behaviour. I, the reviewer, am a scientist involved in the experimental investigation of vision, and when I first glanced through the book I was enthusiastic. The author has done his homework well and guides one intelligently through many aspects of the visual system, so I had high hopes that he might succeed in adding to my understanding of vision from his own insights derived from philosophy. I'm afraid these high hopes were not actually realised, but I think I did learn what NOT to expect from philosophy and shall thereby avoid future disappointment. The book will suit a philosopher who wants to explore vision, but I have a grouse here too, for I think he misses out aspects of the subject that have flourished in recent decades and are of special interest. Perception is based on noisy, uncertain, evidence, yet often leads to astonishingly reliable inferences: wouldn't evidence that our brains do this, and about how they do it, be of interest to philosophers? But before suggesting that Matthan writes a new book, let me tell you about the present one.

It is attractively produced, nicely written, and comes complete with useful index and bibliography. Matthan clearly aims to combine philosophy and the experimentally derived facts of vision into a coherent whole, which is a very welcome effort. He also strives to make the hypotheses, facts, terms and topics he discusses as clear as possible, with a good many definitions interpolated in the text, and a section at the end devoted to "definitions and named theses".

The book has five parts containing 13 chapters, and is preceded by a dozen pages where he locates his work in relation to other approaches to the subject. An important feature, which will be very welcome to physiologically and biologically oriented readers, is the emphasis on "doing" that is shown by his inclusion of it in the title: perception is not a passive process, and this needs to be born in mind continually.

I shall have to be brief about the rich sequence of topics that are discussed in the five main parts. The first (called "Classification") expounds his thesis that sensory systems use proximal stimuli (i.e. the messages from sense organs) to place the distal stimuli (ie the sensed objects that cause sensory messages) into classes. The second, (called "Similarity") deals with the similarity structure of these

classified messages. This includes the process of generalisation, but he emphasises that degrees of similarity and difference are preserved: classified messages are not just the same or different, but have degrees of similarity.

The third part (called "Specialisation") is much concerned with colour and how individual species vary in the way that they use colour information to classify sensory messages. I must confess that his account of philosophers' concerns about the sensory worlds of bats and humans left me unimpressed with the profundity of their approach. Bats don't, I think, tell each other much about the world that they sense through their echolocation system, for it's very unlikely that they can translate what they sense into a language that they can communicate to other bats. In contrast, the world that we sense consciously, which is the world being compared with that of the bat, is based on named objects, events, colours, shapes and movements. We don't have to form complete sentences out of these elements in order to have conscious visual experiences, but all the preliminary work has been done, and it just seems utterly naïve to suppose that the bat's brain translates its experience into a language that can be understood by other bats in a way that is even remotely equivalent to the human use of language.

The fourth part (called "Content") starts with a very clear and interesting account of the motor theory of speech perception, which introduces themes very different from those encountered in vision or olfaction. This section is also rich in other new topics, such as the degree to which sensory messages are coercive (forcing one particular response), or conventional (roughly, having a genetically determined significance).

The final section (called "Reference") is much concerned with visual location, but his approach is predominantly philosophical. It was surprising to find that the precise mapping of the visual field on to the primary visual cortex, and its re-mapping in neighbouring regions, was not discussed, for this feature of brain anatomy presumably indicates the supreme importance of relative position for the way that the brain handles visual information, and to some extent justifies the philosophical concern with place. He also develops interesting ideas about the motion-responding mechanisms giving a sense of "presence", and about the "descriptive" mechanisms that are responsible for classifying sensory messages.

I hope this very brief sketch of this book's rich content will encourage those with a liking for the philosophical approach to read it. He gives an intelligent tour through many topics in perception, and has achieved some success in developing his own original ideas about the subject. Furthermore I thought that many of these ideas are attractive and likely to be acceptable to other scientists. But a reviewer has a duty as a critic as well as a salesman.

I may have already betrayed that I am prone to anti-philosophical thoughts, and, contrary to my initial hopes, this

book has aggravated this weakness. I am infuriated by the tendency to coin words or short phrases that may have clear meanings to their originators, but are impenetrable to otherwise well-informed outsiders. In this book, I had trouble with the frequently used word-pair “epistemic actions”. This is clearly a concept of central importance for the author’s view of the subject, and at first I thought I knew what he meant: they must be responses concerned with knowledge in the abstract, rather than responses that help one to get out of the way of an approaching bus, or responses that help to recognise the letter A. I said to myself “Good, that’s a claim that really interests me”, but as I read on, my interpretation did not quite fit with what he was saying, so I looked into it more closely.

To my surprise “epistemic” is not in the Concise OED, but the Oxford Concise Handbook of Philosophy confirmed that I had got its meaning right: epistemic actions must be actions concerned with knowledge. But what kind of knowledge does Matthan refer to with “epistemic”? I had assumed that it was the new knowledge that sensory experience brings with it, whereas it seems that Matthan principally refers to the implicit knowledge that comes with the genes that we inherit. How was a reader supposed to know that? There are similar problems with the second word, action. Are these actions that depend on prior knowledge, or actions that derive knowledge from current experience, or maybe actions that modify or change previously stored knowledge?

Intrigued by the fact that Matthan does not write about the epistemic aspects of perception in the way that I think they deserve, I looked into the issue further. Knowledge boils down to knowledge of statistical facts about the world, i.e. knowledge of the frequencies of occurrence and co-occurrence of features, objects, events and sequences in the world that impinges on our senses. But these things don’t seem to interest the author, and the neglect of the statistical aspects of vision in this book is confirmed by reference to the index. Whereas “sense-features” has 19 subheadings referring to almost 50 pages of text, one finds no entries at all for “probability”, “statistics”, “information theory”, “coding”, “noise”, “Shannon”, “signal-detection-theory”, “signal-to-noise ratio”, “threshold”, or “Bayes’ theorem”.

It’s a bit of a shock to find that a major philosophical book on perception ignores all these topics, for there have been great advances in the last 50 years both in understanding the theoretical basis for making reliable inferences from uncertain evidence, and in defining the neural mechanisms by which the visual system brings this about. Since we live in an uncertain world, and since our success in making a living in this world depends upon our ability to make reliable predictions, these theoretical and physiological advances are crucial for those interested in the philosophy, as well as the science, of vision. Computer scientists attempting to emulate vision, as well as vision scientists themselves, have been fully aware of the importance of this new understanding.

I cannot make good his omissions, but I shall add a short annotated reading list and hope that anyone who reads Matthan’s book also glances at some of these publications. Would it be too much to hope that Matthan himself will take up the challenge of incorporating this knowledge into his viewpoint? He has already shown a rare ability to forge a coherent account from diverse approaches, and I’m sure there would be a large and eager audience for a second volume, perhaps titled “Perception: how we often manage to guess right”, which would explain how efficient methods of statistical inference help us to survive and flourish in an uncertain world.

### Reading list on statistical inference in perception

Here are references and notes on ten publications, some old, some new, which I hope will give introductory knowledge on three topics important for perception, namely statistical efficiency, information and redundancy, and single neurons and networks. The papers were chosen either because they were the publications that opened my own eyes to the statistical nature of the work our brains do for us, or because they have tutorial value on the issues that I think the volume being reviewed does not treat adequately. I have taken the liberty of including three of my own publications, and these explain some of my own views at greater length. Unfortunately the notes are somewhat jargon-infested because technical terms have been retained for the sake of brevity.

#### *Statistical efficiency*

Hecht S, Schlaer S, Pirenne MH. 1942. Energy, quanta and vision. *Journal of General Physiology* 25:819–840.

This paper showed that the apparent variability of the absolute threshold of vision was not caused solely by biological variation, as was confidently asserted in the psychology departments and textbooks of the time, but was largely attributable to unavoidable fluctuations in the numbers of quanta absorbed from the light stimuli that are absorbed in the photoreceptors. It was this paper that convinced me that statistics was not just a boring stepping-stone to a PhD, but a necessity for understanding the brain and its problems.

Fisher RA. 1925. *Statistical Methods for Research Workers*. Edinburgh, Oliver and Boyd.

This is the prejudiced but charismatic text I was directed to in order to learn more about statistics. I lapped it up, especially the bits about statistical efficiency, for if the brain’s job is essentially a statistical one, efficiency is the natural measure to use for assessing its performance at different tasks. Furthermore it was a measure that could, potentially, be applied to signals inside the brain, as well as those that emanate from it during psychophysical experiments.

Barlow HB. 1980. The absolute efficiency of perceptual decisions. *Phil. Trans. Roy. Soc. Lond. B.* 290:71–82.

The results of Hecht et al. (1942) indicated that 50% of the quanta effectively absorbed from light stimuli at the threshold of vision contributed to the sensation, and a similar conclusion was reached at about the same time by Albert Rose, an engineer developing television cameras. Some other visual tasks, such as detecting small moving patches of sinusoidally modulated light, can be shown to use even higher fractions of the available evidence. Most tasks yield much lower figures, probably because there are no naturally occurring feature detectors whose parameters match those required for high efficiency. High efficiency is not, however, confined to detecting specific patterns. One very readily detects mirror symmetry in arrays of random dots in which a fraction are replicated in mirror symmetric positions and, under selected conditions, it can be shown that 50% of the available statistical information is used. Figures approaching this can also be obtained for the task of detecting coherent motion in random dot kinematograms, as used in the experiments described below. These are tasks of a more complex type because they require detection of the co-occurrence of two events, the dot and its mirror pair or, for motion, the occurrence of a pair of transient changes at two points separated in time and space, rather than the occurrence of a specific, predetermined, pattern.

Newsome WT, Britten KH, Salzman CD, Movshon JA. 1990. Neuronal mechanisms of motion perception. *Cold Spring Harbor Symposia on Quantitative Biology* 55:697–705.

One of the advantages of measuring the statistical properties of sensory signals is that the same measures can be used both for the stimuli themselves, and for the changes in sensory messages that these evoke. One can thus follow the critical information required for performing a sensory task on its way through the brain. The authors of this paper were able to record from neurons in the cortex of monkeys while they were at the same time signalling (through their eye movements) their responses to tests of their ability to detect coherent motion in random dot kinematograms. Many of these single neurons gave neural responses that, by themselves, enabled the motion task to be performed as reliably as the whole animal could perform it and, in some cases, their performance was even better. The parameters of the test stimuli had been selected to match the discriminatory abilities of the single neuron under consideration, but we do not know how the monkey selects the responses of particular neurons to attend to, undistracted by the buzzing confusion of some  $10^7$  other neurons in the relevant area of the brain.

### *Information and redundancy*

Shannon CE. 1951. Prediction and entropy of printed English. *Bell System Technical Journal* 30:50–64.

Shannon estimated the redundancy of printed text by measuring how often subjects could correctly guess a randomly selected character while varying the number of

preceding characters that the subjects had already seen. The average information per character decreased from 4.7 bits to about 1 bit as the number of preceding characters increased from zero to about 20. This was not only an elegant demonstration of the meaning of the terms in Shannon's new definition of information and redundancy, but also proved that humans have a deep knowledge of the statistical structure of written text, and can use it to predict future characters.

Barlow, H. B. (2001). "Redundancy reduction revisited". *Network: Computation in neural systems* 12:241–253.

Attneave and I published papers in the 1950s suggesting that reducing redundancy was what made effective perception possible. This is a review of the strengths and weaknesses of that hypothesis. It argues that redundancy is as important for perception as we said it was, but it is exploited in other ways than reducing channel capacity, which is its main importance for man-made engineering systems.

MacKay DJC. 2003. *Information theory, inference, and learning algorithms* Cambridge: Cambridge University Press.

This is a rich source of tutorial information (at all levels) about the topics in its title, and on a good many others, including statistical tests based on Bayes' theorem.

### *Single neurons and networks*

Barlow HB. 1972. Single units and sensation: A neuron doctrine for perceptual psychology? *Perception* 1, 371–394.

This paper argued that the properties of single neurons are crucial for understanding sensation and perception, for these determine how sensory messages are transformed. It reviewed experimental work done in the decades before its publication and, on this basis, formulated several principles such as: exploiting the redundancy of input patterns, economy of impulses rather than channels, sparse coding, and regarding neural messages as signals of the degree of certainty that features are present. These were formulated as "dogmas" that not everyone liked or accepted, though a good deal of subsequent work seems to indicate that the brain follows them.

van Hateren FH, van der Schaaf A. 1998. Independent component filters of natural images compared with simple cells in primary visual cortex. *Proceedings of the Royal Society, Series B* 265:359–366.

They show that many of the features of neurons in primary visual cortex are reproduced by a program that generates a set of independent filters for representing natural images. The statistics of natural images appear to be important in determining the feature detectors that have evolved. Field & Olshausen, Bell & Sejnowski and others produced similar programs about the same time.

Knill DC, Pouget A. 2004. The Bayesian Brain: the role of uncertainty in neural coding and computation. *Trends in Neuroscience* 27:712–719.

Although our knowledge of the feature-detecting properties of single neurons suggests that they contain the information

required to explain the observed statistical efficiencies of sensory performance, the input to the brain is actually a complex spatiotemporal distribution of activity in a host of sensory neurons, and its outputs are complex spatiotemporal distributions of activity in the neurons going to our effector organs. These authors provide a Bayesian framework for thinking of the statistical aspects of sensation and representation in terms of distributions rather than single neurons. As

well as being more realistic, this may open the way to understanding how the connections of the network are formed in the first place, maintained in working condition through life, and are sometimes capable of modification to repair the degradations of age, damage and disease.

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