Abstract

We review psychological evidence that shows properties distinguishing object descriptions and sensory feature maps. We then outline a neurocomputational approach to the computation of object features from the sensory data and for learning these descriptions. We concentrate on acquiring object concepts that generalise across position on the sensory surface.

1. Introduction

This paper is concerned with the acquisition and use of object shape descriptions that generalize across position in the sensory feature maps. A distinction between sensory and object domains of representation is a crucial feature of many but not all neurocomputational theories of object perception. This distinction is realized in Feldman's four frames theory (1985) as that between the stable feature frame and the world knowledge formulary, in von der Malsburg and Bienenstock's dynamic link theory (1985) as that between layers L1 and L2, in Marr's theory (1982) as that between primal and 2½-D sketches and the 3-D model representation, and in Hinton's theory of shape representation (1981) as that between the retinotopic frame and the object-centred frame. Although these all differ to some extent in the specification of the two domains and the way in which they are related all agree that some such distinction is crucial. Theories in the Gibsonian tradition do not emphasize this distinction, however, and many neurocomputational models of object shape learning seem designed to operate directly upon sensory data rather than upon selective and schematic descriptions of it (e.g. early perceptrons).

Neurophysiological evidence on sensory representations is abundant, but on object descriptions and the way in which they are computed it is as yet scarce and difficult to interpret. We therefore first review the results of psychophysical experiments that provide direct evidence on some of the properties that distinguish sensory and object representations, and on the rate at which object
descriptions are computed. We then describe computational investigations that we have recently begun concerning possible neural mechanisms for learning and computing object descriptions.

2. Psychophysical Investigations

A vast number of psychological investigations are potentially relevant. Here we review just those that have been developed at Stirling specifically to provide evidence on these issues (e.g., Phillips, 1974; Phillips, 1983; Phillips and Singer, 1974; Wilson, 1981). These test memory for novel configurations of simple shapes generated by randomly filling cells in rectangular matrix arrays. Knowledge of shape can then be studied independently of other aspects because features such as colour and texture are held constant. Visual rather than verbal descriptions are implicated because these patterns are much better suited to our visual than to our verbal descriptive capacities. Observed differences between verbal memory and memory for these materials supports this inference. Use of novel configurations enables us to study both recognition and learning. Finally, and most importantly, sensory and object descriptions can be studied within the same paradigm by varying only the quantitative details of the patterns and presentation conditions.

In this paradigm a computer generated pattern or series of patterns is presented under controlled conditions on a video monitor. Memory for the pattern or patterns is tested after a retention interval that varies from a few tens of milliseconds to many seconds. Pattern complexity also varies greatly, from 8 cells within a 4 x 4 matrix, to more than 500 cells within a 32 x 32 matrix. Memory is tested by various versions of recognition, completion, and recall. Recognition and completion can be tested by presenting a second pattern for comparison with the first and by asking the subject to say whether the two patterns are identical or not, or by asking him to point to any changed cell. Changes usually involve only one cell selected at random. Recognition and completion are the tasks most directly applicable to the study of both sensory and object domains. These were used in the experiments to be described.

In certain conditions performance is compatible with what would be expected if it were based upon sensory representations. Subjects are then able to detect small changes in even the most complex patterns with high accuracy. The display conditions required to produce such performance are highly restrictive, however. For example, the retention interval must not be more than a few hundred milliseconds. Under other conditions performance is quite different and is compatible with the view that it is based upon object descriptions. Subjects then have accurate knowledge of only very much simpler patterns. Details of these two kinds of performance and of the conditions under which they occur provides evidence on the properties distinguishing sensory and object domains, and on the relation between them.

The main distinguishing properties are as follows. 1. **Capacity.** Sensory representations have very high capacity. Changes of a single cell can be detected with near perfect accuracy in patterns of