Chapter 1
Application of Connectionist Models to Animal Learning:
Interactions between Perceptual Organization and Associative Processes

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ABSTRACT

Here the authors examine the nature of the mnemonic structures that underlie the ability of animals to learn configural discriminations that are allied to the XOR problem. It has long been recognized that simple associative networks (e.g., perceptrons) fail to provide a coherent analysis for how animals learn this type of discrimination. Indeed "The inability of single layer perceptrons to solve XOR has a significance of mythical proportions in the history of connectionism." (McLeod, Plunkett & Rolls, 1998; p. 106). In this historic context, the authors describe the results of recent experiments with animals that are inconsistent with the theoretical solution to XOR provided by some multi-layer connectionist models. The authors suggest a modification to these models that parallels the formal structure of XOR while maintaining two principles of perceptual organization and learning: contiguity and common fate.

INTRODUCTION AND SCOPE

Learning can be viewed as an adaptive process that allows the melee presented to an animal's senses to be organized according to certain principles in the service of that animal's future interactions with the world. Viewed in this light, understanding the principles of learning is a core objective for artificial intelligence, ethology, neuroscience and psychology. The study of learning in nonhuman animals (henceforth animals) has provided us with a unique stage upon which to investigate these principles in action, under experimentally controlled conditions, and at a variety of levels of analysis: from molecular mechanisms to behavioural ones. This chapter illustrates how evidence from laboratory-based behavioural studies in animals can inform our understanding of some long-standing issues surrounding the nature of the

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mnemonic structures that underpin learning. Our focus will be on configural learning problems - problems that require animals to be sensitive to the presence of patterns of stimulation as opposed to the presence of any individual stimulus. Analysis of the mnemonic structures that underlie an animal's ability to solve such problems has been at the heart of debates concerning the nature of learning across a broad range of disciplines.

PRINCIPLES OF PERCEPTUAL ORGANIZATION AND LEARNING

What sort of principles might underpin how information is organized in the service of future behaviour? The Gestalt school of psychology identified a set of such principles in the context of, among other things, perceptual organization. According to these principles, things that are presented in close *temporal proximity* will be grouped, as will things that are *visually similar* to one another; and the elements of dynamic patterns that have a *common fate* (or move in the same direction) will also be grouped (for a review, see Wertheimer, 1923). These principles of perceptual organization echo the *laws of learning* from associationist psychology (see Warren, 1921). For example, for the associationists, temporal continuity and similarity were held to influence the process of association - influence the strengthening of a mental link between the memory of one stimulus and another (for a recent review, see Hall, 1994). In fact, as Rescorla (1985) has noted, Kohler (1947, p. 163) suggested "the association of two processes is only the aftereffect of their (perceptual) organization." We shall return, in closing this chapter, to the specific suggestion that association can be reduced to an aftereffect of perceptual organization. For now, it is sufficient to note that the way in which perceptual organization and learning interact has been (e.g., Gibson & Gibson, 1955; Postman, 1955) and continues to be a contentious issue (e.g., Hall, Blair & Artigas, 2006; McLaren & Mackintosh, 2002; Mundy, Honey & Dywer, 2007).

CONTIGUITY, SIMILARITY AND COMMON FATE

There is good evidence that temporal proximity and similarity are influential parameters in studies of simple Pavlovian conditioning: The development of conditioned responding during pairings of one stimulus with another is often more rapid when both stimuli are presented in close temporal contiguity (e.g., Schneiderman & Gormezano, 1964; Mahoney & Ayres, 1976) and when the two stimuli are similar to one another (e.g., Grand, Close, Hale & Honey, 2007; Rescorla & Furrow, 1977; Rescorla & Gillan, 1980). That is, the Gestalt psychologists' observations concerning perceptual organization find obvious empirical analogues in studies of a form of learning that has been interpreted in associative terms since its original description (see Pavlov, 1927).

The idea that stimuli with a common fate will be grouped also finds analogue within the associative tradition: Patterns of stimulation (let us call them A and B) that have been paired with the same outcome come to be regarded as similar, and those that have been paired with different outcomes become less so (James, 1890). There is now abundant empirical support for this basic suggestion (e.g., Honey & Hall, 1989; Zentall, Steirn, Sherburne, & Urcuioli, 1991). Moreover, this process of grouping does not simply reflect the fact that stimuli with a common outcome have come to evoke the same response (Hull, 1939; Miller & Dollard, 1941) or the same associate (Honey & Hall, 1989): There is now clear evidence that such effects reflect the fact that stimuli that have been paired with a common outcome are more likely to be *perceptually* grouped than those paired with different outcomes (e.g., Allman, Ward-Robinson & Honey, 1994; Close, Hahn, & Honey, 2009; Delamater, 1998; Honey