CHAPTER 12

ARE THERE UNIVERSAL PRINCIPLES OF SENSORY-MOTOR CONTROL?

In the preceding chapters, we have identified a set of functional problems, notably problems of self-calibration, which need to be solved by sensory-motor systems. We have also suggested neural circuits which are competent to solve these problems. In cases where several qualitatively different circuit solutions are capable of solving a functional problem, and where available data do not unambiguously favor one solution, we have developed enough properties of the solutions to differentiate them in future experiments. Although it was not feasible to describe all possible anatomical and physiological variations of these solutions, we have selected examples which clearly articulate the basic functional issues. These examples should make it easier to interpret functionally related data in variations which we did not explicitly develop.

Many of the functional problems that we have addressed are not restricted to the saccadic eye movement system. This fact raises the question of whether similar neural designs may be used to control other sensory-motor systems than the saccadic system. In a general sense, the answer to this question clearly seems to be "yes." Many of the circuits which we have suggested are naturally decomposed into functionally specialized macrostages, such as the adaptive gain stage (Chapter 3), which are utilized in multiple circuits due to their specialized processing capabilities. Moreover, different sensory-motor systems must communicate via commands that are dimensionally consistent. In particular, our discussion of how intermodality circular reactions are learned (Section 1.3) suggested that several sensory-motor systems compare target position with present position in order to generate their movement commands. In addition, functional problems such as learning the correct gains for movements vs. postures, and compensating for changes in muscle plant characteristics, beset many sensory-motor systems other than the saccadic system. The need to learn motor synergies, rather than individual muscle commands, and to change coordinates between different sensory, motor, and vector stages are also shared by many sensory-motor systems.

Differences between the saccadic control system and other goal-oriented sensory-motor systems may be sought in finer, but nonetheless important, distinctions, such as (I) the distinction between the control of continuous vs. ballistic movements, and (II) the distinction between the control of motor organs that are regularly perturbed by unexpected loads vs. motor organs that are not regularly perturbed by unexpected loads. The first distinction might lead to differences in how target positions and present positions are generated and compared through time, and how each system computes and compensates for self-motion vs. world-motion. The second distinction might lead to differences in automatic load compensation mechanisms and to modified uses of inflow and outflow signals. It remains for future experimental and theoretical work to determine how many of the neural designs which we have suggested for the saccadic system are modified for use in other sensory-motor systems, and how many need to be supplemented by qualitatively new neural designs.