Chapter 17

Recording of Electrical Activity of Neuronal Populations

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Introduction

The problem of how information is encoded and transmitted within the nervous system has challenged neurophysiologists for years. Many attempts to find and describe some general principles for such neural coding have been made, and it is probably fair to say that the opinion about these general principles has changed lately. Today, it seems clear that most information within both the central and the peripheral nervous system is encoded and transmitted by large populations of neurons. For the sensory nervous system there is a continuously growing body of evidence indicating that even simpler peripheral stimuli are transmitted to the central nervous system by large populations of sensory neurons.

Due to this, neurophysiologists have shifted their interest from the activity of single neurons to the multi-unit activity in such populations. Due to technical and practical difficulties, population activity was for a long time assessed indirectly by using sequential recordings of single neurons, and the population was artificially constructed afterwards by pooling these sequentially recorded single neurons. However, the neurons within a neural population must be simultaneously recorded if their population characteristics are to be investigated, and indeed, recent experiments indicate that information is lost if the neural populations are recorded sequentially and pooled (Johansson et al. 1995b). This fact has led to a rapid development of techniques enabling the recording of several neurons simultaneously both in the central and peripheral nervous system.

So why is there a problem with pooled sequential recordings? Well, there are several easily conceived problems associated with such recordings of neural activity. One of the more important problems is that it is difficult to reproduce a stimulus perfectly. The reason for this is that even a series of stimuli might seem identical in terms of some qualities measured by the experimenter (e.g., changes in muscle length), it does certainly not mean that identical effects are produced at the receptor level. For all types of neural activity the receptor responses produced by a given stimulus are likely to change over time due to variations in a number of experimental conditions, e.g., temperature, circulation, depth of anesthesia. Therefore, there is little doubt that the ideal way to study population coding is indeed to record the neurons within the population simultaneously (for elaborate discussion see Deadwyler and Hampson 1997, Johansson et al. 1995b).

This chapter will briefly review some methods for recording multi-unit activity on both the central and the peripheral level in in vivo animal experiments. These are, however, not the only areas where multi-unit recording techniques have been developed. As an example, there are several methods for such recordings of neurons in cell culture preparations. The interested reader is referred to the paper by Breckenridge and co-workers (1995) describing a 64 electrode array, or the paper by Stoppini and colleagues.

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(1997), where an array of 30 biocompatible microelectrodes is described. Both of these electrode arrays are designed for extracellular recordings.

Naturally, this chapter cannot deal with all the developed techniques and it will not be a step-by-step guide to multi-unit recordings. It will, however, give some references to techniques used, and some recent examples will be discussed more elaborately. Furthermore, an example of analysis of population coding will be presented together with some examples of results attained using this analytic method.

It should perhaps be made clear already at this early stage that for a good multi-unit recording setup, a combination of a multi-unit electrode and proper software for spike separation is desirable. Below, these issues will be discussed separately.

Subprotocol 1
Multi-Unit Recording

Procedure

Multi-unit Recording on the Peripheral and Dorsal Root Level

As concerns multi-unit recordings on the peripheral level and the level of the dorsal root, there are not a lot of techniques presented in the literature. We would like, however, to mention a couple of principally different setups. Quite early, an interesting type of multi-electrode was developed in order to record from regenerating severed nerve fibers (Marks 1965). In this method, the severed nerve was made to regenerate through an array of gold tubes, and each of these gold tubes served as an electrode. These techniques could only be used for severed nerve fibers, and naturally, the time between insertion of the electrodes and the time for recording was quite long. Methods were needed for multi-unit recordings in acute experiments. In early attempts to perform such multi-unit recordings, a setup of several single conventional electrodes was used. However, since such electrodes needed a lot of space (partly because they used one reference electrode each), the number of axons that could be recorded from simultaneously was quite limited.

As a response to this demand Djupsjöbacka and coworkers (1994) presented a multi-channel hook electrode for acute cat experiments some years ago. This electrode is shown in Fig. 1, and consists of 12 silver wire hooks which are fixed on a common 'holder' made of a 3-mm-thick black PVC plastic plate. The holder is shaped in a semi-circular fashion to fit optimally in the limited space between the entrance of the L7-L6 spinal roots into the spinal canal, and the pelvic bone. In this holder 12 notches are milled radially. The notches have a width of 0.45mm and a depth of 1.0mm. In each of these notches a hook is mounted tightly by pressing it down into the notch. The hooks are made of 0.50-mm solid silver wire, which is chlorided in order to obtain a stable half-cell potential and a low impedance between the hook and the nerve filament (Geddes et al. 1969). The chloriding is performed after the hooks are mounted on the holder. Each of the 12 hooks constitutes a separate channel. Each channel on the electrode has an individually shielded cable with two conductors – the positive input wire is soldered to the corresponding Ag/AgCl hook, and the negative input wire is soldered to an Ag/AgCl reference needle (see Fig. 1B). Since it would be impractical to have a unique reference needle for every channel, all reference wires are connected to a single reference needle. The shield of the cables is connected to ground. The cables have a cross-sectional area of 0.02 mm² consisting of 10 copper fibers. This makes a thin and flexible bundle of cables. In