

Characterising and Analysing Intracerebral Electrical Activity

PHILIPS

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Academic Medical Center
University of Amsterdam

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During stereotactic functional neurosurgery, intracerebral electrical activity is typically recorded to monitor and refine the target position. Methods are needed to analyse the recorded data. In particular the effects of different types of neurons on the data need to be characterized so as to localise the appropriate neurons.

Transfer of information in the human brain is largely determined by electrical activity of neurons. Individual neurons have characteristic electrical properties that are determined by the electrodynamical behaviour of the cell membrane. The amount of electrical discharge of a neuron depends on several factors including the type of channels present in the cell membrane, the sensitivity of the neurons for specific neurotransmitters and the changes in the extracellular and intracellular electrical potential.

During stereotactic functional neurosurgery, basically two types of signals can be obtained. First, the electrical discharges of individual neurons can be recorded. With a specially designed micro recording needle single/multi unit activity (MER) within an area with a diameter of 100 – 200 micrometer can be picked up. Secondly, with a more course electrode, local field potentials (LFP) can be measured across a larger area with a 1 – 2 mm diameter, that reflect potential variations caused by a larger population of neurons (50 – 500).

With respect to microelectrode recordings, the signals measured consist of a mixture of measurements noise, superimposed neuronal activity from large numbers of neurons in the general vicinity of the electrode, larger action potentials from individual neurons very close to the electrode, and various artefacts, including 50 Hz power-line contamination and vibrations of the stereotactic frame. To evaluate the activity of individual neurons after artefact correction, it is necessary to not only separate out the action potentials of nearby neurons from the background activity, but also to then separate those superimposed multi-unit action potentials into clusters, such that each cluster represents the activity of a single neuron. Several criteria can be used including the amplitude and profile of an individual spike. In addition, the characteristics of the spike train assigned to a single neuron may be used to classify a cluster, since each type of neuron has a specific firing pattern, such as burst, pause or tonic firing. This process is commonly referred to as spike-sorting, i.e., to separate multi-unit activity into activity of different single units.

Considerable investigation of spike-sorting methods has been made in the field of cortical microelectrode recordings, but the application of spike-sorting to intra-operative electrophysiology brings with it several specific complications. First, the data tends to be highly non-stationary, which not only confounds most standard statistical approaches, but also means that units may be present only during part of the recording. Second, the analysis must be done on-line. Most methods are quite computationally intensive, and often require a substantial learning period, which is not feasible intra-operatively. Finally, the method must be automatic. Most methods available are, at best, semi-automatic, requiring the user to set certain data-specific parameters that are based on a subjective interpretation of the data.

Mathematical assistance would be valuable on the following specific points:

1. Automatic assessment of periods of approximate stationarity. Such an assessment must be reliably applicable to relatively short data sets.
2. Automatic sorting of events into different units (where each unit represents the activity of a single neuron. An event is defined to be a short time interval of data, with a high likelihood of being an action potential, and is selected according to some set of criteria.

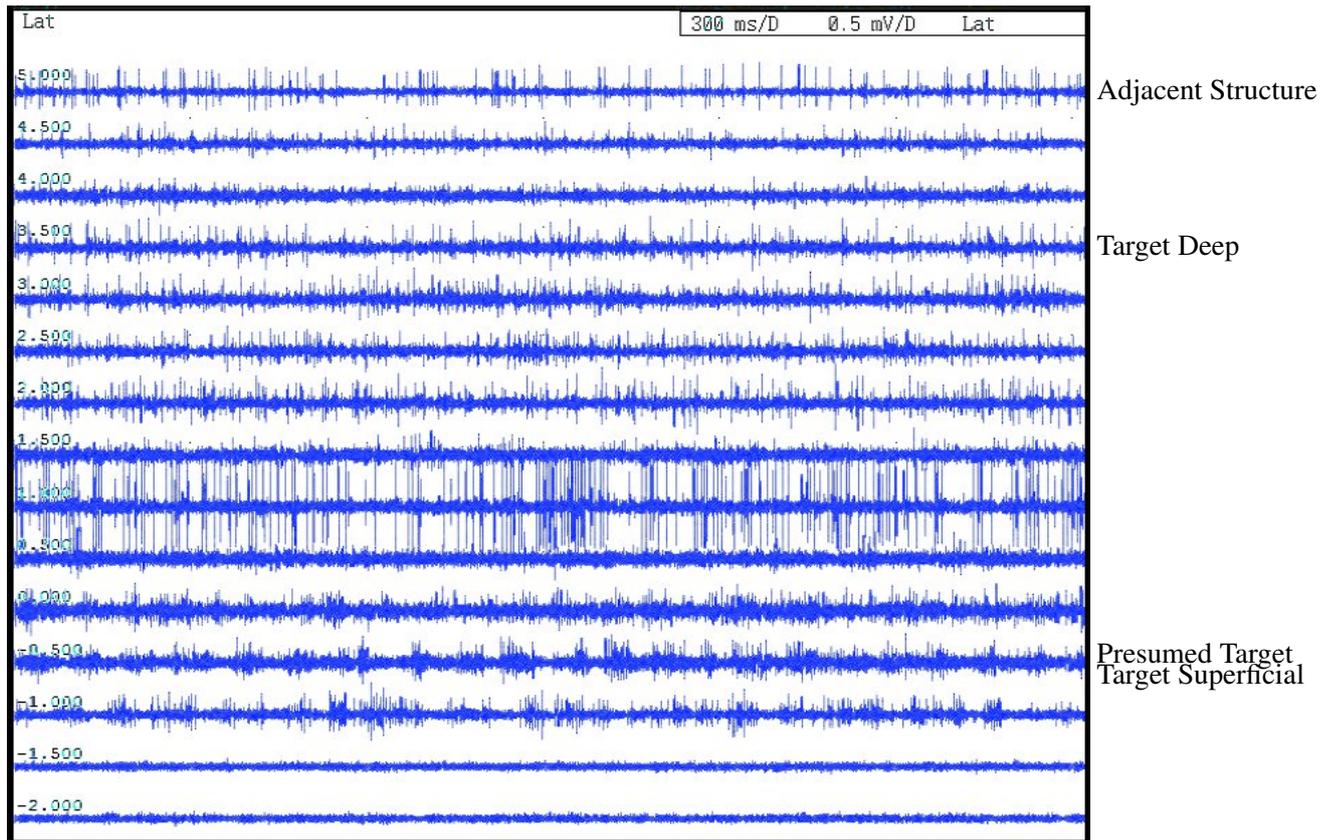


Figure 1: Single/multi unit activity of the presumed target structure for various depths (-2 to +5 mm). The superficial part of the target (-1 to 0 mm) is clearly recognized by a sudden increase in discharge rate characterized by rhythmic bursts of activity of 15 to 25 Hz. Deeper layers of the target region (+1.5 tot 3.5 mm) show an irregular high frequency discharge pattern. Activity of adjacent structures (+5 mm) is clearly distinguishable and consists of a low frequency tonic discharges.