A METHOD FOR IDENTIFYING NOISE-FREE EVOKED POTENTIAL COMPONENTS- APPLICATIONS OF DLM(DIPOLE LOCALIZATION METHOD) TO THESE COMPONENTS

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Abstract

In this paper we shall describe a simple method that might be useful for identifying relatively noise-free components of cerebral evoked potentials. This method will be used to analyze visual and somatosensory evoked responses and DLM(the dipole localization method) will be applied to localize the neural generators of these scalp recorded data.

Introduction

The use of sensory evoked potentials as tests of brain function seems to promise valuable non-invasive procedures for providing information about a variety of nervous system functions. Distinctive features or components of scalp recorded potentials are probably related to underlying neurophysiological processes and if it were possible to describe the neural generators of these components one might be able to establish normative potential patterns, distinguish abnormal patterns in cases of disorder,and generally elucidate the underlying processes.

An approach that has been followed for the problem of localizing the neural generators of scalp recorded evoked components can be summarized as follows. The head is simulated by a homogeneous conducting sphere and the suspected source of surface data is simulated by a single current dipole. Numerically one finds the six parameters for the theoretical dipole that minimizes the residual sum of squares of the differences between theoretical and empirical potentials at the surface recording sites. That is, one minimizes,

$$\mathrm{RHO}(p_1,p_2,p_3,m_1,m_2,m_3)=$$

$$\sum_{j=1}^{n}(V(A_j,D)- V(A_j))^2 \Big/ \sum_{j=1}^{n}(V(A_j)^2$$

where A_j is an electrode site,$V(A_j)$ is the empirical potential at A_j, $V(A_j,D)$ is the theoretical potential at A_j produced by the dipole $D(p_1,p_2,p_3,m_1,m_2,m_3)$ and n is the number of electrode sites.

This method was used by Kavanagh et al and Sencaj and Aunon to investigate the responses to non-patterned light flash and visual pattern stimulation,respectively; Sances et al and Sidman et al applied the technique to somatosensory potentials evoked by median nerve stimulation.[2,4,5,6,7]

With the exception of the last reference these papers have used averaged evoked responses at isolated time points or latencies following the stimulus as input data. These time points have generally been chosen to coincide with the time of occurrence of a potential peak or a reversal of polarity between two scalp recording sites. Since the model greatly simplifies the architectural and functional complexity of the head these authors have been justifiably wary about assigning a physiological meaning to the theoretical source produced by the minimization process.

In our applications we have used this method to calculate the theoretical dipole sources for averaged surface data recorded at a sequence of equally spaced time points in an evoked response record. The rate at which data is sampled has been dictated by the need to encompass the important features or components of a response. We have sampled every ½-1 msec. to detect early somatosensory components, every 3 msec. for the response to an unpatterned light flash and every 6 msec in an application to the visual backward masking paradigm.[3]

If,during an epoch containing a particular EP feature,the minimum values of RHO remain small and if the direction and loci of the minimizing dipoles remain relatively stable, we have inferred that the underlying neural generator is synchronous and possibly localized. In these cases we have attempted to assign a physical meaning to the theoretical source.

We feel that it is important to apply the method over an entire epoch rather than at the isolated time points at which certain potential peaks or polarity reversals occur. By noting continuous changes in the locus and direction of the theoretical source we may be able to draw some conclusions about the dynamic changes in the underlying neural generators as various features in the scalp recorded data appear.

A method for identifying"components"

The following analysis involves data from two experiments; the averaged responses to unpatterned light flash(Augusta,Ga.VA Hospital) and the averaged responses to a shock to the

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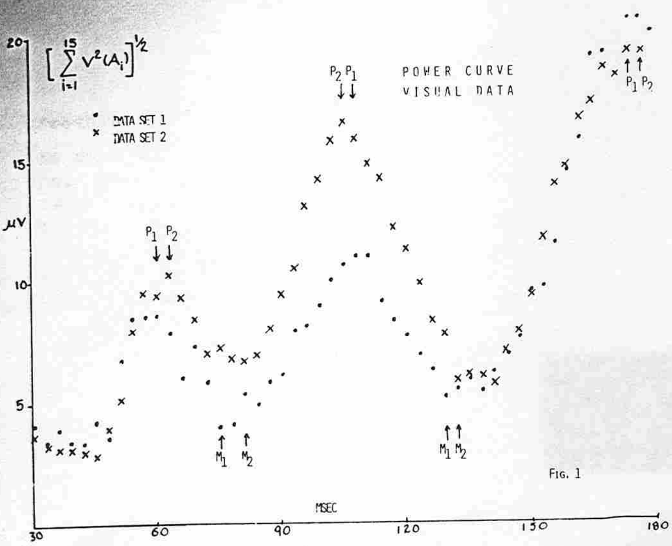

Fig. 1

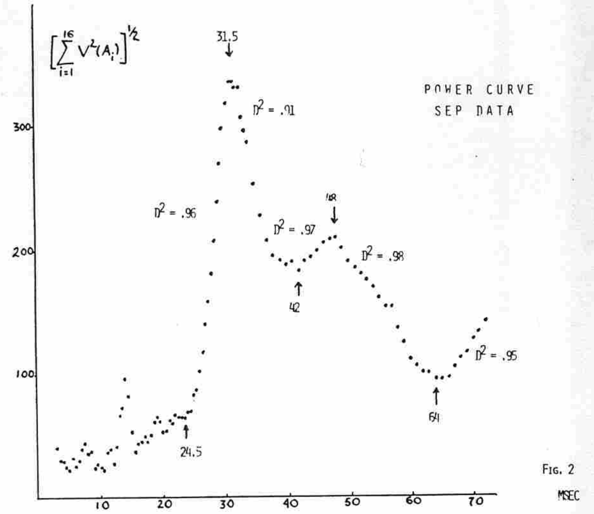

Fig. 2

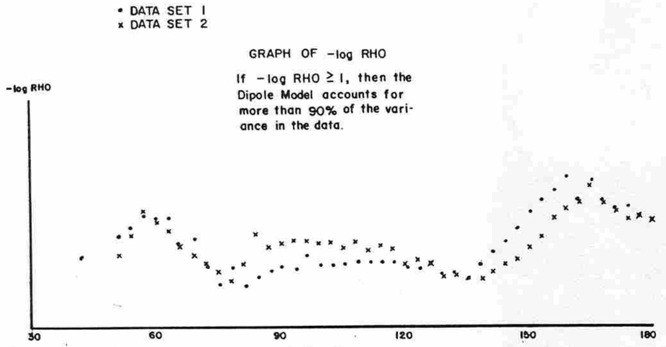

Fig 3

right median nerve(West Haven,Conn. VA Hospital).

In the visual experiment two sets of data were recorded from a single subject. The recording montage consisted of 15 of the 10-20 International System electrode sites referred to linked ears. For each data set the potentials were averaged over 64 stimuli and DLM was applied every 3 msec.

In the somatosensory experiment scalp data was recorded simultaneously from 16 (nonstandard) electrode sites. The reference was again linked ears and responses were averaged over 64 stimuli, DLM was appied every $\frac12$-1 msec.

Figures 1 and 2 show graphs of

$$\left(\sum_i V^2(A_i)\right)^{\frac12},$$

a measure of power, as a function of latency time for the visual and somatosensory experiments, respectively.

In figure 1 the arrows labelled $P_{1,2}$ point to power peaks and occur,for data set 1 at latencies 57 msec.,105 msec.,and 174 msec., and,for data set 2, at latencies 60 msec.,102 msec.,amd 174 msec. $M_{1,2}$ refer to minima and occur at 75 msec. and 129 msec. for the first set of data ,and at 81 msec. and 132 msec. for the second set.

In figure 2 the latencies for peaks and minima are shown on the graph. At the West Haven VA Hospital the data was multiplied by a constant factor giving rise to the vertical scale in this figure.

In each case the power peaks occur at latencies or during epochs that have been considered significant in other studies. The three power peaks for the visual experiment occur during the three independent periods of activity identified through factor analysis.[1] The two power peaks for the somatosensory experiment occur at latencies close to those of the so-called P30-N30 and P55-N55 components.

Determining the "noisiness" of the data

In figures 1,2 we noted that the power graphs appeared to be linear between a successive minimum and peak. For each inter-extremum interval the linear regression of power on latency was performed and the square of the coefficient of determination, D^2, was calculated. This number measures how closely a line fits the data and would be the same as the correlation coefficient if latency time were a random variable.

We have tentatively decided that if $D^2 \geq 0.9$ then the underlying neural source for the scalp recorded potential is synchronous and sufficiently noise-free to apply DLM. Conversely the more random(nonlinear) the data appears the less confident we have been that a synchronous source,if one is active,can be discriminated by DLM.

With the exception of the first peaks in figure 1, D^2 was greater than 0.9 for every inter-extremum interval. In these exceptional cases, D^2 = 0.81 for the time interval 57-72 msec., data set 1, and $D^2=0.87$ for the time interval 60-78 msec., data set 2. Although neither of these values satisfies the criterion mentioned above we have greater confidence in any results derived from the second data set concerning the first power peak.

DLM results

Figure 3 shows the graph of - log RHO as a function of latency for the data from the visual experiment. If - log RHO $\geq$ 1 then RHO $\leq$ 0.1. We have again taken the heuristic approach that if RHO is less than 0.1 then a dipole is a reasonable model for simulating the neural generators of the scalp data. Conversely, if RHO exceeds 0.1 then a dipole does not account for a sufficient amount of the variance in the data. (Kavanagh *et al* used factor analysis to argue that a dipole, with its six parameters, can be used to account for more than 90% of the variance in the data for the visual components discussed above[1] .)

DLM results were computed and graphed for time intervals containing the power peaks noted in the first two figures. These intervals generally included those time points from the midpoint of the inter-extremum interval preceding the peak to the midpoint of the inter-extremum interval following the peak- intervals over which RHO remained small.

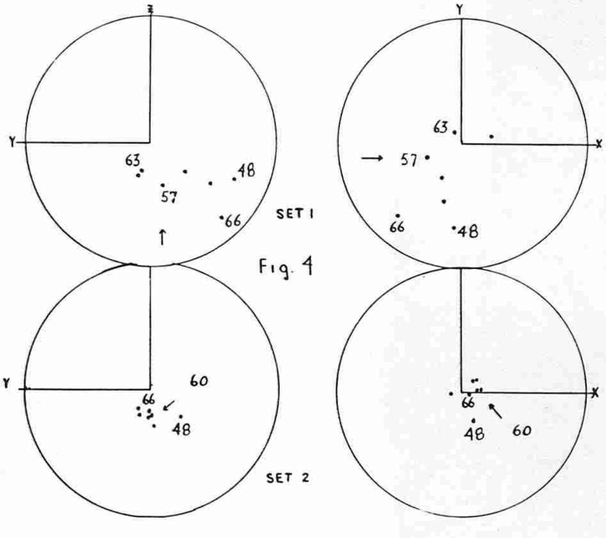

Fig. 4

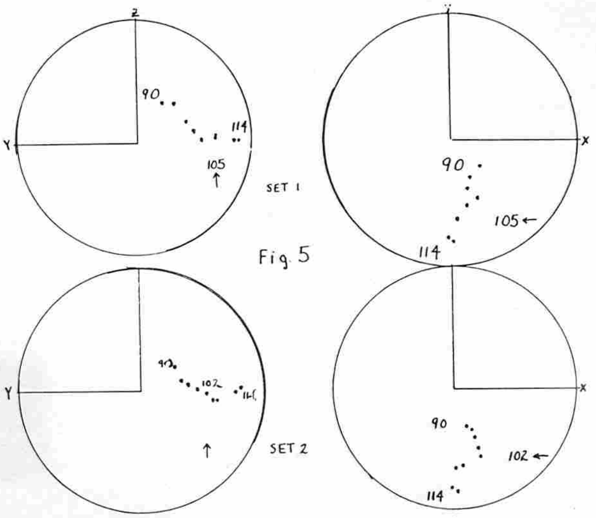

Fig. 5

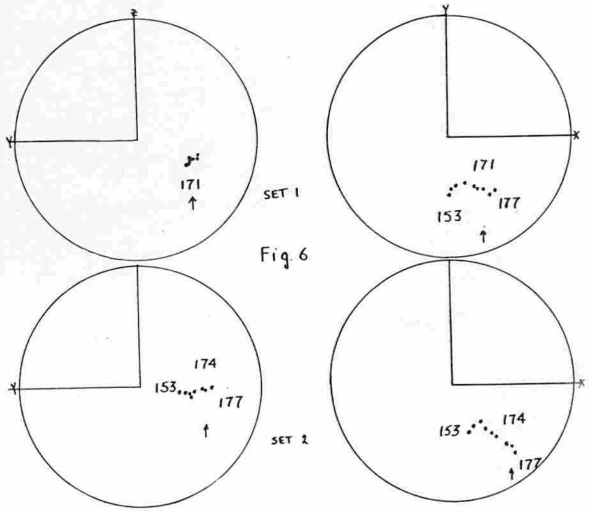

Fig. 6

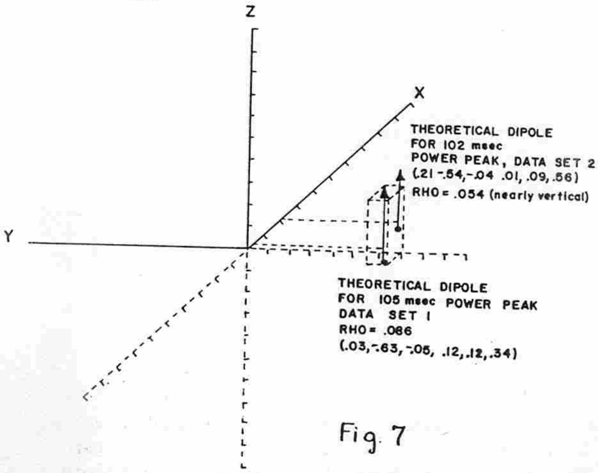

Fig. 7

In figures 4-6 we have shown, for the visual experiment, the theoretical source loci for those time intervals for which RHO 0.1 . The coordinate system for the sphere that simulates the head was chosen so that the z-axis passed through the vertex C_z, the x-axis coincided with the inter-aural line, and the y-axis passed from a point below the inion through a point below the nasion- that is, the origin lies in a region that would be occupied by the "thalamus", the "calcarine fissure" lies in the ~~y-z~~ x-y-plane, and "primary visual cortex" lies in a plane parallel and close to the x-y-plane.

Figures 7 and 8 show the orientation of the virtual source for two of the power peaks.

The theoretical dipolar sources for the time interval 48-66 msec.,data set 2, are centric.(Recall that comparable results for data set 1 are suspect since D^2=.81) The theoretical sources for the time interval 90-114 msec. for both data sets lie toward the "occipital pole" near the"calcarine fissure",and are oriented vertically (perpendicular to "primary visual cortex"). The theoretical sources for the time interval 153-177 msec. also seem to lie in the plane simulating the "primary visual cortex".

Stating these results in a somewhat less speculative way- the loci and orientation of the theoretical sources of these potentials correspond rather well to areas of the cortex known to be active during visual processing.

The last figure (9) shows the theoretical source associated with the second power peak of the somatosensory experiment(the P55-N55 component). This component was discussed last year at this meeting. When these results are corrected to account for the presence of the skull the source is superficial and near the vertex(the correction requires that the source be moved radially, 63% closer to the surface of the sphere).

We remark that for the visual modality the active area of the cortex is extended and would be better simulated by a dipole layer.

Concluding remarks

The preceeding observations are speculative. However, we hope to be able to establish the statistical significance of these ideas by applying them to the wide variety of scalp,pial surface, and depth recorded evoked data,that will be available from the neuropsychology laboratory at the West Haven,Conn. Veterans Administration Hospital and the neurology department of the Augusta,Georgia VA Hospital.

Averaged evoked potentials to all three major stimulus modalities and brain stem EP's will be recorded from age matched normal controls and subjects who have suffered from cerebral vascular accidents,lesions,and demyelinating and epileptiform disorders.

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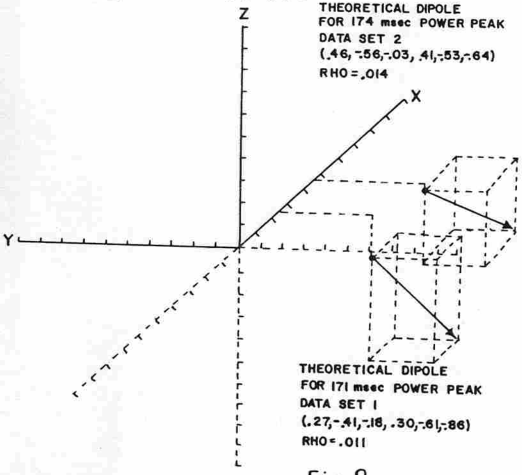

Fig. 8.

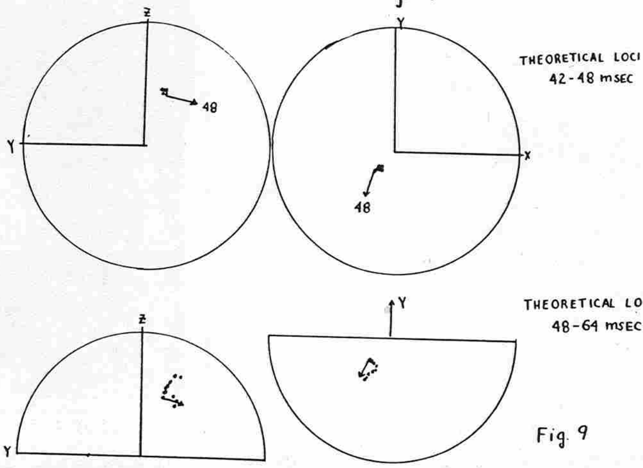

Fig. 9