Striate Cortical Generators of the N75, P100 and N145 Components Localized by Pattern Reversal Visual Evoked Magnetic Fields

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HATANAKA, K., NAKASATO, N., SEKI, K., KANNO, A., MIZOI, K. and YOSHIMOTO, T. *Striate Cortical Generators of the N75, P100 and N145 Components Localized by Pattern Reversal Visual Evoked Magnetic Fields*. Tohoku J. Exp. Med., 1997, **182** (1), 9–14 ——— Magnetic fields evoked by checkerboard pattern reversal visual stimulation to the monocular left or right half-field were recorded over the whole head using a helmet-shaped 64 channel magnetoencephalography system in fourteen normal subjects. The sources of the triphasic N75m-P100m-N145m responses were located using a single current dipole model. Relative locations and orientations of the N75m and N145m dipoles to the P100m dipole were calculated for each subject to reduce errors due to anatomical variability and then averaged for all subjects under the same stimulus conditions. These averaged parameters showed that N75m and N145m originated from the same location in the striate cortex as P100m and reversed their orientations successively by 180° during the time course. ——— visual evoked potential; magnetoencephalography; primary visual cortex; pattern reversal stimulation; N75, P100, N145 components
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The most common components of the transient pattern reversal visual evoked potentials (VEPs) in normal subjects are the waves N75, P100 and N145 (Halliday 1982; American Electroencephalographic Society 1984). These waves are frequently used for evaluation of visual pathways and diagnosis of patients (Kuroiwa and Celesia 1981). However, there is no general agreement about the origins of these components, especially for the minor negative components of N75 and N145 (Halliday and Michael 1970; Barrett et al. 1976; Celesia et al. 1982; Štruel et al. 1982; Maier et al. 1987), because surface recorded VEPs cannot provide unambiguous information about the location of the potentials (Young 1981). Invasive intracranial recording of VEPs in humans is rare (Ducati et al. 1988), but recently the P100 origin was localized to the visual cortex in close

proximity to the calcarine fissure (area 17, 18 or both) (Noachtar et al. 1993). We recently showed that P100 originates from the lateral bottom of the calcarine fissure (area 17) using visual evoked magnetic fields (VEFs) (Seki et al. 1996). This method is non-invasive and has excellent time resolution. In principle, VEFs are more accurate for source localization than VEPs. P100 is the most prominent wave and therefore is the most frequently used landmark for clinical applications, but N75 and N145 are generally observed in association with P100 and have much the same diagnostic value. Therefore, localization of the origins of N75 and N145 is important for clinical diagnosis of patients. Moreover, the time course of information processing in the human visual cortex is very important to investigate the organization of the human visual system.

SUBJECTS AND METHODS

Fourteen healthy male subjects, aged 25 to 51 (mean 34.1) years without neurological or ophthalmological abnormalities, participated in this study. Visual stimulation consisted of reversal of a green-black checkerboard pattern, with each square subtending 0.9° of arc measured at the subject's eye and the total stimulated field subtending $9^\circ \times 9^\circ$. The wavelength of the green squares was 555 nm (half maximum width 30 nm), and the brightness was adjusted to 22 cd/m², with a contrast of greater than 99% to the black squares. The fixation point was 0.9° lateral to the center of the pattern edges, and left or right half-field stimulations were carried out monocularly to the right eye. Recordings were made in a darkened magnetically shielded room using a 64-channel magnetoencephalography (MEG) system (CTF Systems, Inc., Port Coquitlam, Canada). Magnetic fields evoked from the brain were detected by 64 first order gradiometer pickup coils of 20 mm diameter and 50 mm baseline installed in a helmet-shaped liquid helium vessel. The mean inter-coil spacing was 42 mm and coils were uniformly distributed over the scalp. The pattern reversal interval was 500 ms. Two hundred responses were passed through a low-pass filter with a cut off frequency of 100 Hz and notch filters of 50 and 100 Hz to remove line noises, then digitally sampled at 625 Hz and averaged. Two trials were carried out under the same stimulation conditions for each subject to confirm the reproducibility. Source localizations used the Grynszpan-Geselowitz equation (Grynszpan and Geselowitz 1973). This model accounts for the influence of the volume currents within a sphere. The 'best sphere' fit for the head of each subject was determined by magnetic resonance imaging (MRI). The locations and the orientations of the source current are specified as x , y , z , ϕ , θ , and Q values as follows: x , y , z are the position of the current dipole in the MEG coordinate system, x for anterior, y for left lateral, and z for upward direction; ϕ is the azimuth angle between the x -axis and the orientation of the current dipole on the horizontal plane; θ is the declination angle between the z -axis and the orientation of the current dipole on the vertical plane; Q is the dipole moment. The origin of the MEG coordinate

Fig. 1. Examples of (a) waveforms and (b) isofield maps of the visual evoked magnetic fields to right half-field stimulation. The triphasic N75m-P100m-N145m components are clearly shown. The isofield maps for each peak latency are indicated as top down views on the schematic head. The white area shows outgoing magnetic fields and the gray area shows ingoing fields. In all three maps, a single current dipole (arrow) is located in the left visual cortex which inverted with time.

system is at the intersection of the vertical line from the nasion and the line joining the left and right preauricular points. The nasion and the two preauricular points were marked as common fiducial points for matching the MEG and MRI coordinate systems by small coils for MEG and oil-containing capsules for MRI.

RESULTS

Typical data for the visual evoked magnetic responses and the iso-magnetic field contour maps from a subject during right half-field stimulation are shown in Fig. 1. The triphasic N75m-P100m-N145m (magnetic counterpart of N75-P100-N145) complex is clearly seen, and the isofield contour maps for each peak latencies show that the single current dipole approximation is applicable. Dipole fit error due to residual magnetic fields which could not be explained by single current dipole source was 1 to 20 %. These fitting errors depend on signal to noise ratio of the measurement. Therefore, multiple current dipole sources in visual cortices could not explain residual magnetic fields.

The equivalent current dipole location of the most prominent P100m component is superimposed on the MRI of the same subject in Fig. 2. The P100m dipole is located at the lateral bottom of the calcarine fissure as shown previously (Seki et al. 1996). This area has been called the lateral calcarine sulcus (Butler et al.

Fig. 2. Dipole source analysis of the pattern reversal visual evoked magnetic fields to (a) right half-field and (b) left half-field stimulation. The location of the P100m dipole is shown by the solid circle and the orientation by the rod superimposed on the MRI. Mean relative locations and standard deviations of the N75m and N145m dipoles to P100m are also shown as solid squares with bars. The triphasic N75m-P100m-N145m components originate from the almost same location at the bottom of the calcarine fissure (area 17) and not from the extrastriate cortex such as the lingual gyrus (area 18) or fusiform gyrus (area 19). c: calcarine fissure, po: parieto-occipital fissure, lg: lingual gyrus, fg: fusiform gyrus.

1987) or the secondary striate cortex (Stensaas et al. 1974). The P100 dipoles are usually oriented along the depth direction of the calcarine fissure.

Since x , y , z are absolute coordinates of the dipole in the MEG system defined for each subject, calculation of mean positions for statistical analysis of the responses is inappropriate. The anatomical variability of the topographical structure of the calcarine fissure (Stensaas et al. 1974) makes direct comparison between subjects even more difficult. However, the location and orientation of P100m are quite stable and reproducible. Therefore, this point can act as a reference for the relative locations and orientations of the N75m and N145m dipoles. The mean values for these relative parameters are calculated for each component and stimulation condition. The mean relative locations of N75m and N145m with standard deviations are also depicted in Fig. 2.

DISCUSSION

The results of the source localization shown in Fig. 2 clearly demonstrate that N75m and N145m originate in the same region as P100m and not from extrastriate cortex such as the lingual gyrus or fusiform gyrus. The spatial coordinates of the N75 m and N145 m dipole do not differ statistically (t -test, $p < 0.05$) to the P100 m dipole. The relative orientations in both azimuth and declination angle clearly show 180° reversal (t -test, $p > 0.95$) which further supports the conclusion that N75m, P100m and N145m all originate from the same small area of the primary visual cortex.

These experimental results confirm that the origins of the triphasic N75m-

P100m-N145m responses to pattern reversal stimulation are located in the striate cortex. This is remarkable because pattern VEPs have been assumed to contain contributions from several cortical regions and processes (Celesia et al. 1982; Štruel et al. 1982). We do not consider that the extrastriate cortex was not functioning during these time latencies. Instead, we assume that activities in the extrastriate cortex were not observable by VEPs simply because of wide distribution or low synchronization which result in cancellation when averaging techniques are used (Noachtar et al. 1993). One major task for the future is to investigate the specific functions of the extrastriate areas by selecting appropriate visual stimuli.

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References

- 1) American Electroencephalographic Society (1984) Recommended standards for visual system evoked potentials. *J. Clin. Neurophysiol.*, **1**, 15–31.
- 2) Barrett, G., Blumhardt, L., Halliday, A.M., Halliday, E. & Kriss, A. (1976) A paradox in the lateralization of the visual evoked response. *Nature*, **261**, 253–255.
- 3) Butler, S.R., Georgiou, G.A., Glass, A., Hancox, R.J., Hopper, J.M. & Smith, K.R.H. (1987) Cortical generators of the CI component of the pattern-onset visual evoked potential. *Electroencephalogr. Clin. Neurophysiol.*, **68**, 256–267.
- 4) Celesia, G.G., Polcyn, R.D., Holden, J.E., Nickles, R.J., Gatley, J.S. & Koeppe, R.A. (1982) Visual evoked potentials and positron emission tomographic mapping of regional cerebral blood flow and cerebral metabolism: Can the neuronal potential generators be visualized? *Electroencephalogr. Clin. Neurophysiol.*, **54**, 243–256.
- 5) Ducati, A., Fava, E. & Motti, E.D.F. (1988) Neuronal generators of the visual evoked potentials: Intracerebral recording in awake humans. *Electroencephalogr. Clin. Neurophysiol.*, **71**, 89–99.
- 6) Grynszpan, F. & Geselowitz, D.B. (1973) Model studies of the magnetocardiogram. *Biophys. J.*, **13**, 911–925.
- 7) Halliday, A.M. (1982) Visual evoked potential in healthy subjects. In: *Evoked Potentials in Clinical Testing*, edited by A.M. Halliday, Churchill Livingstone, Edinburgh, pp. 71–120.
- 8) Halliday, A.M. & Michael, W.F. (1970) Changes in pattern-evoked responses in man associated with the vertical and horizontal meridians of the visual field. *J. Physiol. (Lond.)*, **208**, 499–513.
- 9) Kuroiwa, Y. & Celesia, G.G. (1981) Visual evoked potentials with hemifield pattern stimulation. Their use in the diagnosis of retrochiasmatic lesions. *Arch. Neurol.*, **38**, 86–90.
- 10) Maier, J., Dagnelie, H., Spekreijse, H. & van Dijk, B.W. (1987) Principal components analysis for source localization of VEPs in man. *Vision Res.*, **27**, 165–177.
- 11) Noachtar, S., Hashimoto, T. & LGders, H. (1993) Pattern visual evoked potentials recorded from human occipital cortex with chronic subdural electrodes. *Electroencephalogr. Clin. Neurophysiol.*, **88**, 435–446.
- 12) Seki, K., Nakasato, N., Fujita, S., Hatanaka, K., Kawamura, T., Kanno, A. & Yoshimoto, T. (1996) Neuromagnetic evidence that the P100 component of the

- pattern reversal visual evoked response originates in the bottom of the calcarine fissure. *Electroencephalogr. Clin. Neurophysiol.*, **100**, 436-442.
- 13) Stensaas, S.S., Eddington, D.K. & Dobelle, W.H. (1974) The topography and variability of the primary visual cortex in man. *J. Neurosurg.*, **40**, 747-755.
 - 14) Štrucl, M., Prevec, T.S. & Zidar, I. (1982) Dependence of visual evoked potentials on change of stimulated retinal area associated with different pattern displacements. *Electroencephalogr. Clin. Neurophysiol.*, **53**, 634-642.
 - 15) Young, W. (1981) The interpretation of surface recorded evoked potentials. *Trends Neurosci.*, **4**, 277-280.
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