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Multifocal Visual Evoked Potential Is Dependent on Electrode Position

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Purpose: To investigate whether the multifocal visual evoked potential (mVEP) is dependent on the electrode position, and to confirm the reproducibility of the mVEP.

Methods: The mVEPs were recorded using the Veris III system with two different bipolar electrode settings. In Position 1, electrodes were placed at equal distances in vertical alignment 2 cm above and below the inion. In Position 2, the electrodes were placed in horizontal alignment at equal distances 2 cm to the left and right of the inion. Dartboard pattern stimulation was conducted. The mVEPs were repeatedly recorded from 4 volunteers, and mainly the second-order kernel response components were analyzed.

Results: Although the reproducibility of mVEP was good in both Position 1 and Position 2, each waveform of the mVEP was drastically different between the two positions. This difference in the waveforms was clearly shown in the center and at the horizontal meridian. We also investigated the first-order kernel response components of the mVEPs. Several traces of the first-order kernel response components did not reveal flat traces. This point is also worthy of consideration.

Conclusion: Responses from mVEPs are clearly dependent on the electrode position.
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Key Words: Electrode position, multifocal visual evoked potential, reproducibility.

Introduction

The visual evoked potential (VEP) is usually recorded using a pair of electrodes placed on the scalp and photopic or pattern stimuli. Pattern VEP gives us useful information about the diagnosis and progress of optic nerve disease.[1–4] We have already reported that using a dartboard pattern, a significantly larger P50 amplitude of pattern electroretinogram (PERG) was obtained from normal volunteers in comparison with a conventional checkerboard-reversing pattern.[5] Recently, the multifocal electroretinogram (mfERG) has been developed by Sutter and Tran.[6] Baseler et al[7] recorded VEP using the same Veris system as used for recording mfERG. They used a 60-segment dartboard pattern stimulus and a bipolar electrode setting.[8] Since then, other investigators have used similar stimulus and recording parameters.[9–11] Our question is whether these various dipoles, if any, could be completely expressed using a one-channel electrode setting. In this study we investigated the effect of electrode position on the multifocal VEPs (mVEPs), in addition to their reproducibility.

Materials and Methods

mVEP Stimulation and Recording

mVEPs were recorded using a Veris III™ system (Mayo, Inazawa, Aichi) and a Veris Science™ soft-

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ware program. The visual stimulus consisted of 60 segments (Dartboard 60 with pattern; Figure 1A) each with 16 checks, 8 white, and 8 black. The contrast reversal modulation of each patch was controlled by binary m-sequences that can be represented as pseudorandom. Mean luminance was 91 cd/m^2, and 95% contrast was selected. Analysis time was 280 milliseconds. The circular field size was 41.2° in visual angle. The visual stimulus was generated on a black and white monitor (MD-B1700; Chuomusen, Tokyo) at a frame rate of 75 Hz. It took 8 minutes to obtain one full mVEP recording.

The subject was seated comfortably, with chin and forehead tightly fixed, and was asked to fixate monocularly on the fixation point in the center of the CRT monitor. The tested eye maintained the fixation during stimulation. The distance between the tested eye and the CRT monitor was 32 cm. Signals were amplified using the model 12-4 Neurodata Acquisition System™ (Astro-Med, Grass Instrument Division, West Warwick, RI, USA), and the band pass was filtered from 1 to 100 Hz. The second-order kernel response component (first slice) was analyzed.

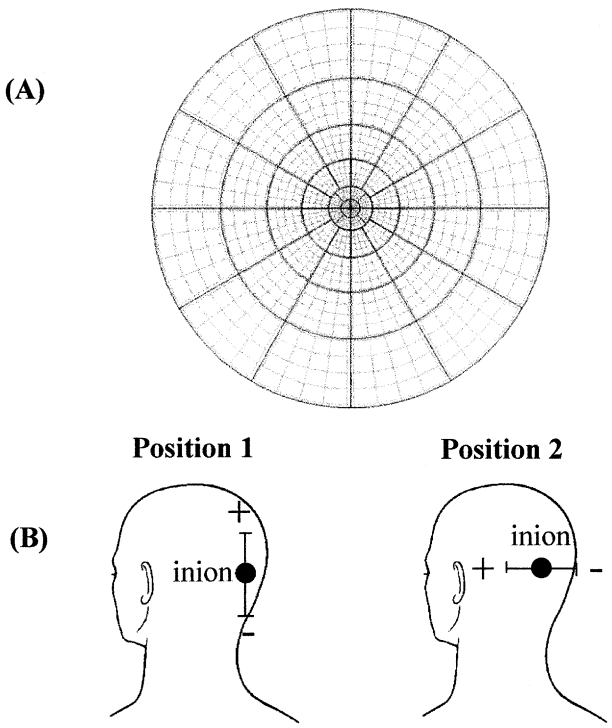


Figure 1. (**A**) Dartboard stimulus used in our study. The dartboard array consists of 60 individual stimulus elements. Each of the 60 patches contains a black and white checkerboard pattern with uniform luminance and 16 checks, which alternate pseudorandomly between two states. (**B**) Electrode placement. In Position 1, electrodes are placed at equal distances in vertical alignment 2 cm above and below the inion. In Position 2, electrodes are placed in horizontal alignment at equal distances 2 cm to the left and right of the inion. A ground electrode is attached to the right earlobe.

Each experiment was repeated three times, and the reproducible mVEP traces were averaged using a Combination program built into the Veris Science™ program. This Combination software program has an effect similar to that of the averaging summation technique and enables us to recognize more clearly an evoked small signal in a large irregular background. Neither the Artifact Removal nor the Spatial Averaging procedure was used in this study.

Electrode Placement

The mVEPs were recorded with two different bipolar electrode settings. The electrode placements are illustrated in Figure 1B. In Position 1, electrodes were placed in vertical alignment at equal distances 2 cm inferior (negative) and 2 cm superior (positive), straddling the inion. In Position 2, electrodes were placed in horizontal alignment at equal distances 2 cm to the right and 2 cm to the left of the inion. A ground electrode was attached to the right earlobe.

Subjects

The mVEPs were recorded from 4 volunteers, A to D, ranging from 18 to 36 years of age. They were given a routine visual examination and the results showed that they had corrected Snellen acuity of 20/20 or better and normal visual fields. None of them had any history of ophthalmologic abnormality. The profiles of each subject from A to D are shown in Table 1. The study followed the tenets of the Declaration of Helsinki, and informed consent was obtained in advance from each subject.

Results

Comparing the mVEP Using Different Electrode Positions

Figure 2 shows typical mVEP response arrays. This particular example was recorded from subject A. The left column, Position 1, presents the results with the vertical electrode alignment, while the right

Table 1. Subject Information

Subject	Age	Eye	Visual Acuity	Diagnosis
A	30	OD	20/20	Normal
B	32	OD	20/20	Normal
C	18	OD	20/20	Normal
D	36	OD	20/20	Normal

column, Position 2, presents the results with the horizontal electrode alignment. There was a distinct difference in the waveforms between Positions 1 and 2, as we can see in Figure 2. This difference in the waveforms is clearly shown in the center and at the horizontal meridian in these 64 elements. The same trials in both positions were repeated three times for each subject to evaluate the reproducibility. The reproducibility of the mVEP was good in both positions.

These four reproducible mVEPs were averaged using the Combination program, and the results are shown in Figure 3A. A distinct difference in the waveforms between Positions 1 and 2 can be observed, in particular in the center and at the horizontal meridian, not only for subject A but also for the other subjects.

Figure 3B illustrates each summed upper and lower hemifield response from the 4 subjects, A, B, C, and D. In each subject, there was a difference in the waveforms between Positions 1 and 2. There were also individual differences in the mVEP traces among the 4 subjects. Furthermore, the polarity of the major components in each of the summed upper

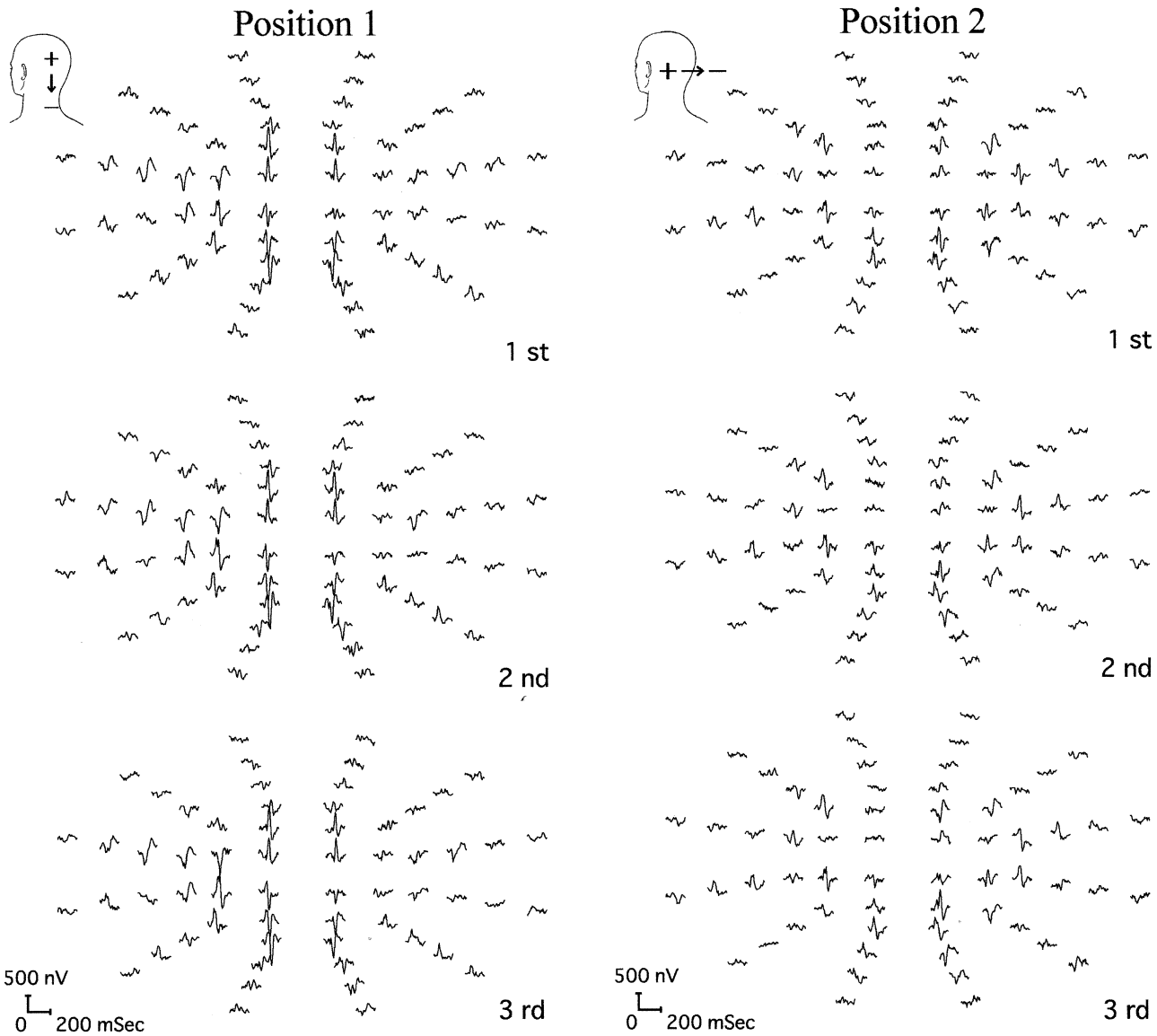
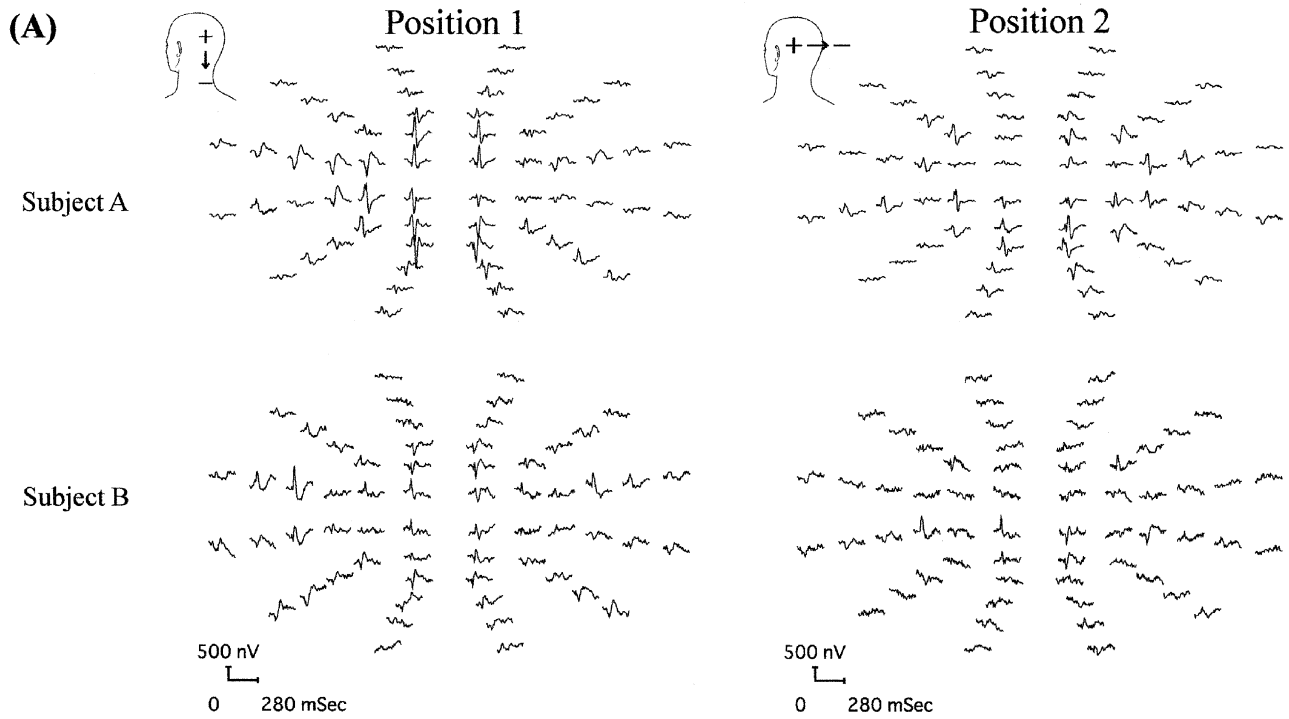
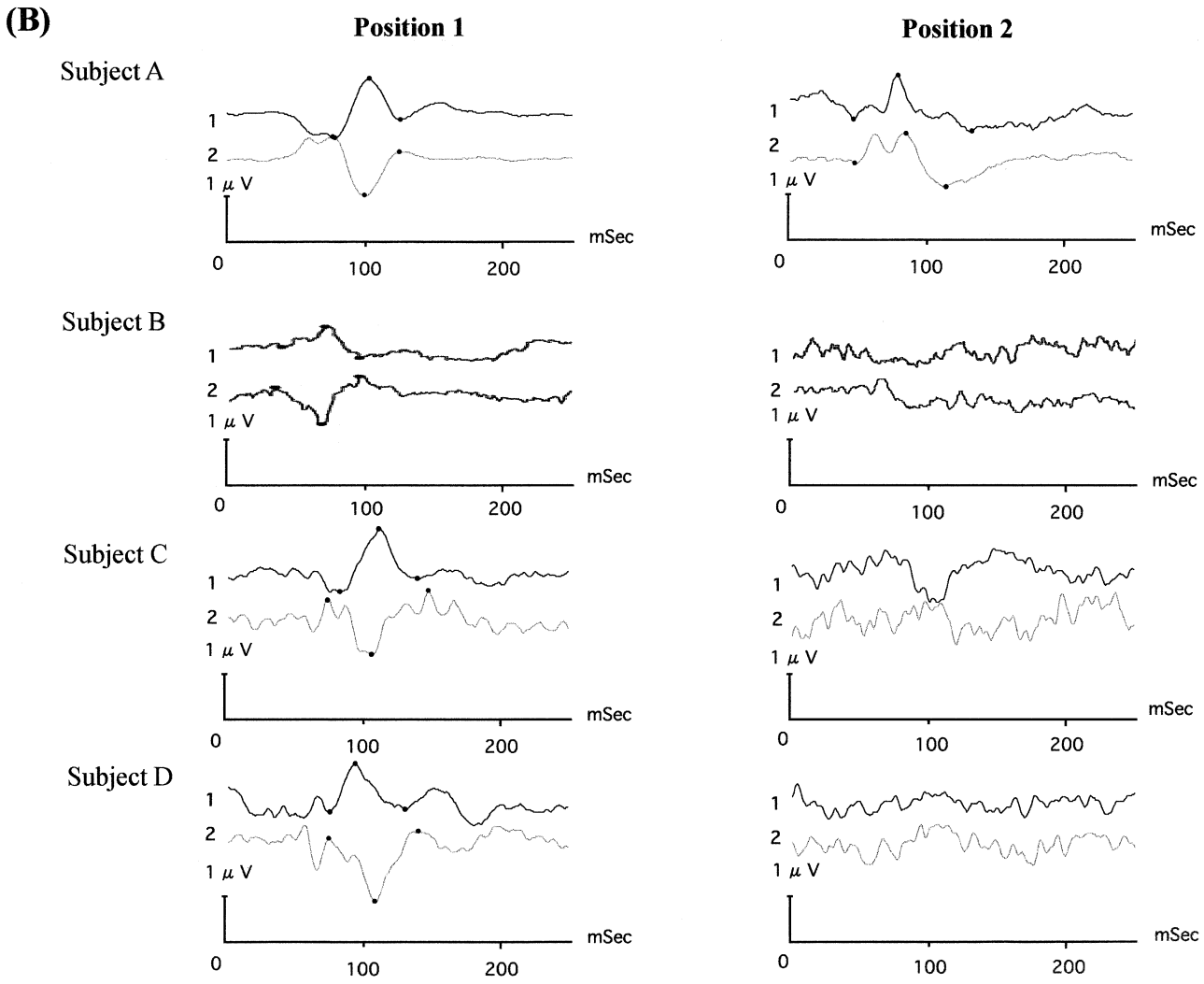


Figure 2. Examples of multifocal visual evoked potential traces recorded from normal subject A. Position 1 (left) was with vertical alignment of electrodes, while Position 2 (right) was with horizontal alignment of electrodes. Three trials were repeated in the same way to assure the reproducibility.


(A)
Position 1
Position 2
Subject A
Subject B
500 nV
0
280 mSec
500 nV
0
280 mSec


(B)
Position 1
Position 2
Subject A
Subject B
Subject C
Subject D
1
2
1 μ V
mSec
0
100
200

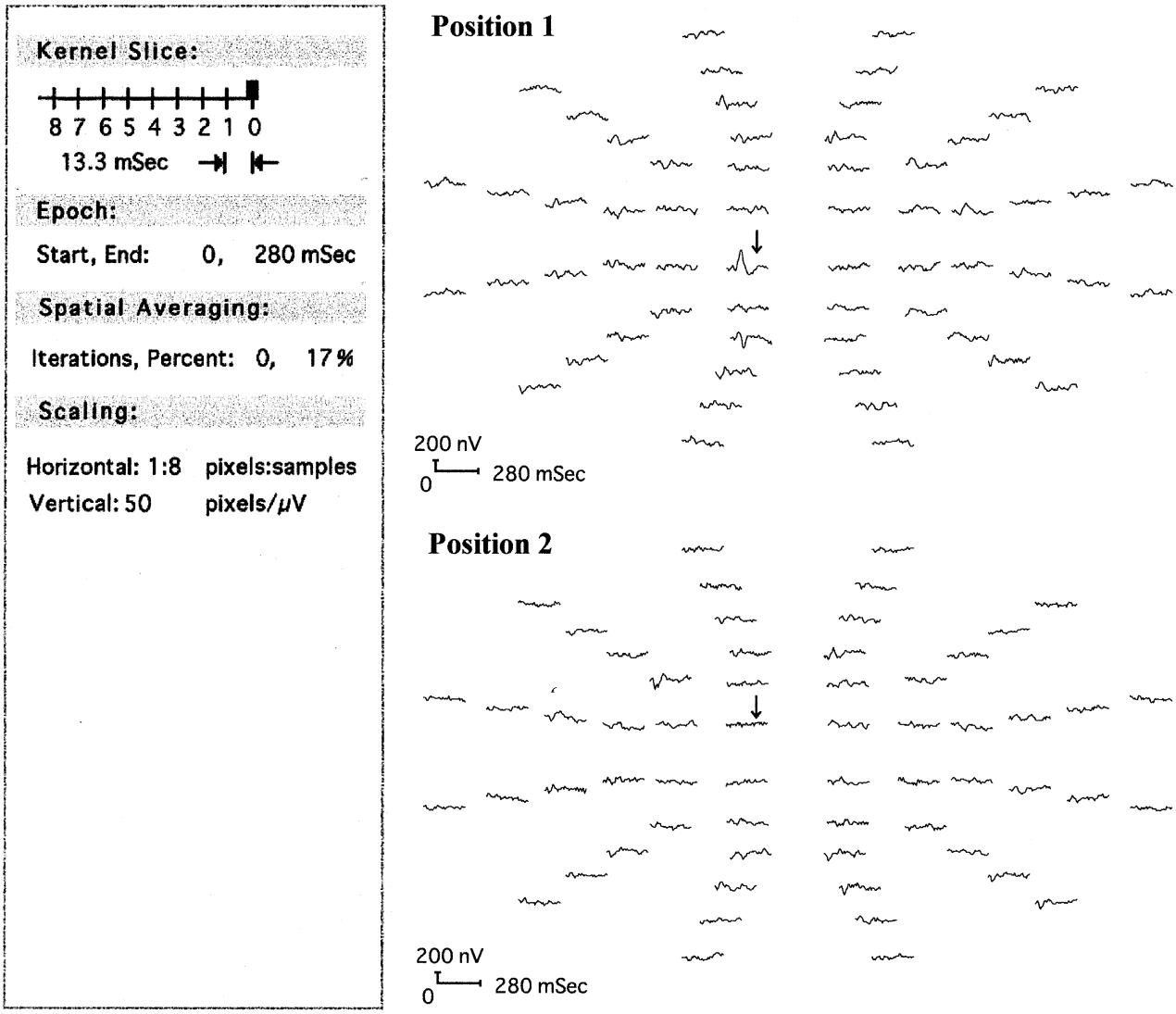


Figure 4. Examples of multifocal visual evoked potential traces recorded from the right eye of subject A using first-order kernel response components. Upper: Position 1, lower: Position 2.

and lower hemifield responses demonstrated an opposite character in Position 1. However, the opposite character was ambiguous in Position 2.

The First-order Kernel Response Components of mVEPs

The second-order kernel response components of mVEPs were analyzed in this study. Finally, we investigated the first-order kernel response components of mVEPs. Some of the traces of the first-order kernel response components of mVEPs recorded from the right eye in subject A showed clearly recordable responses in Position 1 (Figure 4). As is indicated by an arrow, a large response was obtained from the central stimulated region in Position 1. However, the large response was considerably reduced in Position 2.

Figure 3. (**A**) Examples of multifocal visual evoked potential traces from normal subjects A and B recorded using bipolar occipital straddle electrode placement and averaged using the Combination software. (**B**) Examples of upper and lower hemifield responses derived from normal subjects A, B, C, and D, respectively, and averaged using the Combination software. 1: upper hemifield trace, 2: lower hemifield trace.

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Discussion

These consecutive mVEPs recorded from each normal subject were reproducible regardless of whether the electrode was placed on the occipital scalp vertically or horizontally. mVEPs were not simultaneously recorded using electrode Positions 1 and 2, because we had attempted to avoid noise and to improve reproducibility. Because the reproducibility of mVEPs in each position was very good, it was thought that the mVEPs would be similar when simultaneously recorded. However, the waveforms of mVEPs differed considerably between the results obtained with electrode Position 1 and Position 2 placements. The polarity reversal between the averaged hemifield responses was observed in Position 1. This result accords with the previous reports.[6,7,10,12] However, when the electrode placement was changed from Position 1 to Position 2, the polarity reversal became ambiguous.

The dartboard pattern stimuli may produce many electrical dipoles that have various vectors around the visual cortex, because the dartboard pattern seems to consist of more complicated elements than a conventional checkerboard pattern. These findings suggest that mVEPs elicited by the multifocal technique cannot be easily analyzed using the one-channel recording method. In an experiment on 10 normal volunteers, Yanashima[13] recorded pattern reversal VEPs using nasal and temporal half-field stimuli and horizontal placement on the occipital scalp region, and classified the condition of the surface electrical distribution into three types: anatomical, central, and lateralization type. The half-field VEP study suggests that there are differences in the electrical activity of the brain even for normal subjects. If the electrode placement is not suitable, a reduction in the mVEP responses may be revealed. The same electrical dipole may not always be impaired among various ophthalmic diseases. If an impaired dipole obtained from a patient is detected using suitable electrode placement, the response reduction can be clearly observed. When a reduced mVEP response is observed, it should be considered whether the abnormal mVEP is associated with an inadequate electrode placement or with an ophthalmic disease itself. In other words, it may be difficult to reach a conclusion about traces and the ophthalmic disease they indicate because mVEPs tend to change largely depending on the electrode position. In extreme cases, it may be possible that the mVEP abnormality indicated in an ophthalmic patient cannot always be attributed to the property of an eye disease.

Finally, we are inclined to be hesitant about using the second-order kernel response component in mVEP, based on our previous reports[14–17] on the second-order kernel response component of mfERG. The nonlinear component that is extracted by the subtraction of the first flash and the second flash ERGs from double flash ERG is different from the second-order kernel response component of 75-Hz pseudorandom flicker ERG (double flash stimulation consists of first and second flash stimuli). The first-order kernel response component ought to be zero theoretically under the condition of pattern stimulation when both pattern polarities are equal. This is in contradiction to a paper[9] published in 1998. However, mVEP traces in first-order kernel response components were not actually flat, as shown in Figure 4. This is partly because the intensity of the CRT monitor is not homogeneous under the usual stimulus conditions. In the common stimulation we use, however, it would be possible that pattern polarity is not equal. We need to carry out a further examination to resolve this question.

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