

TECHNICAL CONTRIBUTION

POLARITIES AND FIELD CONFIGURATIONS OF THE VERTEX
COMPONENTS OF THE HUMAN AUDITORY EVOKED RESPONSE:
A REINTERPRETATION¹

KENNETH A. KOOI, ANCEL C. TIPTON AND ROBERT E. MARSHALL

Departments of Psychiatry and Neurology, University of Michigan Medical Center, Ann Arbor, Mich. 48104 (U.S.A.)

(Accepted for publication: January 9, 1971)

Vaughan and Ritter (1970) have recently proposed that all components of the human, average, auditory evoked response (AER) to repetitive stimulation, including the long latency vertex potentials, can be ascribed to a dipole source reversing polarity at the level of the sylvian fissure. This assertion brings to the fore the need for further information about the spatial distribution of vertex potentials over the surface of the head as determined with a remote, non-cephalic reference. Since a true sylvian phase reversal of the late components of the AER would have far-reaching theoretical and clinical interpretive implications, we have been prompted to carry out studies especially relevant to this point.

SUBJECTS AND METHODS

Five normal adult males served as subjects. Three (S1, S2, S3) were studied systematically with a technique that evolved from preliminary experiments in the other two subjects using a variety of electrode arrays and common reference locations.

The scalp electrodes were located in accordance with the 10–20 system placements. Additional electrodes were placed on the nose, on the chin, and on the two sides of the neck in line with the central and temporal electrodes. The distance from the temporal to the neck electrode was made the same as that between the central and temporal electrode. A non-cephalic reference was obtained by interconnecting electrodes applied at the right sterno-clavicular junction and the 7th cervical spine, the cardiac potential being balanced through a 50K potentiometer. A linear array of 7 equally spaced electrodes, extending laterally from a midline point, anterior to the vertex and one-third the distance between the vertex and nasion, to the mastoid process was utilized in some recording sessions.

The auditory stimulus was a 30 msec burst of a 1000 c/sec tone with an intensity of approximately 70 dB above the normal auditory threshold. This was delivered through a Trimm

2K impedance headset actuated by a Grass physiological stimulator modulated in turn by a second Grass stimulator. The stimulus was presented regularly every 2 sec. Sound level was measured by a General Radio type 1551-C sound-level meter.

Response averaging was carried out with 2 CAT 400 computers with synchronized sweep circuits. Amplification was achieved with standard Grass EEG amplifiers. Because the non-cephalic reference introduced a moderate amount of tonic myogenic activity in some subjects, the bandpass of the system was restricted to 1–30 c/sec. The basic procedure involved a summation of 150 responses obtained simultaneously from a set of 8 electrode pairs. The procedure was then repeated, all conditions of the examination remaining unchanged. The system was calibrated by a similar summation of a 10 μ V square-wave pulse. A Hewlett-Packard Model 7004B X–Y recorder fitted with a point plotter was used to chart the data.

The subjects sat in a comfortable lounge-type chair, eyes open, their gazes fixed at midlevel. Background light intensity was moderate.

Wave designations conform to those used by Davis *et al.* (1966).

RESULTS

Inspection of Fig. 1 shows that the anterior–posterior and transverse voltage gradients of N_1 , the principal electro-negative component of the AER, and P_2 , the subsequent electro-positive wave, have a high degree of correspondence in each subject. Polarity relationships remain the same for both N_1 and P_2 at all cephalic sites. Spatial voltage relationships vary from subject to subject, the maximal field strength being at or close to the midline in either the midfrontal (S1 and S2) or posterior frontal (S3) region with differential rates of decline anteriorly, posteriorly and laterally.

The AERs at spaced intervals along the midline of a subject (S1) with substantial nasal activity are shown in Fig. 2.

The transverse voltage gradients of the N_1 – P_2 complex may be essentially symmetrical on the two sides, as exempli-

¹ Presented in part at the 24th Annual Meeting of the American EEG Society, Sept. 17–19, 1970.

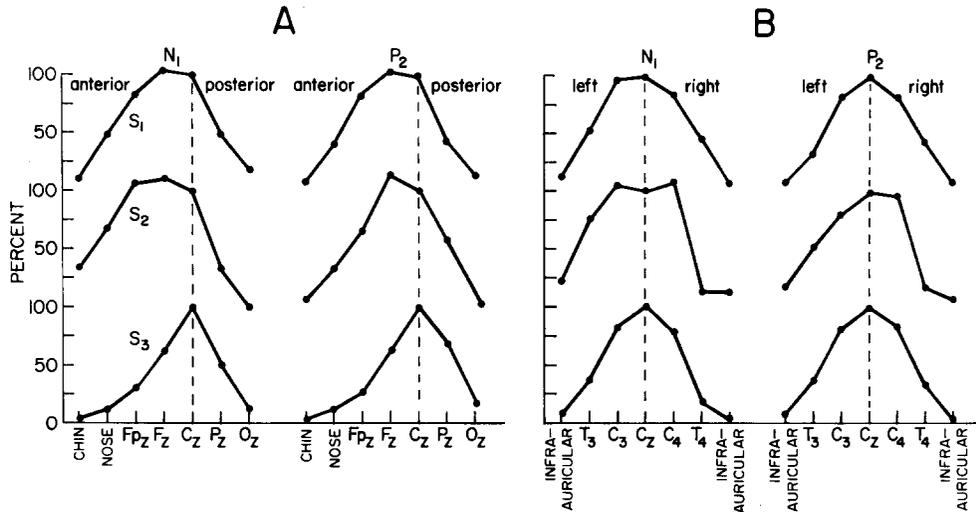


Fig. 1. Graphs show instantaneous cephalic voltage relationships of the N_1 and P_2 components of the AER for midline (A) and transverse (B) montages as derived with a common non-cephalic reference in three subjects (S1-3) for averages of 300 responses. The data are normalized for each component relative to the voltage of the respective deflection at the vertex (C_z). The voltage of N_1 represents the difference in voltage level between the initial electropositive trough and subsequent electro-negative peak of the major triphasic complex. The voltage of P_2 is the difference between the peak and subsequent trough. Instant of trough or peak at vertex (C_z) was taken as point of reference in time for voltage measurements in all areas. Measurements were made separately on each of two sets of 150 responses and combined.

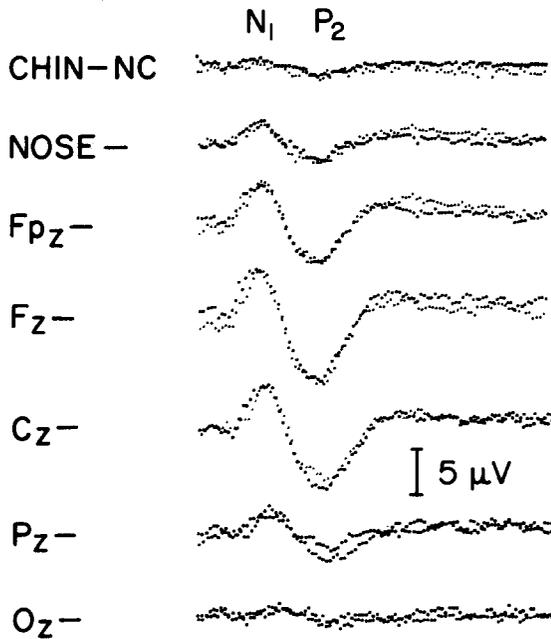


Fig. 2. Primary midline data for S1. In this and subsequent figures, two sets of averages of 150 responses each are superimposed. Analysis period is 500 msec. Negativity is up. Scalp lead designations and placements are those of the 10-20 system of the International Federation. NC, non-cephalic; IA, infra-auricular; L, left; R, right.

figed by S1 (Fig. 1 and 3) and S3, or distinctly asymmetrical, as seen in S2. The activity recorded by the temporal electrodes (T_3 , T_4) warrants particular attention since N_1 is prolonged in the temporal area and may consist of two separate components, the second culminating 25-30 msec later than the vertex negativity.

Consideration of the data illustrated in Fig. 3 makes the results of interconnecting a transverse line of electrodes at approximately the level of the central plane to a common nasal reference predictable. Given the gradually decreasing field strength outward and downward from the general region of the vertex already demonstrated, the representation of the field gradients achieved in this manner will show an instrumental inversion beneath that locus where N_1 and P_2 have essentially the same magnitudes as they have at the nose (Fig. 4). For regions beneath the temporal lobe (LIA), which are inherently almost completely silent, the activity recorded will be largely that contributed by the nasal reference. In the temporal region (T_3), cognizance must be given to the effect of the later culmination of N_1 in determining the final wave form.

DISCUSSION

Because of their point of maximal amplitude, widespread distribution, long latency, similarity of wave form and location with stimuli of different sensory modalities, and occasional occurrence at the time of omission of an expected stimulus (Davis 1939; Davis *et al.* 1939), vertex responses have been generally viewed as reflecting activity within non-specific and diffusely projecting thalamo-cortical pathways. The recent contention of Vaughan and Ritter (1970) is at sharp variance with this concept, their proposal being that all components

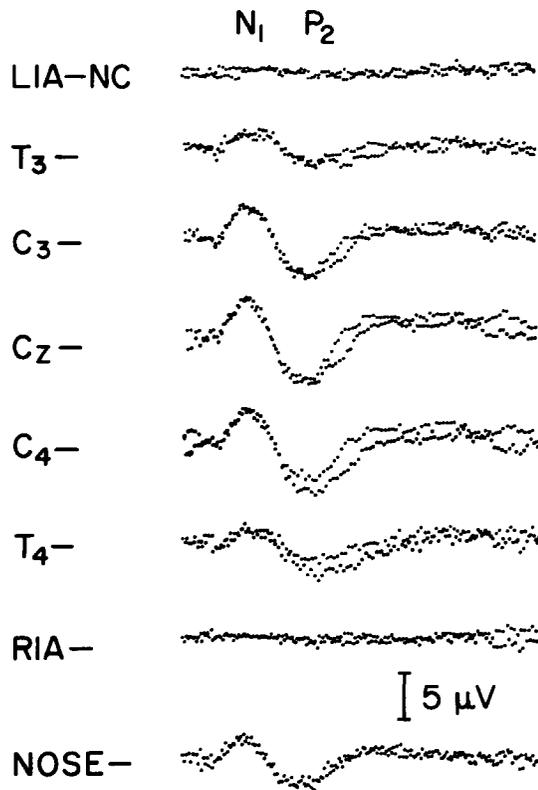


Fig. 3. Primary transverse data for S1.

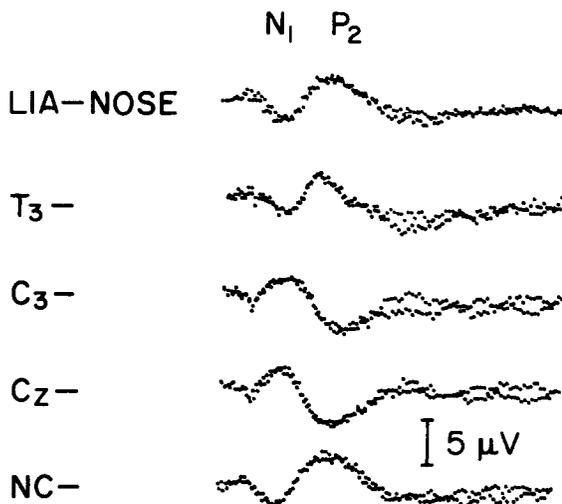


Fig. 4. Results of transverse leads paired with common nasal reference in S1. Compare phase relationships between the various linkages with those illustrated in Fig. 3. Note findings in non-cephalic nose linkage obtained simultaneously.

of at least one type of sensory response—the AER—can be attributed to activity arising in the primary receiving area of the cortex. Our data neither confirm nor controvert the tradi-

tional viewpoint; they are, however, incompatible with Vaughan and Ritter's proposal. The present data, gathered with a remote reference, show no phase reversal of either N_1 or P_2 between leads situated above and below the sylvian fissure, which makes the conclusion inescapable that the field configuration does not conform to that of a horizontally oriented dipole originating in primary auditory cortex. It was brought out further that the choice of a reference site is critical since a simple instrumental phase reversal may simulate a horizontally oriented dipole. The use of a common nasal reference leads to instrumental inversion of the display in the situation under examination because the nasal region is more active with respect to the N_1 and P_2 components than temporal and infratemporal sites.

The substantial size of the voltages recorded from the nasal region—50% or more of the vertex voltages in some subjects—warrants comment. It may reasonably be viewed as a manifestation of one or more factors related to the source voltage, namely, large magnitude, large areal extent, favorable spatial orientation or proximity. These conditions would be satisfied by the presence of numerous, radially oriented neural elements in the prefrontal-orbital cortex responding to an auditory signal. An additional factor may be operating: the effect of the many aerated cavities in the nasal area is to increase local current density by making fewer pathways available for current flow. Voltage, in turn, increases. The opposite situation exists in the temporal region where bulky soft tissue masses act to "shunt" current, leading to rapid diminution of field strength.

Satisfactory evidence of the independence of early and late components of the AER might be derived from clinical data in which a lesion produced a dissociated effect upon one or the other. However, the possibility of reflex myogenic responses obscuring or modifying the early temporal components of the AER, and the inherent proximity of cortical and thalamic portions of the auditory system militates against ready acquisition of this type of data. In the visual system, where anatomical and technical factors are more favorable, dissociated effects are commonplace and attention has been called to two such examples (Kooi and Sharbrough 1966; Kooi and Rengifo 1967).

SUMMARY

The cephalic spatial distributions and phase relationships of the late components, N_1 and P_2 , of the auditory evoked response, elicited by repetitive moderate-intensity tone pips, were assessed in man with a non-cephalic reference. There was no evidence of a polarity reversal at any site on the head, failing to confirm Vaughan and Ritter's (1970) sylvian phase reversal hypothesis.

RESUME

POLARITES ET CONFIGURATIONS DE CHAMP DES COMPOSANTES AU VERTEX DE LA REPONSE EVOQUEE AUDITIVE HUMAINE: REINTERPRETATION

Les distributions spatiales et les relations de phases des composantes tardives N_1 et P_2 de la réponse évoquée auditive

obtenue par stimuli sonores répétitifs d'intensité modérée sont mesurées sur le scalp, chez l'homme, au moyen d'une référence non-céphalique. Cette étude n'apporte aucune preuve d'une inversion de polarité à un point quelconque de la tête, ce qui ne confirme pas l'hypothèse d'inversion de phase sylvienne de Vaughan et Ritter.

REFERENCES

DAVIS, H., DAVIS, P. A., LOOMIS, A. L., HARVEY, E. N. and HOBART, G. Electrical reactions of the human brain to auditory stimulation during sleep. *J. Neurophysiol.*, **1939**, 2: 500-514.
 DAVIS, H., MAST, T., YOSHI, N. and ZERLIN, S. The slow

response of the human cortex to auditory stimuli: recovery process. *Electroenceph. clin. Neurophysiol.*, **1966**, 21: 105-113.
 DAVIS, P. A. Effects of acoustic stimuli on the waking human brain. *J. Neurophysiol.*, **1939**, 2: 494-499.
 KOOI, K. A. and RENGIFO, R. Unusual photically evoked vertex wave in a patient with a unilateral thalamic tumor. *Electroenceph. clin. Neurophysiol.*, **1967**, 22: 191P.
 KOOI, K. A. and SHARBROUGH III, F. W. Electrophysiological findings in cortical blindness. Report of a case. *Electroenceph. clin. Neurophysiol.*, **1966**, 20: 260-263.
 VAUGHAN, H. G. and RITTER, W. The sources of auditory evoked responses recorded from the human head. *Electroenceph. clin. Neurophysiol.*, **1970**, 28: 360-367.

Reference: KOOI, K. A., TIPTON, A. C. and MARSHALL, R. E. Polarities and field configurations of the vertex components of the human auditory evoked response: a reinterpretation. *Electroenceph. clin. Neurophysiol.*, **1971**, 31: 166-169