ELECTROPHYSIOLOGICAL STUDY OF THE INFERIOR CORPORA QUADRIGEMINA IN THE CAT

(UDC 612.858.7 : 612.014.421.7)

Ya. A. Al'tman and Z. P. Lebedeva

Laboratory of Auditory Physiology, Institute of Physiology, USSR Academy of Sciences, Leningrad
(Presented by Academician V. N. Chernigovskii)
Translated from Byulleten' Éksperimental' noi Biologii i Meditsiny, Vol. 59, No. 6,
pp. 7-11, June, 1965
Original article submitted October 9, 1963

One index by which the activities in the different parts of the auditory system can be assessed is the electrical response to appropriate stimulation developing in these structures. There is now a considerable volume of material defining electrical responses in the main parts of the system-cochlea, cochlear nuclei, medial geniculate body and auditory zone of the cortex [1-3]. Electrical responses in the inferior corpus quadrigeminum have not been investigated in the same detail. Papers dealing with electrophysiological study of this part of the auditory system make occasional references to the form and locations of electrical responses [4, 5, 7, 8, 12, 14, 18], the cycle of amplitude recovery [12, 19], and differences in the electrical responses to monaural and binaural stimulation [7, 17, 18]. Several investigators have examined the activities of single neurons in the inferior corpus quadrigeminum [9, 10, 11, 13, 16, 18].

A systematic analysis of the quantitative characteristics of electrical responses to acoustic stimulations in the inferior corpus quadrigeminum was now attempted.

METHOD

Thirteen experiments were carried out on 11 fully grown cats under sodium amytal (75 mg/kg intraperitoneally). Tracheotomy was first performed and access to the inferior corpus quadrigeminum was them obtained removal of the bone over the posterior pole of the hemisphere and division of the dura mater. The hemisphere was displaced 3-4 mm forward and held there by gauze pads (the occipital pole of the hemisphere was removed with the thermocautery in three animals), so that the inferior corpus quadrigeminum was well exposed. An electrode (a steel wire 0.12-0.15 mm in diameter in glass insulation) was brought to the surface of the inferior colliculus and inserted, by means of a micromanipulator under visual control, to a depth of from 2.5 to 4 mm. The experiments were carried out in a sound-proof room. The stimuli were clicking sounds about 0.2 msec in length. The acoustic stimulation and method of recording have been described in detail in an earlier communication [3]. The positions of the electrodes were afterwards determined from Nissl-stained serial sections.

RESULTS

The electrical response in the inferior colliculus to the clicking sound began with a small negative component 1-2 msec in length (Fig. 1, A). This negative component was absent in some experiments (Fig. 1,B). The negative component was generally followed by two positive components, each lasting 2-3 msec. The relative amplitude of the positive components might vary, the first being larger, equal to or smaller than the second (Fig. 1, A; Fig. 3, A). Sometimes the two could not be clearly distinguished. The response then contained one positive wave, 4-6 msec in length, showing one or several teeth (Fig. 1, B). A negative wave followed the positive components (Fig. 1, B). In some cases this negative wave was absent, and the second positive component, returning slowly to the zero line, was increased in length (Fig. 1, A).

The thresholds for the development of a response were much the same in most of the animals. With an average threshold values of -2 dB, relative to the audibility threshold for man, measured under the same conditions, the

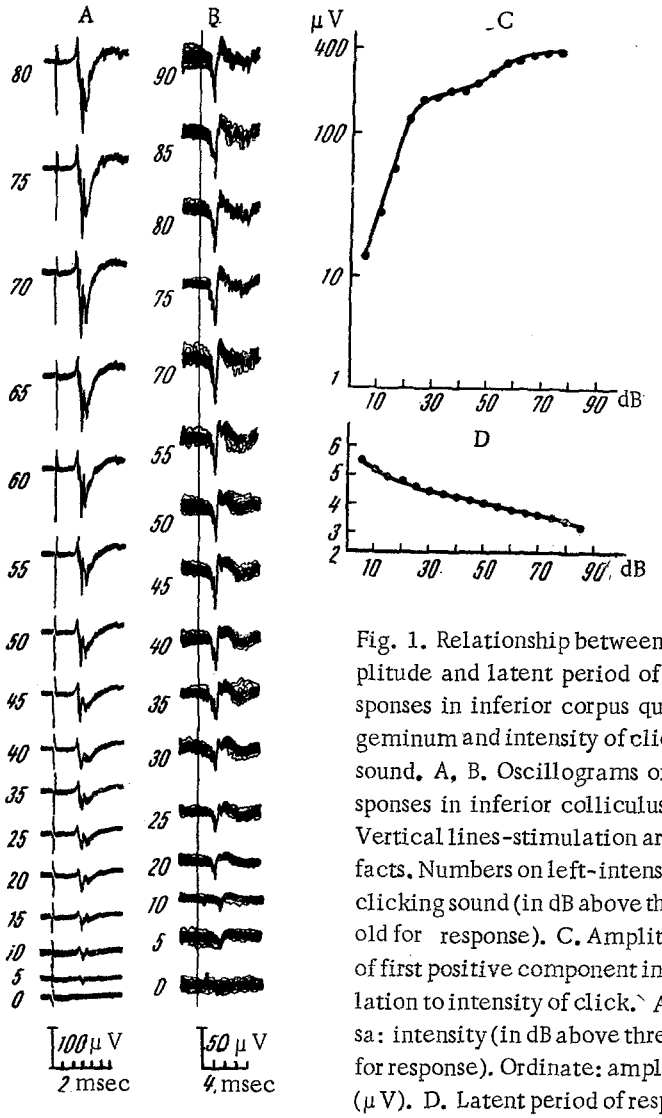
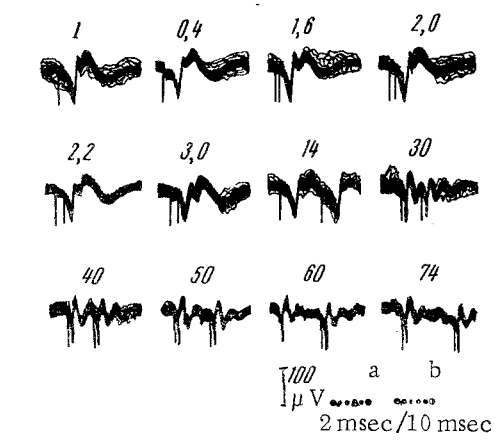


Fig. 1. Relationship between amplitude and latent period of responses in inferior corpus quadrigeminum and intensity of clicking sound. A, B. Oscillograms of responses in inferior colliculus. Vertical lines-stimulation artefacts. Numbers on left-intensity of clicking sound (in dB above threshold for response). C. Amplitude of first positive component in relation to intensity of click. Abscissa: intensity (in dB above threshold for response). Ordinate: amplitude (μV). D. Latent period of response in relation to intensity of click (average findings). Abscissa-intensity of click (in dB above threshold for response). Ordinate-time (msec). In this and following oscillograms the responses were recorded by the superposition of 20-30 reactions in the one frame. Deflection downward -positivity.

scatter (σ) for the individual animals was ± 8 dB. Increasing the loudness of the click (from about threshold to maximum) regularly reduced the latent period from an average value of 5.5 to one of 3.2 msec (Fig. 1, A, B, D). The amplitudes of the positive components were regularly increased by increase of intensity. In moderate ranges of stimulus intensity (30-35 or 35-40 dB above the threshold for a response), the increases of loudness had no appreciable effect on the amplitude of the response, as is seen in the graph for amplitude in relation to intensity, in the form of some leveling off, after which the climb becomes gentler (Fig. 1, C).

One of the most important criteria for assessment of activities in the different parts of the auditory system is the cycle of amplitude recovery, as revealed by the action of paired signals with varying intervals between (ΔT). It was found that a separate response to the second stimulation developed when $\Delta T = 2$-3 msec, and that there was complete restoration when $\Delta T = 40$ msec (Fig. 2). The graphical method of distinguishing the response to the second signal revealed that a response to the second stimulation appeared when $\Delta T = 1.4$-1.8 msec. With complete restoration of the amplitude of the response to the second click, the cyclical features (Fig. 2, A) characteristic for the central parts of the auditory system, could be observed. The fact that the periodicity is less evident in the graph (Fig. 2, B; average values) is in all probability due to the averaging of values for slightly different stages in the cycle in the individual experiments.



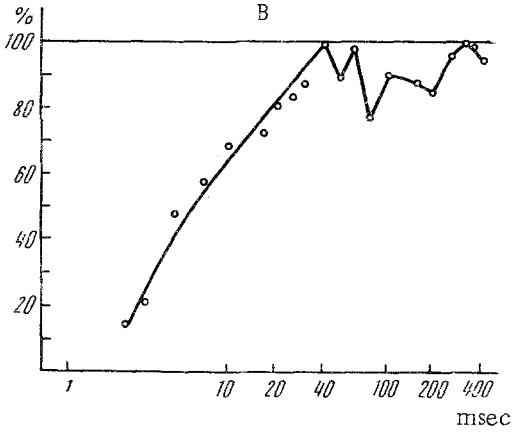


Fig. 2. Recovery of amplitude of electrical responses in inferior corpus quadrigeminum. A) Oscillograms. 1) Response to first click (intensity 40 dB above threshold for response). Numbers over other oscillograms-value of ΔT (a) time scale for T from 0.4 to 14 msec; b) the same for ΔT from 30 to 74 msec). B) Recovery of first positive component (average findings). Abscissa-ΔT (msec). Ordinate—amplitude of response to second click (percentage of response to first click).

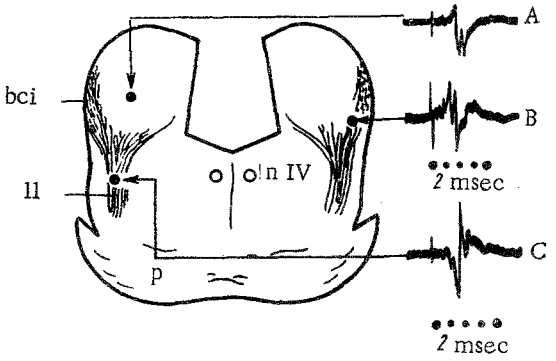


Fig. 3. Electrical responses in inferior corpus quadrigeminum and lateral lemniscus. A) Electrode in center of nucleus. B) electrode at point of entry of fibers of lateral lemniscus. C) electrode in lateral lemniscus. bci-brachia of inferior colliculus. II-lateral lemniscus. nIV-nucleus of trochlear nerve. p-pons.

The form of the electrical response in the inferior colliculus as observed in this investigation (negative component, two positive components and a negative wave) is in conformity with the descriptions given in a number of other papers [4, 5, 7, 8, 12, 18]. What is important is to discover the source of the various components of the response and, more particularly, the origin of the main element, the positive components. Only the origin of the negative wave has been considered in the literature, and this, according to Jungert [12], is the result of activity in the dendritic layer of the nucleus of the inferior corpus quadrigeminum.

Responses in both right and left inferior corpora quadrigemina were recorded simultaneously in one of the experiments in this investigation. In each colliculus one electrode was in the center of the nucleus and the other in its lateral part, i.e. in the region where fibers of the lateral lemniscus enter. When recordings were made from the latter site, a number of fast negative oscillations were seen grafted on to the positive components of the response (Fig. 3, B). The latent period for these oscillations was practically the same as the latent period for the initial negative wave in the response recorded in the inferior colliculus and in the response in the lateral lemniscus (Fig. 3). The duration of these negative oscillations did nor exceed the duration of the first positive component. It was therefore thought that the rapid negative oscillations were the result of discharge by presynaptic fibers in the lateral lemniscus, entering the inferior colliculus, whereas the positive components in the response represented postsynaptic activity of nerve elements in the nucleus itself. If this is correct, the electrical responses seen in Fig. 3 should be explained in the following manner. When the electrode was remote from the point of entry of the lemniscus fibers (recording from the medial part of the nucleus of the inferior colliculus), the fast components were reduced in amplitude, and were recorded in the form of the initial negative component. When the electrode was still further from the point of entry of the lemniscus fibers, the initial negative component might be absent, or it might show a tendency to have its polarity reversed (Fig. 1, B).

The thresholds for responses in the inferior colliculus are considerably lower (by 30-40 dB) than those established by other authors [4, 5, 14, 18]. It was thus possible, in our case, to plot the course of the amplitude curve over a much wider range of intensities, whereas the other authors who have examined this relationship [4, 5, 14, 18] were only able to record the steeper part of the amplitude curve. The lower thresholds for the development of responses

in the inferior colliculus also made it possible to establish that there was an average difference of 2.3 msec between the latent periods for these responses to clicks of threshold and maximum intensity (Fig. 1, D). Kemp et al. [14] and Gershuni [4, 5] found that this difference did not exceed 1-1.5 msec. The present observations on the amplitude recovery cycle are in agreement with the results obtained by others [12, 19]. Finally, it should be pointed out that the values for the various characteristics of the electrical responses in the inferior corpus quadrigeminum, as established in this investigation, are intermediate between the values for the corresponding characteristics in the cochlear nucleus below [3] and the medial geniculate body above [1, 2].

LITERATURE CITED

1. Ya. A. Al'tman and A. M. Maruseva, Fiziol. Zh. SSSR No. 11, (1960) p. 1345.
2. Ya. A. Al'tman and A. M. Maruseva, Dokl. Akad. Nauk SSSR 135, No. 6 (1960) p. 1546.
3. Ya. A. Al'tman, E. A. Radionova, and G. I. Ratnikova, Fiziol. Zh. SSSR No. 10 (1963) p. 1163.
4. G. V. Gershuni, Fiziol. Zh. SSSR 29, No. 5 (1940), p. 369.
5. G. V. Gershuni, Fiziol. Zh. SSSR 29, No. 5 (1940), p. 380.
6. A. M. Maruseva, In: Electrophysiology of Nervous System, Rostov-on-Don (1963), p. 249.
7. H. W. Ades, J. M. Brookhart, and J. Neurophysiol. 13 (1950), p. 189.
8. M. A. B. Brazier, Ann. N. Y. Acad. Sci. 92, 3 (1961), p. 1054.
9. B. Campbell, Proc. Roy. Soc. Exp. Biol., 55 (1944), p. 258.
10. S. D. Erulkar, Proc. Roy. Soc. Exp. Biol. 150 (1959), p. 336.
11. J. E. Hind, J. M. Goldberg, D. D. Greenwood et al., J. Neurophysiol., 26 (1963), p. 321.
12. S. Jungert, Acta Otolaryngol. (Stockh.) Suppl. 138 (1958), p. 13.
13. Y. Katsuki, T. Sumi, H. Uchiyama et al., J. Neurophysiol., 21, (1958), p. 569.
14. E. H. Kemp, G. Coppee, and E. H. Robinson, Am. J. Physiol., 120 (1937), p. 304.
15. E. H. Kemp and E. H. Robinson, Am. J. Physiol., 120 (1937), p. 316.
16. J. E. Rose, D. D. Greenwood, J. M. Goldberg et al., J. Neurophysiol., 26 (1963), p. 294.
17. M. R. Rosenzweig and E. J. Wyers, J. Comp. Physiol. Psychol., 48 (1955), p. 426.
18. W. R. Thurlow, N. B. Gross, E. H. Kemp et al., J. Neurophysiol., 14 (1951), p. 289.
19. A. R. Tunturi, Am. J. Physiol., 147 (1946), p. 311.

All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. *Some or all of this periodical literature may well be available in English translation.* A complete list of the cover-to-cover English translations appears at the back of this issue.
