Response Patterns to Pure Tones of Cochlear Nucleus Units in the CF-FM Bat, *Rhinolophus ferrumequinum*

G. Neuweiler and M. Vater
Arbeitsgruppe Neuro- und Rezeptorphysiologie, Fachbereich Biologie der J.W. Goethe-Universität, D-6000 Frankfurt, Federal Republic of Germany

Received September 30, 1976

Summary. 1. In horseshoe bats temporal response patterns to pure tone stimuli (10–100 kHz, 20 ms duration, 0.5 ms rise/fall-time) of 149 cochlear nucleus units (DCN and PVCN) have been recorded.

2. Distribution of the units' Best Frequencies (BF): low frequency neurons 26% (BF 10–65 kHz); FM-frequency neurons 20% (BF 65–81 kHz, i.e. frequencies occurring in the FM-part of the bat's echo signal); filter frequency neurons 52% (BF 81–88 kHz, i.e. frequencies occurring in the CF-part of the bat's echo signal); high frequency neurons 2% (BF > 88 kHz) (Table 1).

3. According to PST-histograms the neurons were classified as: sustained responders (28%, Fig. 1 D, E); transient responders (51%, Fig. 1 A–C); negative responders (4%, Fig. 1 F) and complex responders (17%, Fig. 2–4). In the latter class response patterns drastically change with stimulus frequency and intensity. These units have suppressory sidebands on one or both sides of the excitatory field, sometimes overlapping and enclosing the excitatory area (Fig. 2 and 4). Frequently excitatory response patterns display simultaneous inhibitory processes the latency and duration of which depend on stimulus parameters.

4. In a few complex responders two or more excitatory areas exist, the BF of which may be harmonically related (Fig. 3 and 4).

5. Tuning curves of four auditory nerve fibers are reported showing two separate excitatory areas: a broad less sensitive one from 37 to 79 kHz (low frequency tail) and a narrow, more sensitive one from 82 to 90 kHz (Fig. 5).

Introduction

In mammals the cochlear nucleus is the first station of neuronal interactions in the ascending auditory pathway. It proved to be a complex structure consisting of three distinct nuclei, the anterior ventral (AVCN), the posterior ventral (PVCN) and dorsal cochlear nucleus (DCN) the latter having a three layered...
cortical like structure (Brawer et al., 1974). The auditory nerve fibers bifurcate into an ascending branch projecting into the AVCN and a descending one projecting into the PVCN and DCN. Histological and neurophysiological evidence suggest that an intranuclear pathway exists from AVCN to DCN (Evans and Nelson, 1973b). Within the different nuclei several types of neurons including interneurons have been identified (Osen, 1969; Kane, 1974; Brawer et al., 1974).

It may be expected that the histologically demonstrated complexity results in intricate neuronal interactions already at this peripheral level. Recent single unit studies (Evans and Nelson, 1973a; van Gisbergen, 1974; Godfrey et al., 1975a, b; Young and Brownell, 1976) demonstrate complex temporal response patterns elicited by pure tone stimuli, indicating frequency dependent interactions of inhibition and excitation of different time courses.

In echolocating horseshoe bats (R. ferrumequinum) a narrow filter tuned to the constant frequency part of the echo signal of about 83 kHz is built into the auditory system (Neuweiler, 1970). For the bat the filter opens up the possibility to detect movement of targets by analyzing minor frequency modulations within the constant frequency part of the echo caused by Doppler-shifts. This precisely tuned filter is already realized within the cochlea by morphological specializations of the basal part of the basilar membrane (Bruns, 1976a, b). Correspondingly in the cochlear nucleus of horseshoe bats a large population of neurons has been recorded which is narrowly tuned to the frequency range of the filter from 81–88 kHz (Suga et al., 1976). These filter units typically have $Q_{\text{peak}}$-values of 20 to 400, thus far exceeding tuning precision of peripheral neurons recorded from any other mammal or bat not using constant frequency signals for echolocation.

These results have focused our interest on the cochlear nucleus as a likely main center for detailed analysis of echo informations. It is intended to study the responsiveness of cochlear nucleus neurons in horseshoe bats to auditory stimuli relevant for echolocation, i.e. pure tones, FM-sweeps and especially combinations of pure tones and FM-signals with noise bands. In this paper temporal response patterns of cochlear nucleus neurons to pure tone stimulations are presented. No attempt to localize histologically the units within the different nuclei has been made, however, according to site and direction of electrode tracks most if not all units are recorded from DCN and PVCN.

**Material and Methods**

8 *Rhinolophus ferrumequinum* were used for this study. Surgical procedure, recording and stimulation set up were generally the same as described in a previous paper (Suga et al., 1976). 5 bats have been anesthetized by Urethane i.p. (1.2 mg/g bodyweight) resulting in a more stabile respiration compared to that in barbiturate-anesthesia (3 bats). Without brain ablations the electrode was advanced rostro-ventrally through the cerebellum into the cochlear nucleus.

Auditory neuron activity was recorded by a WPI-DAM5 differential-preamplifier and fed through a window discriminator. PST-histograms were computed on-line on a PDP 12 computer, stored on DEC-tape and evaluated off-line by programs written by H. Zöller (Program WIED-NEU and AUF-NEU).