PITCH AND COCHLEAR NERVE FIBRE TEMPORAL DISCHARGE PATTERNS

E.F. Evans

Department of Communication & Neuroscience, University of Keele, Keele, Staffordshire, ST5 5BG, U.K.

1. INTRODUCTION

Controversy still exists concerning the role played by the temporal discharge patterns of cochlear nerve fibres in determining the pitch assigned to complex stimuli (see Evans, 1978 for review). Recently, attention has been focussed on a stimulus, similar to one originally used by Seebeck, consisting of a pulse train having alternate intervals of 4.7 and 5.3 ms (Whitfield, 1979, 1980; Moore, 1980). This stimulus, when heard unfiltered has an ambiguous pitch of 100 or 200 Hz. In contrast, Whitfield (1979, 1980) reported intervals corresponding to the 4.7 and 5.3 ms intervals in the stimulus to predominate in the interspike interval histograms (ISIH) of cochlear nerve fibres having characteristic frequencies (CFs) from 0.55 to 2 kHz, in the guinea pig. He consequently raised the questions why the pitches corresponding to these intervals were not heard, and conversely why the 200 Hz pitch heard appeared to have no corresponding interval in the neural discharge patterns. In response, Moore (1980) has argued that neural intervals corresponding to the pitches heard should be present in the discharge patterns of cochlear fibres of CFs corresponding to the dominant region for the pitch heard, usually some 3 - 5 times the frequency matching the pitch.

The present experiments were carried out in an attempt to clarify the situation, and to provide information on an underlying secondary question. This is how well do cochlear fibres, having narrow-band filtering properties to continuous single- and multiple-component stimuli, in terms of the weighting of their phase-locking properties (Evans, 1978, 1980b, 1981), behave as filters in response to impulsive stimuli? Experiments were carried out on single fibres of the cat's cochlear nerve and also on an electronic analogue of a cochlear nerve fibre having linear band-pass filtering properties (Evans, 1980a).

2. METHODS

The stimulus in all experiments was a pulse train of rectangular pulses, 100 μs in width and having alternate intervals of 4.7 and 5.3 ms (see Fig. 1), synthesized by computer, and presented closed-field to the ear by a Bruel & Kjaer 4134 condenser-driver system (with compensation for distortion). ISIH and autocorrelation histograms were obtained from cochlear fibres at several sound levels in steps of 10-20 dB from below threshold to the stimulus up to about 60 dB above. In addition, the frequency threshold curve (FTC) of each fibre was determined by computer.

The details of the stimulation and recording techniques, physiological controls, and of plotting the FTCs are given in Evans (1979). Briefly, micro-pipettes are used for recording the activity of single fibres in the cochlear nerve of pentobarbitone anaesthetized cats. The cats were selected for freedom from middle ear disease and great care was taken to minimise noise exposure during the surgical preparation by avoiding drilling and bone snipping. The threshold of the gross cochlear action potential to tone pips from 0.5-40 kHz was monitored at intervals throughout the experiments and did not deteriorate. The bulla was intact but vented to atmospheric pressure.

ISIH and autocorrelation histograms were computed on- and off-line by a Computer Automation Alpha 2/40 minicomputer system used for the synthesis of the stimuli. A 'silo' DAC and hardware spike clock (Cambridge Electronic Design Ltd.

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502 system) enabled synthesis of stimuli to be effected while logging spike data with a resolution of 1 µs. Each histogram was computed on 4096 spikes, with 512 bins of width 60 µs for fibres with CFs below 1 kHz, and 30 µs for those above (e.g. Fig. 1). Fast Fourier transforms (FFTs) were computed from autocorrelation histograms constructed with bin widths of 100 µs (e.g. Fig. 2). FTCs were obtained by an on-line up-down threshold tracking method described in Evans (1979) in response to 50 ms tone bursts having 5 ms rise-fall times.

Fig. 1. Autocorrelation histograms of spike discharge patterns of 11 cochlear fibres with CFs indicated in response to a click train stimulus with alternate intervals of 4.7 and 5.3 ms (see lower left of Figure). For CFs: 0.25-0.93 kHz, bin width was 60 µs; 1.24-3.78 kHz, 30 µs. 512 bins in each histogram, 4096 spikes. All fibres, with the exception of that with CF of 0.6 kHz, are from one cat. Stimulus level: constant in terms of electrical signal to the earphone at −40 dB (about 20-30 dB above response threshold of the fibres).