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Some peculiarities of auditory sensations evoked by pulsed microwave fields

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Rectangularly pulsed, 800-MHz microwaves were coupled via waveguide from a 500-W source to the parietal area of the head of normal human observers (*Os*). Pulse widths from 5 to 150 μs and pulse-repetition rates (PRRs) from 50 to 20,000 pulses per second (pps) were employed. Sine-wave audio-frequency (AF) signals could be presented alternately to or concurrently with microwave pulses (RF signal) under conditions in which *O* could adjust the amplitude, frequency and phase of the AF signal. By matching timbre and loudness of the perceived RF and AF signals during a succession of psychophysical measures -- some while *O*'s head was being immersed in water -- the *Os* yielded the following results: (1) Both loudness and perceptual thresholds of the RF signal were biphasic functions of pulse width and of PRR; (2) When pulse widths increased toward 100 μs, some subjects perceived a different sound that was lower in pitch and was referred externally to the head; (3) By appropriate phasing of AF and RF signals after matching for pitch and timbre, loudness of the RF signal could be reduced below the threshold of perception; and (4) Extent of immersion of the head in water was correlated with reduced loudness of the RF signal. Some of the data are interpreted as posing explanatory difficulties for an exclusively thermoelastic mechanism of RF hearing.

1. INTRODUCTION

The RF-hearing or Frey effect, an auditory response to pulsed electromagnetic fields, has been studied for nearly two decades [cf. *Frey*, 1961 with *Frey and Messenger*, 1973]. A promising hypothesis of the mechanism of perceiving the pulses is based on thermoelastic expansion: the absorbed pulse of energy is believed by proponents of this hypothesis to produce a very small but very rapid increment of temperature in the head, which causes a slight expansion of as yet unspecified tissues, that in turn creates a wave of pressure to which the cochlea is sensitive [cf. *Foster and Finch*, 1974; *Lin*, 1976; *Guy et al.*, 1975; *Chou and Guy*, 1979].

Development of artifact-free techniques of measuring bioelectric activity [cf. *Frey et al.*, 1968; *Guy et al.*, 1975; *Tyazhelov et al.*, 1977] has recently made it possible for one to study electrophysiologically the potentials of single neurons or of neuronal populations of the auditory cortical analyzers as evoked by pulsed RF fields [*Lebovitz and Seaman*, 1977; *Chou et al.*, 1977]. However, in spite of the lengthy period of time that the RF-hearing effect has been known, relatively few studies have been made of its psychophysical properties [*Frey*, 1961, 1962, 1963; *Constant*, 1967; *Frey and Messenger*, 1973; *Guy et al.*, 1975]. Further psychophysical investigation of the phenomenon should be undertaken to evaluate the adequacy of the thermoelastic hypothesis, and to shed more light on the perceptual qualities of "radio sound." These were our aims in the studies reported here.

2. METHODS AND MATERIALS

2.1. *Sources of RF and AF signals and controls.*

The source of pulsed fields was a 0.8-GHz generator with a maximal output power of 500 watts. The source was coupled to a rectangular section of waveguide (15 × 27 cm) by a 3-meter length of coaxial cable. The open end of the waveguide was mounted firmly on a foamed plastic rest that permitted coupling of energy to the parietal area of an observer's head. Rectangular pulses of 150- to 5-μs duration could be generated at a range of pulse-repetition rates (PRRs) that extended from 50 to as high as 20,000 pulses per second (pps) for shorter pulse widths.

The rise time of discrete pulses was less than 1 μs. The pulses were either generated continuously or in trains of 0.1- to 0.5-s duration that could be presented at a rate of 0.2 to 2.0 trains s^{-1}.

A controlling device enabled the pulsed RF waves to be presented to *O* either independently of, or simultaneously with, acoustic sine waves that could be generated at the same temporal parameters. The acoustic signals were generated by a loudspeaker from which a pair of small hollow tubes extended that could be coupled directly to *O*'s ears.

A push-button switch was located on a remote control panel in ready access to *O*, who, by pressing the button, could inform an investigator of a perceptual threshold, of