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Hearing Research 202 (2005) 28–34
HEARING RESEARCH
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Concurrent measurement of the detectability of tone bursts and their effect on the excitability of the human blink reflex using a probe-signal method

Geoffrey R. Hammond [a,*], Yaël Seth [a], James R. Ison [b]

[a] School of Psychology, The University of Western Australia, Crawley, WA 6907, Australia
[b] Brain and Cognitive Sciences, University of Rochester, Rochester, NY 14627, USA

Received 9 January 2004; accepted 23 July 2004
Available online 24 November 2004

Abstract

The probe-signal method has shown that auditory signals that are either presented more often in a series of trials or that are immediately preceded by cues of the same frequency on a single trial are detected more readily than signals of other frequencies. The frequency range in which detection is favored defines an attentional band, which is thought to result from an effective attenuation of deviant frequencies in the cochlea, possibly by activation of the olivocochlear bundle. In a 2IFC procedure in which the first observation interval was preceded by a 1300-Hz cue, subjects detected cued probe tones (at 1300 Hz) but not uncued probe tones (at 1000 Hz or 1600 Hz) at better than chance levels. Concurrent elicitation of a blink reflex by presentation of an air puff in the first observation interval on a random half of the trials showed that cued probes, but not uncued probes, inhibited the size of the blink reflex. These data show that uncued probes do not enter into the low-level sensory processing in the brainstem which is responsible for reflex modification. This finding is consistent with the view that stimuli whose frequency falls outside an attentional band are excluded at the auditory periphery.
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Keywords: Auditory attention; Attentional band; Olivocochlear bundle; Blink reflex; Prepulse inhibition

1. Introduction

Listeners' ability to detect stimuli with particular acoustic features is determined in part by their recent exposure to stimuli that share those features. One example of this general phenomenon is illustrated by the probe-signal method: brief low-intensity auditory signals in noise are detected when signals of that frequency occur frequently or when they are preceded by audible cues at the same frequency, whereas probes at other, deviant, frequencies are detected less often or not at all (Greenberg and Larkin, 1968; Macmillan and Schwartz, 1975; Scharf et al., 1987). Systematic variation of probe frequency in this method has revealed an auditory filter centered on the 'expected' probe frequency acquired by repeated presentation of probes at that frequency or by an explicit frequency cue. The filter, which resembles the normal peripheral auditory filter (Patterson, 1974), is sharply tuned with a bandwidth close to that of a critical band, and with an effective attenuation of about 7 dB (Dai et al., 1991). Probes at or near the center frequency of the filter are detected whereas probes whose frequency lies outside the filter

Abbreviations: 2IFC, two-interval forced choice; CI, confidence interval; dB, decibel; EMG, electromyographic; Hz, Hertz; N, sample size; OCB, olivocochlear bundle; PPI, prepulse inhibition; SPL, sound pressure level

* Corresponding author. Tel.: +61 8 6488 3236/61 8 9380 3236; fax: +61 8 6488 1006/61 8 9380 1006.
E-mail address: geoff@psy.uwa.edu.au (G.R. Hammond).

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doi:10.1016/j.heares.2004.07.018

band are detected at chance or near-chance levels. The operation of this filter has been characterized by Scharf as an attentional band, and considered to be an elementary form of selective auditory attention that favors the detection of some acoustic events at the expense of others (Scharf, 1998). Other studies have used the probe-signal method to demonstrate the existence of attentional bands for a variety of auditory features, implying that this form of feature selection is a general process in hearing (Arbogast and Kidd, 2000; Greenberg and Larkin, 1968; Wright and Dai, 1994, 1998).

Observations of patients who have undergone vestibular neurotomy to relieve symptoms of Ménière's disease have shown that the surgical procedure has only minor effects on auditory performance in general but specifically reduces frequency selectivity in the probe-signal method. The filter function in the operated ear is flattened or eliminated compared to the same ear before surgery and to the healthy ear after surgery, such that 'unexpected' probe frequencies are detected with high levels of accuracy (Scharf et al., 1994, 1997). This finding implies that the attentional filter operates at the periphery of the auditory system to exclude sounds with deviant frequencies from central auditory processing and is established and maintained by activity of the olivocochlear bundle (OCB), a bundle of auditory efferents which is sectioned by vestibular neurotomy. We report here evidence that sounds with attended, but not unattended, frequencies modify the expression of the blink reflex in normal listeners, indicating that sounds with unattended frequencies do not engage an early stage of sensory processing in the brainstem.

The amplitude of simple brainstem reflexes in humans and other animals is sensitive to low-intensity acoustic events that occur just prior to reflex elicitation (Hoffman and Ison, 1980; Ison and Hoffman, 1983). In particular, brief and insignificant auditory stimuli that appear from about 50–250 ms before elicitation of a blink reflex inhibit the size of the reflex, an effect now commonly known as prepulse inhibition (PPI, Ison and Hammond, 1971, p. 450). Several lines of evidence point to the conclusion that PPI results from a very early and obligatory stage of sensory processing: first, PPI occurs on the first presentation of the prepulse and persists despite repeated presentation of the prepulse alone (Ison et al., 1973); second, it is present during sleep (Silverstein et al., 1980); third, it is present in brain-damaged animals including rats with large cortical lesions (Hammond, 1974) and decorticate rats (Davis and Gendelman, 1977); and fourth, it follows the same general parametric functions in a variety of animals, including frogs, rats, pigeons, rabbits, and humans (Hoffman and Ison, 1992). There is accumulating evidence that auditory prepulses evoke PPI through activation of a circuit within the midbrain that originates in the cochlear nucleus and projects in turn to the inferior colliculus, the superior colliculus, and the pedunculopontine tegmental nucleus, which makes inhibitory connections with the output motoneurons of the blink reflex in the facial nucleus (Koch and Schnitzler, 1997; Koch, 1999).

Three features of PPI make it a valuable complement to psychophysical measures of sensory function. First, it is an implicit sensory process that does not require conscious decision or response, and hence may be used as an objective indicator of sensory function; second, it reveals the operation of low-level brainstem processing that acts to regulate motor excitability; and third, it is present with prepulse intensities around the psychophysical detection threshold, and hence is a sensitive indicator of sensory function. These three features of PPI were exploited in the present experiment, whose aim was to determine whether probes that fell either within or outside an attentional frequency band would be equally able to inhibit a blink reflex elicited just after their presentation. From previous research, we expected that low-level probes that fall within an attentional band would inhibit the blink reflex (Hoffman and Wible, 1970; Reiter and Ison, 1977). In contrast, if probes that fall outside an attentional band are excluded at the ear and are not processed in the brainstem, as implied by a current view of attentional bands (Scharf et al., 1994, 1997), they would not affect the blink reflex.

2. Materials and methods

2.1. Subjects

Twenty volunteers (6 males, 14 females) were tested. Their ages ranged from 19 to 29 years with a median of 21.5 years. Four subjects had previously served in a pilot experiment. The Human Research Ethics Committee at The University of Western Australia approved the procedures and all subjects gave informed consent before participating.

2.2. Apparatus and general procedure

Psychophysical and reflex indicators of sensory detection were measured concurrently with subjects sitting comfortably in a sound-attenuated room. Acoustic stimuli were generated on a SoundBlaster Live! sound card and presented diotically through Sennheiser Linear HD265 headphones. The acoustic stimuli were calibrated using a Brüel and Kjær artificial ear coupled with a Brüel and Kjær sound-pressure-level meter.

2.2.1. Psychophysical measurement

Immediately before testing, individual auditory thresholds for detecting a 250-ms 1300-Hz tone in diotic broadband noise (overall level 60 dB SPL) were obtained using an adaptive two-interval forced-choice

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