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Suppression of otoacoustic emission is unchanged after several minutes of contralateral acoustic stimulation

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Abstract

The influence of variable durations of contralateral acoustic stimulation on the suppression of click-evoked otoacoustic emissions was investigated in order to determine whether olivocochlear efferent fibers are equally effective whatever the acoustical stimulation duration or if they show fatigue. The suppression effect was measured for contralateral stimulus durations ranging from 10 to 180 s prior to the onset of otoacoustic emission recording, and continuing throughout the recording time (60 s). No significant stimulus duration effect was found.

Keywords: Otoacoustic emission; Contralateral stimulation; Medial olivocochlear efferent system; Efferent fatigue

1. Introduction

In 1963, Fex described the activation of olivocochlear efferents by sounds delivered to both ears (Fex, 1963). Cody and Johnstone (1982) later recorded the activity of a single medial olivocochlear efferent unit in response to ipsilateral stimulation, in guinea pigs. Several studies indicated that almost 60% fibers are more responsive to ipsilateral stimulations, 30% to contralateral and 10% to both (Robertson and Gummer, 1985; Liberman and Brown, 1986). These results are supported by anatomical data showing that medial olivocochlear efferents are mainly crossed (i.e., two-thirds) (Guinan et al., 1983, 1984; Brown, 1987; Robertson et al., 1987) and receive inputs essentially from contralateral structures (Robertson and Winter, 1988). Globally, the medial efferent system is mainly ipsilateral.

However, a contralateral acoustic stimulation (CAS) is currently used to activate the olivocochlear efferent neurons (Buno, 1978; Liberman, 1988; Warren and Liberman, 1989a,b). Several reasons underlie the widespread use of such CAS. First, applying low-level

sounds to the contralateral ear enables observation of effects on overall sound-evoked activity, such as compound action potentials, rather than solely on unitary responses (Liberman, 1989). Secondly, although the efferent discharge rates are lower in response to acoustic stimuli as compared to electrical stimuli, sound activation may be considered to be closer to natural efferent stimulation conditions. Thirdly, the non-invasive character of acoustic stimulation delivered to the external ear canal greatly facilitates studies in humans, particularly since the discovery of otoacoustic emissions (OAEs) by Kemp (1978).

Click-evoked OAEs (CEOAEs) represent a particular kind of overall sound-evoked activity originating directly from cochlear processes. They are believed to reflect the oscillation properties of the outer hair cells (OHCs) (Brownell, 1990), on which medial olivocochlear efferent fibers synapse directly. Thus, CEOAEs are the most direct means of observing overall efferent effects on the OHCs. Contralateral sound stimulation has been shown to induce a reduction in CEOAE amplitude (Collet et al., 1990; Veuillet et al., 1991) as well as in that of distortion product OAEs (Puel and Rebillard, 1990; Chéry-Croze et al., 1993; Moulin et al., 1993) and spontaneous OAEs (Mott et al., 1989). This sup-

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pression effect has recently been demonstrated to be almost entirely due to the olivocochlear efferents, although the middle ear muscle reflex pathway may also be activated by CAS (Giraud et al., 1995).

All recordings of overall responses, such as brain-stem auditory evoked potentials or OAEs, necessitate averaging over one to several minutes. For example, averaging 300 sweeps, as currently used in CEOAE recordings, requires 1 min under optimum conditions. However, a prerequisite for using CAS during the recording is that the efferents be functional throughout the recording time. No specific data relating to this question are, however, available in the literature. In most protocols described in the literature, it is assumed that, in using CAS, repeated brief recordings are preferable to one long one. An earlier study by Wiederhold and Kiang (1970) demonstrated that the decrease in discharge rate of auditory neurons under electrical stimulation of the crossed olivocochlear bundle (COCB) persisted as long as the electrical shocks were delivered, i.e., 350 s. It is not yet known whether the suppression effect has the same temporal characteristics when the COCB is stimulated acoustically. The aim of the present study was to determine whether CAS duration alters the effectiveness of the efferent system by investigating the influence of CAS duration on the suppression of transiently evoked OAEs, which can be considered as a good physiological indicator of efferent activation. The results should allow the validation of commonly used protocols and should provide experimental reference data for the design of new experiments.

2. Material and methods

2.1. Subjects and auditory screening

The experiment consisting of non-invasive recording of click-evoked OAEs (CEOAEs) in the presence and absence of contralateral broad-band noise (BBN) of various durations was performed on a sample of 20 young human subjects. All the subjects were volunteers and the experiment was conducted with their informed consent. Recordings took place in a sound-proof room with subjects recumbent.

Tonal audiometry was performed in a sound-proof room, using an audiometer (DAII, Madsen) at 0.25, 0.5, 1, 2, 4 and 8 kHz, according to ISO 6189 standards. Tympanometry and middle ear muscle reflex recordings were performed in a sound-proof room, using an impedance meter (702, Amplaid).

2.2. CEOAE recordings

CEOAEs were recorded using the Otodynamics

ILO88 apparatus with ILO88L software. A standard miniaturized acoustic probe, consisting of a loudspeaker and a microphone placed in the right external ear canal, delivered acoustic stimulation and recorded responses. CEOAEs were analyzed conventionally during the 20 ms following the onset of stimulation by non-filtered 80 μ s clicks at a rate of 50/s. The ILO88 system controlled stimulus presentation and CEOAE measurement. The amplitude response was calculated automatically from 2.5 to 20 ms in order to eliminate stimulus ringing artifacts. In each recording session, two separate averages collected in related buffers (a and b) were processed within a pass-band of 0.5–6 kHz by routine control software. Each a and b average was determined in the ILO88's linear acquisition mode, which presents 260 stimulus sets consisting of four clicks having the same level and polarity. To test the reliability of CEOAEs, the a and b averages were compared mathematically (Bray and Kemp, 1987). The magnitude of the stimulus waveform, expressed in peak equivalency decibels of sound pressure level (dB SPL), was measured in the external ear canal and adjusted by the ILO88 software. Conventionally, the ear from which CEOAEs were recorded was considered as "ipsilateral".

2.3. Contralateral noise

The contralateral noise was a broad-band noise (BBN) delivered by a clinical audiometer (455, Amplaid) through an earphone (Telephonics, 39P, bandwidth 0.05–8 kHz). The BBN was composed of all frequencies between 0.05 and 8 kHz. Individual subjective perception thresholds for the contralateral BBN were measured for each subject and found to be equal to less than 15 dB SL.

2.4. Experimental procedure

CEOAEs were recorded in response to a 63 dB SPL stimulus in presence and absence of a 35 dB SL (sensation level) CAS, preceding the onset of CEOAE recording by a variable time (10, 20, 40, 80 or 180 s; see Fig. 1). A CEOAE recording without CAS was made before each recording in the presence of CAS. At the beginning of the experiment a first reference recording was made, in the non-linear acquisition mode at 80 dB SPL, with and without a 35 dB SL CAS delivered simultaneously to the CEOAE recording. The CEOAE recording duration was 60 s in most subjects. Recordings longer than 60 s were eliminated and re-done.

2.5. Suppression effect calculation and statistics

The effectiveness of the efferent system was calculated by subtraction of the amplitudes of CEOAEs re-

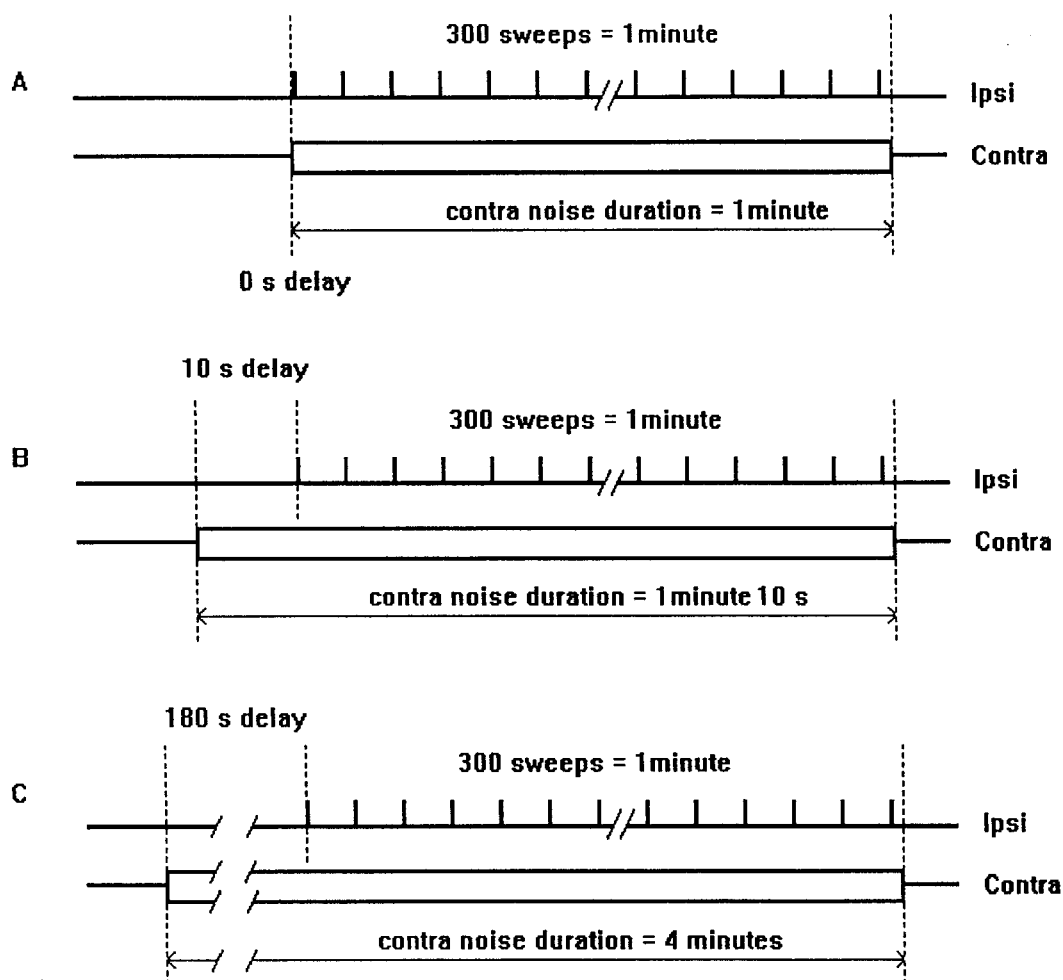


Fig. 1. Experimental paradigm. Ipsi- and contralateral stimuli. A: CAS begins at onset of CEOAE recording. B and C: CEOAE recording is delayed by a variable amount of time (10–180 s).

coded in the presence and absence of CAS. The suppression value is expressed in dB.

A one-way ANOVA was performed for the various CAS duration conditions.

3. Results

The suppression of OAEs, evoked by 63 dB SPL clicks under 35 dB SL contralateral BBN, ranged between 0.7 dB and 1.1 dB. These suppression values, plotted in Fig. 2, correspond to the difference in magnitude between CEOAEs recorded in presence and in absence of CAS and are consistent with those classically obtained by the Euclidean distance calculation method (Chéry-Croze et al., 1994) in normally hearing subjects (Giraud et al., 1995). Suppression was less in the non-linear acquisition mode at 80 dB SPL than in the linear mode at 63 dB SPL. Although the non-linear mode allows much higher stimulation levels, suppression remained stronger for low-level ipsilateral stimulation.

This finding is in agreement with the results of Vuillet et al. (1991).

Fig. 2 describes the effect of CAS duration on CEOAE suppression. No statistically significant effect of CAS duration was observed (non-significant ANOVA). Despite, a slight decrease in suppression when the CAS preceded CEOAE recording by 20 s, the CAS was as effective when its onset was synchronized with the beginning of CEOAE recording as when it began 3 min before recording. Suppression ranged from 1.1 dB when the CEOAE recording was not delayed to 0.7 dB when the CAS onset preceded the CEOAE recording by 3 min.

4. Discussion

The first aim of this study was to establish experimental reference for the design of new protocols with overall cochlear response recordings requiring several minutes averaging. The choice of exploring durations

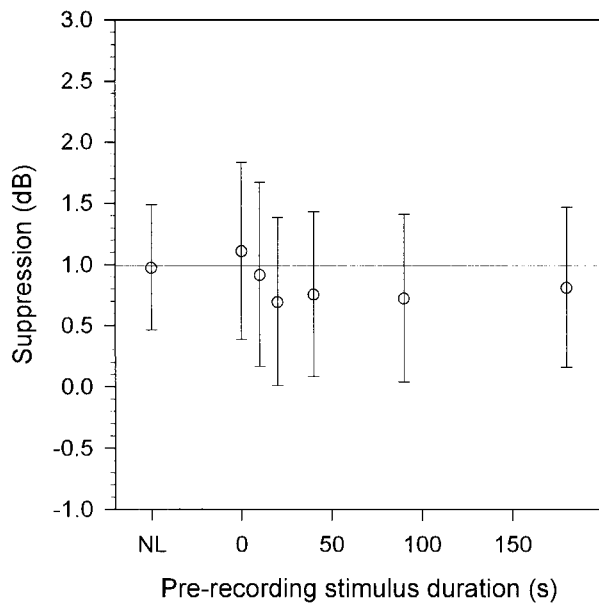


Fig. 2. CEOAE suppression as a function of CAS duration preceding CEOAE recording. The suppression, in dB, is the difference in magnitude between CEOAE recorded with and without CAS. NL means one recording made in the non-linear acquisition mode at 80 dB SPL. Vertical error bars represent standard deviation.

ranging from 0 to 3 min preceding CEOAE recording (corresponding to 1–4 min total CAS duration) was essentially based on the absence of specific literature data concerning efferent fatigue under acoustical stimulation conditions. Secondly, the majority of CEOAEs or brainstem auditory evoked potential protocols do not require more than 4 min per average. The absence of significant CAS duration effect, as shown in the present experiment, might suggest further investigation of durations longer than 3 min. Only a slight tendency towards reduction of suppression was observable at 3 min. Therefore, it can reasonably be supposed that acoustical stimulation has the same long-lasting effectiveness in COCB activation as electrical stimulation has been shown to have (Wiederhold and Kiang, 1970). Indeed, after 350 s of sustained electrical stimulation of the COCB, these authors observed no alteration in the decrease of the discharge rate of primary afferent fibers. The absence of suppression alteration as long as the stimulus persisted reveals an absence of COCB fatigue. However, 4 min stimulation is possibly not long enough to cause efferent fatigue, if such exists.

Short contralateral sound durations (80–408 ms) were used by Hood and Berlin (1995) in a forward masking paradigm, showing that suppression increased with noise duration up to 240 ms but then decreased with longer durations. As Hood and Berlin concluded, their results confirm in humans those of Liberman and Brown (1986) for cat efferent fibers which showed a certain minimum noise duration to be necessary to ac-

tivate the efferents. These results suggest that suppression may not be optimized in a continuous CAS paradigm. However, Warren and Liberman (1989b) using CAS demonstrated that a continuous stimulation induces greater auditory nerve discharge reduction than do intermittent sounds. One possible explanation for the absence of any efferent fatigue in our study might be that the activation of efferent fibers is not maximal using continuous sounds. Indeed, in response to a sound, efferents exhibit a very regular discharge pattern (Robertson and Gummer, 1985) which had suggested their particular sensitivity to amplitude modulated sounds (Gummer et al., 1988). Intermittent sounds are closer to amplitude modulated sounds. Suppression depends on the rate and the duration of intermittent stimuli, so that they could be either more or less effective than the continuous sound. Therefore it can be proposed that continuous sounds are probably not optimal stimuli for efferent neurons so that they cannot lead to fatigue. This could account for the absence of significant alteration in efferent effectiveness after 4 min of sustained CAS.

It can be concluded from our study that, within 4 min of low-level continuous acoustic stimulation, there is no manifestation of significant efferent fatigue: the suppression observed with CEOAEs remains constant throughout, despite a slight decrement 80 s after CAS onset. It should therefore be possible to use greater numbers of averages in protocols, without modifying suppression characteristics. Nevertheless, CAS duration may possibly modify the persistence of suppression after stimulus offset (Hood and Berlin, 1995).

References

- Bray, P. and Kemp, D.T. (1987) An advance cochlear echo technique suitable for infant screening. *Br. J. Audiol.* 21, 191–204.
- Brown, M.C. (1987) Morphology of labeled afferent fibers in the guinea pig cochlea. *J. Comp. Neurol.* 260, 591–604.
- Brownell, W.E. (1990) Outer hair cell electromotility and otoacoustic emissions. *Ear Hear.* 11, 82–92.
- Buno, W. (1978) Auditory nerve activity influenced by contralateral ear sound stimulation. *Exp. Neurol.* 59, 62–74.
- Chéry-Croze, S., Moulin, A. and Collet, L. (1993) Effect of contralateral sound stimulation on the distortion product 2f1-f2 in humans. *Hear. Res.* 68, 53–58.
- Chéry-Croze, S., Moulin, A., Collet, L. and Morgon, A. (1994) Is the test of efferent system function a relevant investigation in tinnitus? *Br. J. Audiol.* 28, 13–25.
- Cody, A.R. and Johnstone, B.M. (1982) Temporary threshold shift modified by binaural acoustic stimulation. *Hear. Res.* 6, 413–424.
- Collet, L., Kemp, D.T., Veuillet, E., Duclaux, R., Moulin, A. and Morgon, A. (1990) Effect of contralateral auditory stimuli on active cochlear micro-mechanics. *Hear. Res.* 43, 251–262.
- Fex, J. (1963) Augmentation of the cochlear microphonics by stimulation of efferent fibers to the cochlea. *Acta Otolaryngol. (Stockh.)* 50, 540–541.
- Giraud, A.L., Collet, L., Chéry-Croze, L., Magan, J. and Chays, A. (1995) Evidence of a medial olivocochlear involvement in the con-

- tralateral suppression of otoacoustic emissions in humans. *Brain Res.* 705, 15–23.
- Guinan, J.J., Jr., Warr, W.B. and Norris, B.E. (1983) Differential olivocochlear projections from lateral vs medial zones of the superior olivary complex. *J. Comp. Neurol.* 221, 358–370.
- Guinan, J.J., Jr., Warr, W.B. and Norris, B.E. (1984) Topographic organization of the olivocochlear projections from the lateral and medial zones of the superior olivary complex. *J. Comp. Neurol.* 226, 21–27.
- Gummer, M., Yates, G.K. and Johnstone, B.M. (1988) Modulation transfer function of efferent neurons in the guinea pig cochlea. *Hear. Res.* 36, 41–52.
- Hood, L.J. and Berlin, C.I. (1995) Noise duration affects bilateral, ipsilateral and contralateral suppression of transiently evoked otoacoustic emissions in humans. *Abstr. Assoc. Res. Otolaryngol.* 18, 123.
- Kemp, D.T., 1978. Stimulated acoustic emissions from within the human auditory system. *J. Acoust. Soc. Am.* 64, 495–496.
- Liberman, M.C. (1988) Response properties of cochlear efferent neurons: monaural versus binaural stimulation and the effect of noise. *J. Neurophysiol.* 60, 1779–1798.
- Liberman, M.C. (1989) Rapid assessment of sound evoked olivocochlear feed-back: suppression of compound action potentials by contralateral sound. *Hear. Res.* 38, 47–51.
- Liberman, M.C. and Brown, M.C. (1986) Physiology and anatomy of single olivocochlear neurons in cats. *Hear. Res.* 24, 17–36.
- Moulin, A., Collet, L., Duclaux, R., 1993. Contralateral auditory stimulation alters acoustic distortion products in humans. *Hear. Res.* 65, 193–210.
- Mott, J.B., Norton, S.J., Neely, S.T. and Warr, W.B. (1989) Changes in spontaneous otoacoustic emissions produced by acoustic stimulation of the contralateral ear. *Hear. Res.* 38, 229–242.
- Puel, J.L., Rebillard, G., 1990. Effect of contralateral sound stimulation on the distortion product 2f₁-f₂: evidence that the medial olivocochlear system is involved. *J. Acoust. Soc. Am.* 87, 1630–1635.
- Robertson, D. and Gummer, M. (1985) Physiological and morphological characterization of efferent neurons in the guinea pig cochlea. *Hear. Res.* 20, 63–78.
- Robertson, D. and Winter, I.M. (1988) Cochlear nucleus input to olivocochlear neurones revealed by combined anterograde labelling in the guinea pig. *Brain Res.* 462, 47–55.
- Robertson, D., Cole, K.S. and Harvey, A.R. (1987) Brainstem organization of efferent projections to the guinea pig cochlea studied using the fluorescent tracers Fast blue and Diamidino yellow. *Exp. Brain Res.* 66, 449–457.
- Veuille, E., Collet, L. and Duclaux, R. (1991) Effect of contralateral acoustic stimulation on active micromechanical properties in human subjects: dependence on stimulus variables. *J. Neurophysiol.* 65, 724–735.
- Warren, E.H., III and Liberman, M.C. (1989) Effects of contralateral sound on auditory nerve response. I. Contribution of cochlear efferents. *Hear. Res.* 37, 89–104.
- Warren, E.H., III and Liberman, M.C. (1989) Effects of contralateral sound on auditory nerve response. II. Dependence on stimulus variables. *Hear. Res.* 37, 105–122.
- Wiederhold, M.L., Kiang, N.Y.S., 1970. Effects of electrical stimulation of the crossed olivocochlear bundle on single auditory nerve fibers in the cat. *J. Acoust. Soc. Am.* 48, 950–965.