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Stronger bilateral efferent influences on cochlear biomechanical activity in musicians than in non-musicians

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Abstract

The auditory sensory end organ is under the control of the central nervous system via efferent projections. Contralateral suppression of otoacoustic emissions (acoustic signatures of the cochlear biomechanical activity) provides a non-invasive approach to assess olivocochlear efferent activity in humans. Using this approach, the present study compared professional musicians with musically-inexperienced subjects. The results revealed stronger bilateral cochlear suppression, suggesting larger efferent influences in both ears, in musicians. Furthermore, in indicating no difference in left/right asymmetry of efferent-mediated suppression between the two groups, the present findings suggest that the observed differences in olivocochlear activity reflect bilaterally-enhanced activity of the cortical auditory structures in musicians rather than differences in cerebral hemispheric asymmetry between the two groups. © 1999 Elsevier Science Ireland Ltd. All rights reserved.

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The mammalian cochlea receives innervation from the superior olivary complex (SOC) of the brainstem, through the olivocochlear bundle (OCB) [20]. The OCB comprises a bulk of fibers that originate in the medial nuclei of the SOC and contact the outer hair cells (OHCs) of the cochlear organ of Corti: the medial olivocochlear bundle (MOCB) [23]. By-products of OHC activity induced in the cochlea and propagated backwards through the middle ear can be recorded in the external ear canal as acoustic vibrations called otoacoustic emissions (OAEs) [11]. Upon electrical stimulation of the OCB [19] or contralateral acoustic stimulation at intensities known to excite OCB fibers [5], the amplitude of evoked otoacoustic emissions (EOAEs) is reduced. The second effect, known in the literature as the contralateral EOAE suppression effect, allows to study MOCB functioning in humans. Based on this approach, lines of evidence for stronger MOCB activity in professional musicians (Ms) than in subjects with no particular musical experience – referred to as 'non-musicians' (NMs) in the following – were recently provided by the finding of larger contralateral EOAE amplitude attenuation in the former than in the latter group [15,16]. This finding can be interpreted as an indication that MOCB activity is generally larger in Ms than in NMs. So far, however, the difference has only been tested in the right ear. Recently, results showing that MOCB activity is larger in the right ear in right handers [12] have appeared in the literature and opened the possibility that MOCB functioning is, as other brain functions, lateralized. That the auditory efferent asymmetries constitute yet another aspect of a more general asymmetry between the two sides of the brain remains to be determined [13]. In this framework, the question arises of, whether the observed difference in MOCB functioning between Ms and NMs reflects a difference in auditory efferent laterality between the two.

To address this question, MOCB functioning was measured in the left and right ears of 32 subjects (18 females, 14

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males; mean age = 26.66 ± 3.74 years) divided into two groups: one group of subjects with no particular musical experience 'NMs'; the other group of subjects who were either professional musicians or students of the National Music Academy of Lyon (Ms), had begun music studies between the age of 3 and 11 years old, and had been playing their instrument around 4 h a day for more than 20 years. The two groups were paired for age and sex. Handedness was assessed in all subjects using the Edinburgh Handedness Inventory [18]. The results indicated that all NMs were right handed; 13 out of the 16 Ms were right handed, two were left handed, and one could use either hand. Furthermore, the laterality quotient was on average 88.75 (SD = 12.58) in NMs and 63.13 (SD = 41.27) in Ms, which indicates less marked laterality in Ms than in NMs.

Following the method, developed by Collet et al. [5], the activity of the MOCB system was assessed by means of the contralateral EOAE amplitude attenuation effect; this effect consists in a reduction in EOAE amplitude on presentation of an acoustic stimulus in the opposite ear. EOAE amplitude attenuation was measured in the right and left ears, successively in the presence and in the absence of a contralateral broadband noise, in a random order. EOAEs were recorded using the method developed by Bray and Kemp [4], which consists of measuring ear-canal sound pressure variations consecutive to rarefaction clicks. The whole procedure (stimulus generation, response recording, averaging and analysis) was monitored by the Otodynamics ILO 88 v. 3.92 software. All measurements were made while subjects reclined in a sound-proof cabin. All the subjects had normal pure-tone hearing thresholds, within 20 dB HL at octave frequencies, between 125 and 8000 Hz, with less than 10 dB difference in sensitivity between ears. The data are presented in Table 1.

Fig. 1 illustrates the effect of contralateral noise on EOAEs in a musician subject. In agreement with earlier results [5,15,16], a decrease in EOAE amplitude was observed in all subjects upon contralateral noise stimulation. As represented in Fig. 2, the EOAE amplitude attenuation effect proved to be significantly larger in Ms than in NMs, in both the right and the left ears (Mann–Whitney rank sum test; $T = 205$, $P < 0.05$ for the right ear; $T = 209$, $P < 0.05$ for the left ear). This finding of stronger bilateral EOAE attenuation in Ms rules out the possibility, which had been left intact by earlier studies [15,16] in which only the right ear was tested, that differences in EOAE attenuation between Ms and NMs are side-specific; on the contrary, the present finding indicates enhanced MOCB activity on both sides in Ms.

Another possibility, which had not been eliminated by previous studies, is that the observed differences in EOAE attenuation between Ms and NMs resulted, in fact, from differences in baseline EOAE amplitude. The results of the present study raise a couple of arguments against this possibility. Firstly, no statistically significant difference in mean otoacoustic emission amplitude was found between the two groups for the same ear. Secondly, no significant correlation was found between the baseline amplitude of EOAEs and the contralaterally-induced decrease of this amplitude. Therefore, the stronger EOAE attenuation effects found in musicians appear to be genuine.

Another interesting question, which the present study allows to address further, is that of the origin of the enhanced MOCB activity in Ms. Given that the MOCB constitutes a final string in a chain of descending auditory pathways originating in the auditory cortex [10], it is conceivable that differences in centrifugal activity between Ms and NMs proceed from differences in the degree of activation of more central auditory structures. Together with data on the influence of sleep and visual or auditory attention on MOCB activity [6–8], electrophysiological results indicating an influence of central arousal on MOCB activity [21] support the hypothesis of a link between the activity of the central nervous and olivocochlear systems. On the other hand, there are data in the literature to suggest the existence of differences in hemispheric asymmetry and/or musical processing between Ms and NMs [1,9,22]. Therefore, a difference in efferent interaural asymmetry patterns may be expected between the two groups. To address this issue, we tested for differences in the degree of interaural asymmetry in EOAE attenuation between Ms and NMs. In agreement with previous results [12], the contralateral EOAE attenuation was found to be larger in the right ear than in the left ear in the control subjects (Wilcoxon signed rank test, $W = 90$, $P < 0.05$, $N = 16$). However, the same right-ear dominance was obtained in musicians ($W = 88$, $P < 0.05$) and the interaural asymmetry in cochlear suppression – an attenuation quotient computed as the ratio of the algebraic difference between the right and left EOAE attenuations and the absolute value of the sum of

Table 1

Data measured in non-musicians and musicians

	Non-musicians		Musicians	
	Right ear	Left ear	Right ear	Left ear
EOAE amplitude[a]	11.01 ± 0.96	10.26 ± 0.89	12.36 ± 0.86	11.64 ± 1.13
Stimulus-equivalent attenuation[b]	–1.11 ± 0.16	–0.72 ± 0.14	–2.27 ± 0.37	–1.41 ± 0.34
Attenuation quotient[c]	–0.24 ± 0.11		–0.25 ± 0.10	

[a]Evoked otoacoustic emission amplitude, expressed in dB sound pressure level; [b]stimulus-equivalent attenuation (SEA, see definition in legend of Fig. 2), expressed in dB; [c]attenuation quotient, computed as the ratio: (right ear SEA – left ear SEA)/ |right ear SEA + left ear SEA|.

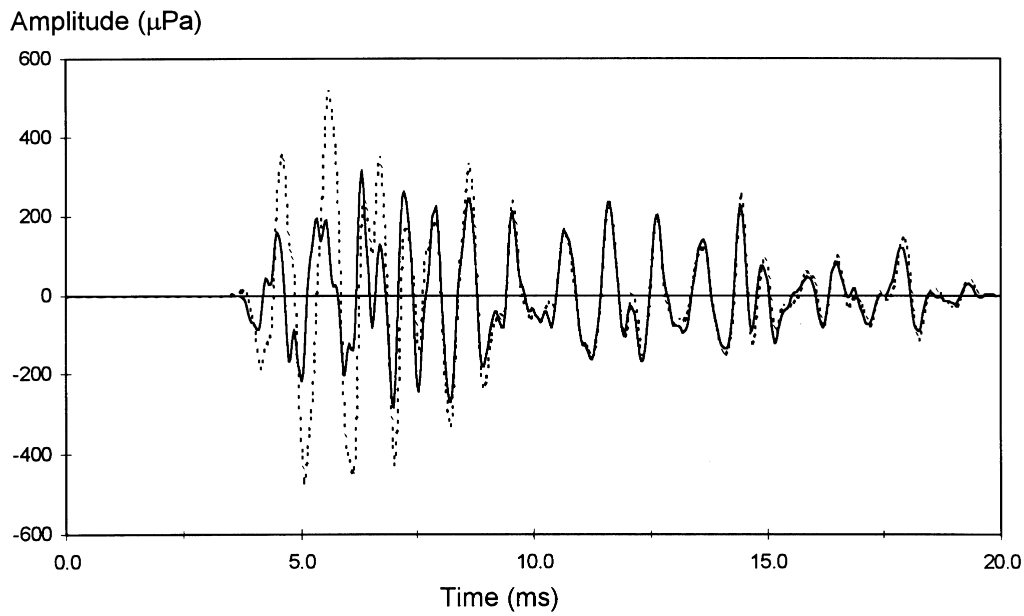

Fig. 1. Illustration of the contralateral evoked otoacoustic emission (EOAE) amplitude attenuation effect in a musicians' right ear. The dashed and solid traces represent evoked otoacoustic emission waveforms – amplitude in μPa as a function of time in ms – recorded in the absence and in the presence of noise in the opposite ear, respectively. In the presence of contralateral noise, EOAE amplitude is reduced.

these attenuations – proved not to differ significantly between the two groups. This lack of difference in interaural asymmetry of olivocochlear inhibition between Ms and NMs indicates an undifferentiated, bilateral, rather than a side-specific, lateralized enhancement of olivocochlear activity in Ms. However, it is worth noting that the testing conditions and the stimuli for the assessment of MOCB functioning (namely, passive listening and binaural stimulation with clicks and broadband noise), may have resulted in undifferentiated bilateral activation of central auditory structures [2]. The possibility that differences in MOCB-functioning laterality between Ms and NMs show up in other listening conditions, involving active listening, monaural stimulation and/or musical sounds, remains opened.

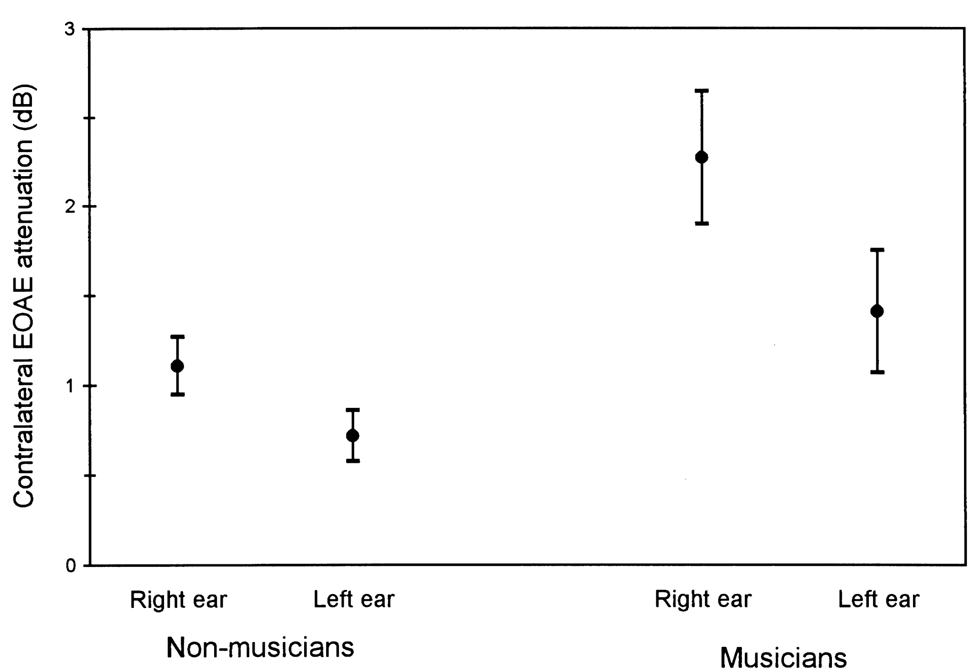

Fig. 2. Mean contralateral evoked otoacoustic emission (EOAE) attenuation effects (expressed in dB) for right ear and left ear in musicians and non-musicians. This effect is expressed in terms of decreases in stimulus level using the stimulus-equivalent attenuation (SEA) metrics which is defined as the mean reduction of the ipsilateral stimulation intensity required to obtain the same attenuation in EOAE amplitude as elicited by contralateral stimulation, the higher the number on the ordinate, the larger the reduction in EOAE amplitude induced by contralateral noise stimulation. Error bars represent the standard errors of the across-subject mean.

Overall, the present results indicate that MOCB activity is larger in both ears in Ms than in NMs and that an interaural asymmetry in MOCB functioning, favoring the right ear, exists in the two groups. The perceptual implications of the bilaterally-enhanced MOCB activity in musicians remain to be determined; according to data in the literature, they might include enhanced auditory selective attention [8], reduced auditory fatigability [15,19] and improved signal-in-noise perception [14,17].

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