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MASKING LEVEL DIFFERENCES FOR COCHLEAR AND BRAIN STEM LESIONS

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SUMMARY – Masking level differences (MLD) for 500 Hz pure tones and for spondees were obtained from 48 subjects. Twelve were without otologic or neurologic complaints (normal), 12 had high frequency, noise-induced hearing losses, 12 were diagnosed otologically as having Ménière's disorder, and 12 had neurologically diagnosed central nervous system (CNS) disorders. Results indicated that high frequency, noise-induced hearing losses do not affect MLD for 500 Hz stimuli, but do diminish the size of MLD for speech. Masking level differences for both 500 Hz and spondees were decreased for the Ménière's disorder group. The group of patients having CNS disorders attributed to multiple sclerosis, to inflammatory lesion of the pons, to degenerative processes of the cerebellum and adjacent nervous tissue, or to brain stem cerebrovascular accident had normal hearing according to conventional pure tone and speech testing, but attained smaller than normal MLD for 500 Hz and spondees. These findings agree closely with results obtained in an earlier study and continue to suggest that, given normal peripheral auditory function, MLD tests may have unique value in detection of subtle lesions of the central auditory nervous system.

The fact that a normal auditory system can make advantageous use of subtle differences in simultaneous acoustic events at the two ears is well known. A number of laboratories have devoted much time and effort to determine to what extent the auditory system can utilize differences in various auditory stimuli delivered to both ears simultaneously or almost simultaneously.

One such phenomenon which has been investigated extensively is known as binaural release from masking, or more commonly, masking level differences (MLD). The phenomenon involved concerns the ability of the auditory system to take advantage of phase differences in a masking noise or in a signal delivered to the two ears simultaneously.

Figure 1 depicts some of the more common experimental conditions used for investigating binaural release from masking. The lettering on the forehead of each caricature gives the designation for the different listening conditions. The large letters "S" and "N" represent signal and noise respectively. The small letters reveal whether the signal or noise are presented monaurally, "m," or the phase relationship between ears of the signal or the noise when presented binaurally. The small "o" represents no phase difference between ears for the signal or the noise, while "π" indicates a phase reversal, *i.e.*, 180° phase difference between the signal or the noise at the two ears.

The top left drawing reveals delivery of the signal and the noise monaurally (SmNm), a difficult condition for the listener. If, however, the signal is main-

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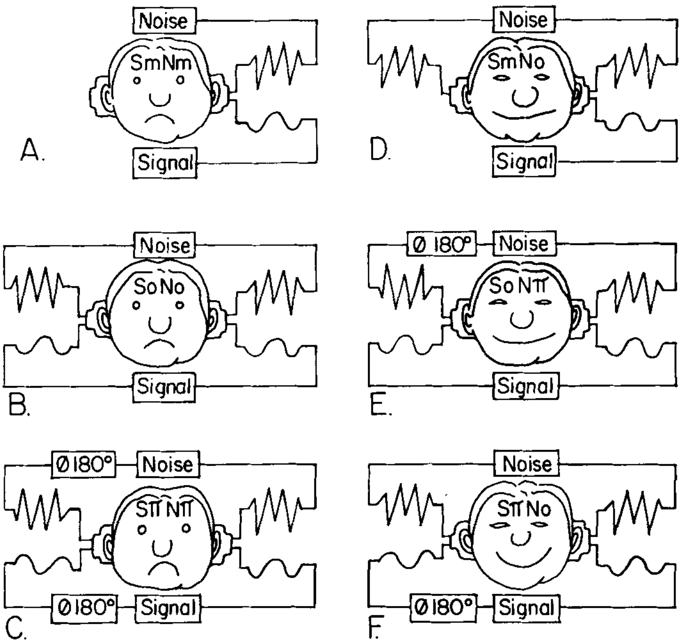

Fig. 1. Stimulus conditions for MLD tests. S - Signal, N - Noise, m - Monaural, o - In phase at two ears, π - 180° out of phase at two ears.

tained in the noise at a just-audible level for monaural hearing, the addition of an identical noise at the opposite ear results in easier detection of the signal. This condition is labelled SmNo. When identical signals and noises are presented bilaterally (SoNo), the listening situation reverts to a difficult one. Signal detection under this condition is similar to that experienced when the signal and noise are presented monaurally. However, putting the noise 180° out of phase between ears ($N\pi$), while the signal remains in phase between ears (So) eases the listening situation. If both the signal and noise are 180° out of phase with themselves ($S\pi N\pi$), the listening task is difficult and similar to that encountered in the SmNm and SoNo conditions. The best listening condition occurs when the signal is out of phase by 180° at the two ears while the noise is maintained in phase bilaterally, $S\pi$No. In this condition, a low frequency tone or speech can be heard at levels less intense than required for hearing in the more difficult SmNm, SoNo and $S\pi N\pi$ conditions. A similar but smaller advantage occurs for the SmNo and $SoN\pi$ conditions.

The fact that masked thresholds improve for normal hearers in the noted conditions has been known since the reports of Licklider[1] and of Hirsh[2] in 1948. Since then, these observations have been confirmed in a variety of experiments. Further, since MLD phenomena obviously involve more than separate processing of information from each ear, it has been theorized that some form of correlational processes within the central auditory nervous system (CANS) are responsible.[3]

Until recently, MLD tests have not been administered to persons having known hearing losses, or to persons with medically diagnosed lesions of the CNS. Three separate investigations have established that smaller than normal MLD are obtained from persons having hearing impairments attributed to Ménière's disorder.[4-6] One study has found normal MLD for 500 Hz, but decreased binaural release from masking for speech in persons having high frequency, noise-induced hearing losses.[6]

The observation of MLD of normal

size for persons having temporal lobe lesions or even hemispherectomies is of considerable interest.[6,7] Such findings indicate that unqualified participation by both cortical hemispheres is not necessary to attain binaural release from masking. It would appear that MLD are mediated in the CANS at some level or levels below the auditory cortex. In this context, our earlier observations of small MLD for patients having multiple sclerosis (MS)[6,8] take on added interest, particularly since the brain stem and midbrain seem to be sites of predilection for MS plaques. The critical point here is that both the MS subjects and the cortical lesion subjects typically have normal hearing for pure tones and speech. Since the MS group yields small MLD and the cortical lesion group normal MLD, an obvious speculative conclusion is that MLD may have unique value in detection of brain stem and/or midbrain lesions. The recent report of Noffsinger *et al*[9] showing reduced MLD for a patient having a lateromedial inferior pontine syndrome lends further credence to such a supposition.

SUBJECTS AND PROCEDURES

For further evaluation of MLD behavior for patients having otologic or neurologic abnormalities, four groups of subjects were tested. The same test procedures and materials employed in our previous work[6,8] were utilized. Briefly, masked thresholds for 500 Hz pure tone stimuli and for spondees were determined. As in most other studies of MLD the SoNo condition served as the reference condition. Our interest was in the masked threshold improvement observed when either the signal ($S\pi No$) or the noise ($SoN\pi$) was 180° out of phase with itself at the two ears. Thresholds for a pulsed 500 Hz tone were determined via Békésy audiometry. A continuous narrow band noise centered at 500 Hz was maintained at 80 dB SPL at both earphones throughout the three pure tone test conditions. White noise set at 80 dB SPL served as the masker in the same listening conditions when spondees were the stimuli. Speech reception thresholds were determined via a descending approach.[10]

Twelve normal hearing subjects (pure tone thresholds at 250-8000 Hz and speech reception thresholds no poorer than 25 dB HL bilaterally re ANSI 1969[11]) having no otologic or neurologic complaints were tested to serve as a control group. This group was tested to assure that the equipment utilized at a new test site would yield results similar to those obtained earlier with other apparatus.

Additional groups of 12 patients having unilateral Ménière's disorder and of 12 individuals with noise-induced sensorineural hearing loss were also tested for comparison to our earlier findings with larger samples having the same otologic diagnoses. All hearing impaired patients had unmasked thresholds no poorer than 50 dB HL at 500 Hz and speech reception thresholds no poorer than 40 dB HL bilaterally. These criteria assured that each patient would experience at least 10 dB threshold shift in the SoNo reference condition.

Finally, a group of 12 patients having neurologically diagnosed CNS disorders was tested. The disease process was ongoing in ten; two others had suffered brain stem insults earlier, but had essentially recovered at the time of testing. Nine patients had a diagnosis of MS. Of the others, one had an idiopathic inflammatory lesion of the pons, one was afflicted with progressive degeneration of the cerebellum and adjacent nervous tissue, and one had suffered a brain stem cerebrovascular accident involving the medial longitudinal fasciculus between the III and VI cranial nerve nuclei. At the time of testing the latter had recovered to the point of having minimal neurologic symptomatology. Each of the 12 subjects in this group had 25 dB HL or better 250-4000 Hz and speech reception thresholds bilaterally. Seven ears revealed mild hearing losses at 6000 or 8000 Hz.

RESULTS

The averaged data for each group are given in Table I. The values in the columns headed $S\pi No$ and $SoN\pi$ reveal

TABLE I

MEAN MLD IN dB OBTAINED FOR FOUR GROUPS OF SUBJECTS (N = 12 IN EACH GROUP)

	500 Hz		*Spondees*	
Group	$S\pi No$	$SoN\pi$	$S\pi No$	$SoN\pi$
Normal	11.7	9.3	7.3	6.9
Noise-induced loss	11.6	8.4	5.1	4.9
Ménière's disorder	4.8	2.9	3.0	2.9
CNS	9.8	7.3	5.0	3.8

the dB improvement in masked thresholds for these conditions relative to the SoNo reference.

Masking level differences for 500 Hz stimuli were about the same size for the normal subjects and for the patients with noise-induced hearing losses. These values are virtually identical to those obtained in earlier studies with larger samples (N = 50).[6] Hence, these results support our earlier observations that MLD at 500 Hz are not affected by high frequency, noise-induced hearing losses.

Binaural release from masking was reduced considerably for the group of patients having unilateral Ménière's disorder. These results are also in agreement with other reports on MLD for such patients.[4-6] It is apparent that low frequency sensorineural hearing loss such as associated with unilateral Ménière's disorder does alter the input from one side sufficiently to diminish binaural release from masking.

The 500 Hz MLD for the MS and brain stem lesion group are about 2 dB smaller than those of the normal group. This difference is not large, but given the similarity of the results for the normal and noise-induced loss groups who also had normal hearing at 500 Hz, the fact that there was a difference at all is of interest. The average 500 Hz MLD observed for this CNS group was about 2 dB larger than that observed for a group of 100 MS patients in an earlier study.[6]

Mean speech MLD for the control group (Table I) were virtually identical to those obtained in an earlier study.[6]

The results for the noise-induced hearing loss group are of particular interest for two reasons. First, mean MLD for the noise-induced hearing loss group are smaller than those observed for the normal group in spite of the fact that both had normal speech reception thresholds bilaterally. Second, these results closely match those obtained previously. Thus it appears that high frequency hearing losses such as those produced by excess noise exposure can influence binaural release from masking. Persons having noise-induced, high frequency sensorineural hearing losses frequently complain of difficulty in understanding conversational speech against speech or noise backgrounds in spite of normal speech reception thresholds and excellent speech discrimination in quiet and in noise.[12] Further research is needed to explore this aspect of their difficulty.

Masking level differences for speech attained by the Ménière's disorder patients were small as were their 500 Hz MLD. The data reported here are within 0.2 dB of the average we observed earlier for a group of 20 such subjects. Apparently the disturbance in end organ function accompanying this pathological condition disrupts the quality of transduction necessary for normal MLD.

Binaural release from masking for spondees on the order of 5 dB for the $S\pi No$ condition, and 4 dB for the $SoN\pi$ condition was obtained for the MS and brain stem lesion patients. These results almost exactly replicate those obtained earlier from 100 MS patients, being within 0.1 dB and 0.6 dB for the $S\pi No$ and $SoN\pi$ conditions respectively. The reduction in MLD size for these patients cannot be attributed to hearing loss since their speech reception thresholds and 250-4000 Hz thresholds were normal; in only a few instances were there mild losses at 6000 and 8000 Hz. Therefore, reduced MLD for these patients is more logically tied to some

TABLE II

NUMBER OF SUBJECTS ACHIEVING MLD SMALLER THAN INDICATED VALUES

	500 Hz	*Spondees*
Group	<8 dB $S\pi No$ and/or <5 dB $SoN\pi$	<6 dB $S\pi No$ and/or <4 dB $SoN\pi$
Normal	0	0
Noise-induced loss	0	7
Ménière's disorder	8	12
CNS	1	7

disruption in the CANS integration of binaural input than to peripheral auditory damage.

Another way of comparing these data to our earlier work is to consider the incidence of "abnormally small" MLD. In the earlier data, only 2 (4%) of our 50 normal subjects attained 500 Hz MLD smaller than 8 dB for the $S\pi No$ condition or smaller than 5 dB for the $SoN\pi$ condition. Only 3 (6%) of the 50 normals achieved MLD for speech smaller than 6 dB and 4 dB for the $S\pi No$ and $SoN\pi$ conditions respectively. On this basis, MLD at 500 Hz smaller than 8 dB ($S\pi No$) and 5 dB ($SoN\pi$), or smaller than 6 dB ($S\pi No$) or 4 dB ($SoN\pi$) for speech were considered to be "reduced."[6]

If these criteria are applied in the present instance as shown in Table II, none of the 12 normal subjects attained MLD for either 500 Hz or spondees smaller than the lower limits of normal. The same was true for 500 Hz MLD for the high frequency, noise-induced hearing loss subjects. However, seven of the noise-induced hearing loss cases experienced reduced MLD for speech. In the Ménière's disorder group, 8 of 12 failed to achieve MLD at or above the indicated levels for 500 Hz; all attained binaural release from masking less than the indicated cutoff levels for speech.

Of the CNS patients, only the patient with an inflammatory lesion of the pons attained reduced MLD for 500 Hz. This patient, four of the nine MS patients, and the patient with ongoing degeneration of the cerebellum and adjacent nervous tissue also obtained reduced MLD for speech. The incidence of reduced MLD for speech observed for the MS patients is similar to that observed in our earlier sample of 100 such patients. It is also imporatnt that of the three other CNS lesion patients in the present sample, those with active pathology at the time of testing demonstrated reduced MLD, at least for speech. The other patient who had reassumed nearly normal neurological status at the time of testing, attained 8 dB of binaural release from masking for speech for the $S\pi No$ condition and 5 dB for the $SoN\pi$ condition.

CONCLUSION

From the preceding review of data, it is clear that binaural release from masking is influenced by disturbances in cochlear function. Noise induced-hearing losses do not affect MLD for 500 Hz, but do diminish binaural release from masking for spondees. The alteration in cochlear transduction associated with unilateral Ménière's disorder disrupts processing to the extent that binaural release from masking is sharply reduced.

Given normal peripheral function, however, it appears that MLD are frequently affected by lesions of the CNS associated with MS, or other pathologies in the brain stem and/or midbrain region.

The data presented here indicate that MLD tests utilizing speech are more sensitive to subtle CANS dysfunctions than are tests utilizing 500 Hz pure tone stimuli. This observation is in accord with other attempts directed at detecting auditory lesion beyond the cochlea and VIII nerve. That is, complex tasks utilizing complex stimuli such as speech are necessary for detection of dysfunction in the CANS.

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