Binaural Intelligibility Level Differences in Normal and Hearing-Impaired Individuals

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Introduction

Release from masking, or the masking level difference (MLD), is a phenomenon in which the binaural auditory system can take advantage of interaural phase differences to improve the detection of signals in a background of noise. The MLD phenomenon can be observed for both tonal and speech signals at or near threshold levels. Similarly, intelligibility of speech presented at suprathreshold levels can be improved by manipulating interaural phase angles of the signal or the background noise. The improvement of suprathreshold speech intelligibility has been referred to as the binaural intelligibility level difference (BILD) (Levitt & Rabiner, 1967). Although numerous studies have investigated MLDs for speech and pure tones (e.g., Gerber, Jaffe, & Alford, 1971), relatively little research has been directed toward the investigation of BILDs. Furthermore, investigation of release from masking has dealt primarily with young normal-hearing populations (Gerber, 1972). No evidence has been presented thus far to determine how the hearing-impaired elderly perform release-from-masking tasks at suprathreshold levels, that is, how they are affected by the BILD phenomenon.

In addition to the theoretical significance of this question, practical implications also exist. Perhaps the most difficult problem facing the hearing-impaired elderly is understanding speech in the presence of background noise. To determine if the BILD phenomenon can be applied to relieve this problem through improvements in hearing-aid design, it is first necessary to determine how the elderly are affected by the BILD under laboratory conditions.

This study, therefore, set out to answer the following questions:

1. Will interaural phase reversal of a speech signal presented in a background of multitalker noise result in improved speech intelligibility in the hearing-impaired elderly?
2. Would such improvement in intelligibility from interaural phase reversal be comparable to that of normal-hearing elderly subjects and normal-hearing young subjects?
3. Will the degree of improvement depend on the signal-to-noise ratio (S/N) of the stimuli?
4. Will the degree of improvement from phase-shifting the noise differ from phase-shifting the signal?

Method

Subjects

Subjects included three test groups. Group 1 (normal-hearing young adults) consisted of 15 subjects aged 20 to 24 (mean, 22) years. Their speech reception thresholds (SRTs) ranged from 0 to 5 dB, and speech discrimination was 100% in each ear. Group 2 (normal-hearing elderly) comprised 15 subjects aged 60 to 80 (mean, 70) years. Their SRTs ranged from 0 to 20 dB and speech discrimination ranged from 90% to 100%. Group 3 (presbyacusics) consisted of 15 subjects aged 60 to 82 (mean, 72) years. Their SRTs ranged from 35 to 65 dB, and speech discrimination ranged from 68% to 100%.

All testing was conducted in a sound-treated two-room audiometric suite with a two-channel audiometer. Signals were presented through TDH-39 headphones with MX-41 cushions. The audiometer was calibrated to ANSI 1969 standards.

Apparatus

The experimental arrangement is shown in Figure 1. The two signals (S, which consisted of PB word lists, and N, which consisted of multitalker noise) were presented by means of separate audiotapes. Signal S was played on one tape player and signal N on another. Both tape players were connected to a custom-made inverter-mixer network designed specifically for this study. The inverter contained two phase-inverter switches, allowing each input channel to be phase-shifted by 180°, and two attenuators, allowing each channel to be attenuated in relation to the other. The outputs of the inverter led to the tape inputs of the audiometer.

Procedure

Each subject was tested during two sessions. During the first session, the subject underwent a basic audiometric evaluation. This included pure tone air and bone conduction audiometry, measurement of SRT, and word discrimination testing, including obtaining PB max.

During the second session, each subject was tested in three listening conditions. In condition 1, the primary speech signal and the competing noise were presented to both ears simultaneously in phase (this is the $S_0 N_0$ condition). In condition 2, the noise was presented in phase, but the signal was presented 180° out of phase at the two ears (this is the $S_\pi N_0$ condition). In condition 3, the signal was in phase, but the noise was 180° out of phase at the two ears (this is the $S_0 N_\pi$ condition).

Each of the three test conditions was presented at three S/N ratios (-10 dB, 0 dB, and +10 dB). The S/N ratios were maintained by keeping the signal S constant while varying the intensity of signal N. Zero dB of signal S was defined as PB max for each subject. The various S/N ratios were obtained by manipulating the attenuator control on the channel for signal N on the inverter box.

Figure 1: Block diagram of apparatus.

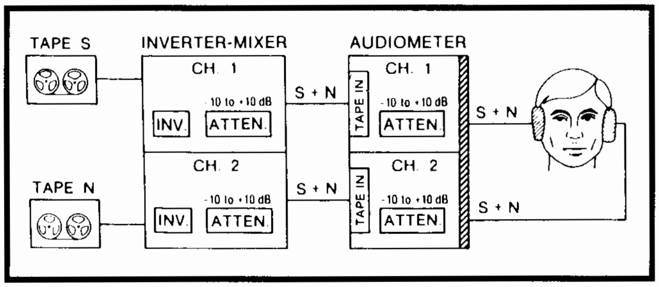
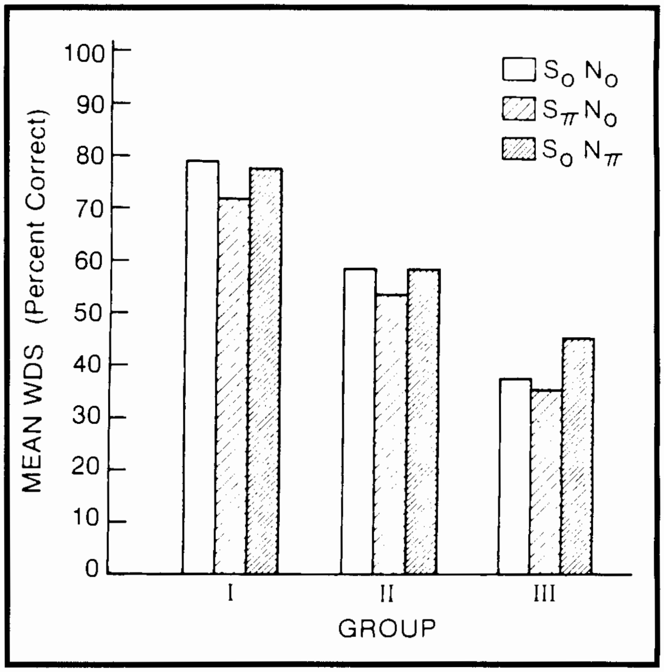


Figure 2: Mean word discrimination score (WDS) for all test groups at each phase condition. Signal-to-noise (S/N) ratio = -10dB.



Results

Figure 2 summarizes the mean word-discrimination scores (WDSs) for all test groups at all phase conditions at an S/N ration of -10 dB, Figure 3 at an S/N ratio of 0 dB, and Figure 4 at an S/N ratio of +10 dB. Data were analyzed by a multiple factor analysis of variance with repeated measures using a 3x3x3 factorial design. The Duncan post-hoc test was used to determine the differences between and within the groups.

Examination of these figures and Table 1 indicates several findings. The mean WDS is different ($p<0.01$) between each of the groups for each S/N ratio. For example, at an S/N ratio of -10 dB, the mean WDS was 79% for the normal-hearing young (group 1), 59% for the normal-hearing elderly (group 2), 38% in the hearing-impaired elderly (group 3) in the $S_0 N_0$ condition. In the $S_\pi N_0$ condition, group 1 scored 72%, group 2, 54%, and group 3, 36%. In the $S_0 N_\pi$ condition, group 1 had a mean WDS of 78%, group 2, 59%, and group 3, 48%. However, upon examination of Figures 2 through 4, this difference appears to become less apparent as the S/N ratio improves. At an S/N ratio of 0 dB, group 1 had a mean WDS of 94%, group 2 a mean of 86%, and group 3 a mean of 80% in the $S_0 N_0$ condition. In the $S_\pi N_0$ condition, group 1 scored 94%, group 2, 87%, and group 3, 77%. In the $S_0 N_\pi$ condition, group 1 had a mean WDS of 95%, group 2, 89%, and group 3, 83%. At an S/N ratio of +10 dB, the smallest differences were very small. The mean WDS for group 1 was 98%, group 2, 94%, and group 3, 90% in the $S_0 N_0$ condition. In the $S_\pi N_0$ condition, the WDS for group 1 was 98%, group 2, 92%, and group 3, 87%. Finally, in the $S_0 N_\pi$ condition, the mean WDS for group 1 was 98%. group 2, 93%, and group 3, 91%.

Table 1: Summary of mean word discrimination scores (*M*) and standard deviations (*SD*s), in percent correct, at each test condition for each test group.

	Test Condition, Signal-to-Noise Ratio (dB)																	
	S_0N_0						$S_\pi N_0$						S_0N_π					
	-10		0		+10		-10		0		+10		-10		0		+10	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Group I	79	9	94	3	98	2	72	7	94	5	98	2	78	8	95	4	98	2
Group II	59	14	86	8	94	4	54	12	87	5	92	5	59	16	89	7	93	2
Group III	38	14	80	14	90	10	36	14	77	17	87	10	48	17	83	10	91	5

Figure 3: Mean WDS for all test groups at each phase condition. S/N ratio = 0 dB.

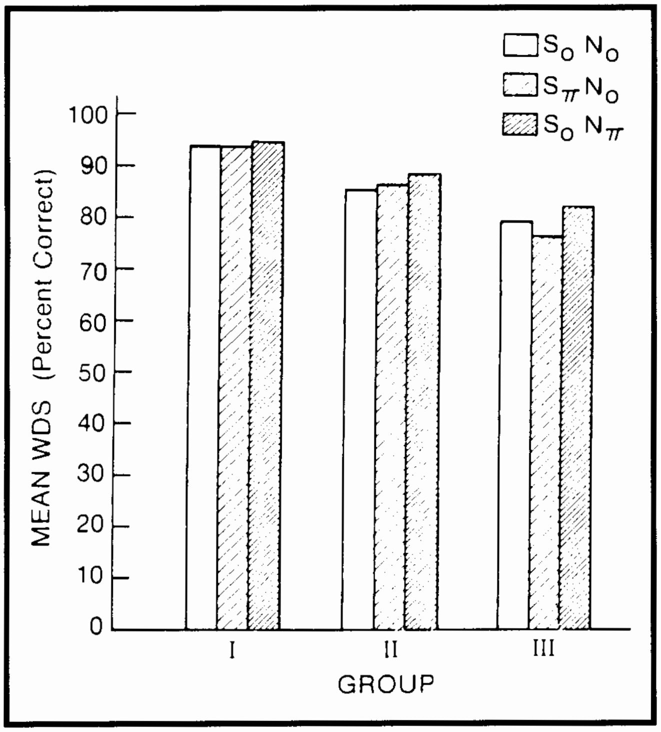
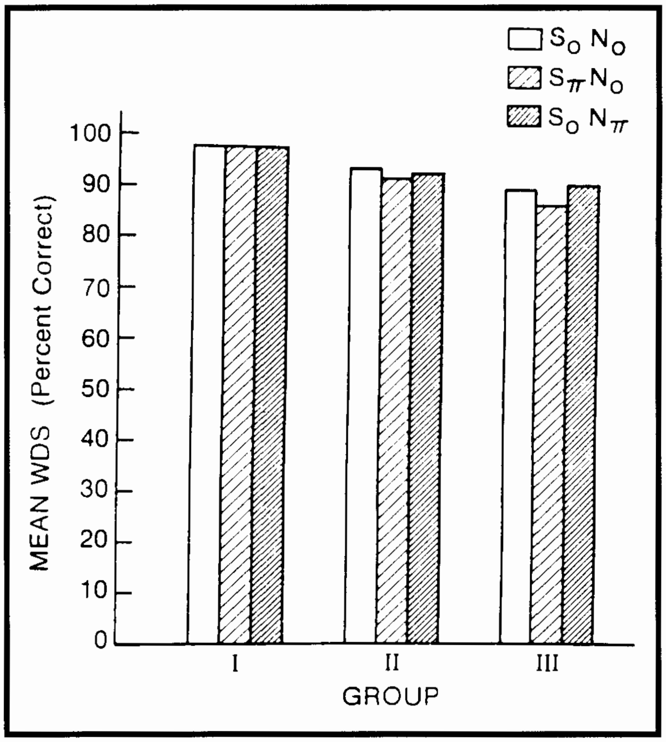


Figure 4: Mean WDS for all test groups at all phase conditions. S/N ratio = +10dB.



The mean WDS of the normal-hearing young was highest and that of the hearing-impaired elderly was lowest at each S/N ratio tested. These differences were most obvious at an S/N ratio of -10 dB. All groups had an improvement in the WDS for each phase condition as the S/N ratio improved. There were differences between each phase condition; however, they became minimal or nonexistent as the S/N ratio improved.

The WDS was significantly different ($p<0.001$) among the normal-hearing young, the normal-hearing elderly, and the hearing-impaired elderly when neither phase nor the S/N ratio were considered. The mean overall WDS was 90% for the young subjects, 79% for the elderly subjects, and 79% for the presbyacusics.

Significant differences ($p<0.001$) also were found for the effect of phase condition. The overall mean WDS in the S_0N_0 condition was 80%, in the $S_\pi N_0$ condition and in the S_0N_π condition 82%. Significant differences ($p<0.001$) among the S/N ratios also were seen: the overall WDS was 58% at -10 dB, 87% at 0 dB, and 94% at -10 dB. When the effect of interaction between group and phase was examined, differences were found at $p<0.001$. Interaction effect of group and S/N ratio and phase was not significant at the $p<0.001$ level. Effect of interaction between S/N ratio and phase was not significant at $p<0.01$ but was significant at $p<0.05$. No statistical significance was observed for interactions among group, phase, and S/N ratio.

Differences between groups were assessed for each of nine experimental conditions. Under condition 1 (S_0N_0, S/N = -10 dB), each of the three groups was significantly different from the other. For condition 2 (S_0N_0, S/N = 0 dB), the normal-hearing young differed significantly from the hearing-impaired elderly, but the elderly groups did not differ significantly ($p<0.01$) from each other. However, both of the normal-hearing groups did not differ from each other either. The results for condition 3 (S_0N_0, S/N = +10 dB) were identical to those for condition 2. For condition 4 ($S_\pi N_0$, S/N = -10 dB), all the groups differed significantly from each other. For condition 5 and 6 ($S_\pi N_0$, S/N = 0 dB; $S_\pi N_0$, S/N = -10 dB), the only significant difference was between the normal-hearing young and the hearing-impaired elderly. For condition 7 (S_0N_π, S/N = -10 dB), the normal-hearing young were significantly ($p<0.01$) different from the normal-hearing elderly and the hearing-impaired elderly, whereas the elderly groups did not significantly differ from each other. For condition 8 (S_0N_π, S/N = 0 dB), the only significant differences ($p<0.01$) were, again, between the normal-hearing young and the hearing-impaired elderly. For condition 9 (S_0N_π, S/N = + 10 dB), the normal-hearing young were significantly different from both the elderly groups, but the latter did not differ from each other.

There were no significant differences within groups for any phase condition at all the S/N ratios at the 0.01 or 0.05 levels of confidence.

Conclusions

On the basis of these results it appears that:

1. Phase reversal of a speech signal in a background of multitalker noise did not result in a significant improvement of speech intelligibility in the hearing-impaired elderly;
2. Similar results were found in the normal-hearing young and elderly;
3. Improvement was significant regardless of the S/N ratio; and
4. Improvement was insignificant regardless of whether the signal or noise was phase-shifted.

Although BILDs were seen in many of the individuals in the hearing-impaired elderly, high variability of scores resulted in statistically insignificant BILDs in all groups. Several factors may account for these findings.

5. Release from masking for threshold signal detection may function in a different manner than release from masking for suprathreshold speech discrimination.
6. Speech maskers may affect release from masking in a manner different from noise maskers.
7. The interaural intensity level of signal presentation may affect the BILD phenomenon.
8. Poor reliability of W-22 word lists - as demonstrated, for example, by Thornton and Raffin (1978) - may contribute to high variability of scores, thus obscuring any consistent BILD that may be present.

Discussion

It was not surprising that the S/N ratio had a profound effect on speech discrimination in noise. As the S/N ratio improved, the groups behaved more like one another in speech discrimination ability. It also was not surprising to find that the normal-hearing young, the normal-hearing elderly, and the presbyacusics performed significantly different from one another on a task involving speech discrimination in noise. However, it is interesting that the hearing-impaired elderly appeared to be as different from the normal-hearing elderly as the normal-hearing elderly were from the normal-hearing young. This indicated that speech discrimination is affected by both age and hearing sensitivity. If age were the only factor affecting discrimination, then the two elderly groups would have been expected to score much like one another but different from the young group. Similarly, if hearing sensitivity were primarily responsible for the discrimination scores, one would expect the two normal-hearing groups to obtain scores similar to one another but different from the presbyacusics. This clearly was not the case, and hence should influence our clinical judgement.

In summary, although binaural intelligibility level differences were found for many normal and hearing-impaired individuals, high variability of scores within the groups resulted in statistically insignificant BILDs for W-22 word lists presented in a background of multitalker noise.

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