AN EVALUATION OF THE CROS-TYPE HEARING AID

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Until recently, there was little the clinical audiologist could offer in the way of help to the unilaterally impaired listener. Armed with the knowledge that one good ear is usually sufficient for most communicative needs, the audiologist often counselled that due to the limitations inherent to modern hearing aids and the unique problems of the one-eared listener, amplification would not be satisfactory. This type of individual frequently indicated that his hearing was adequate for face-to-face communication, but that he encountered considerable difficulty under some adverse circumstances. Harford and Dodds (1) cited three typically difficult situations encountered by the unilaterally impaired listener: First, when listening to speech originating from the side of the bad ear; second, when communicating in a noisy environment and; third, when attempting to locate the source of a sound. In the past, recommendations to this type of individual were generally restricted to suggesting that he modify his environment whenever possible to allow his good ear to be directed toward the sound source.

Within the last few years, Harford and his associates have proposed a method which allows the unilaterally impaired listener to benefit from amplification. The method, dubbed CROS (contralateral routing of signals), involves the location of the hearing-aid microphone on the side of the impaired ear with the receiver located at the side of the unimpaired ear. Thus, sounds directed to the poorer ear are amplified and routed across the head for hearing by the good ear. Harford and Barry (2) noted that the results of routine speech audiometry are often similar whether or not the CROS aid is worn. They stated:

"Until more sensitive clinical tests are developed, the most meaningful approach to the final recommendation relative to CROS is its actual use by the patient. . . ."

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The present study deals with efforts to develop procedures for evaluating CROS. Specifically, we were interested in determining whether the advantages and disadvantages, if any, of the CROS aid could be demonstrated in the laboratory.

Subjects for the investigation were twenty unilaterally impaired veterans selected on the basis of clinical audiograms. We required pure-tone threshold averages over the range from 500 to 2000 Hz to be better than 25 dB hearing level (HL) for the good ear, and poorer than 60 dB HL for the bad ear (International Standards Organization [ISO]–1964). Figure 1 shows the median pure-tone threshold levels for the better ears of the group in hearing level re ISO. Interquartile ranges for the losses at each test frequency are indicated by the striped lines about the median values.

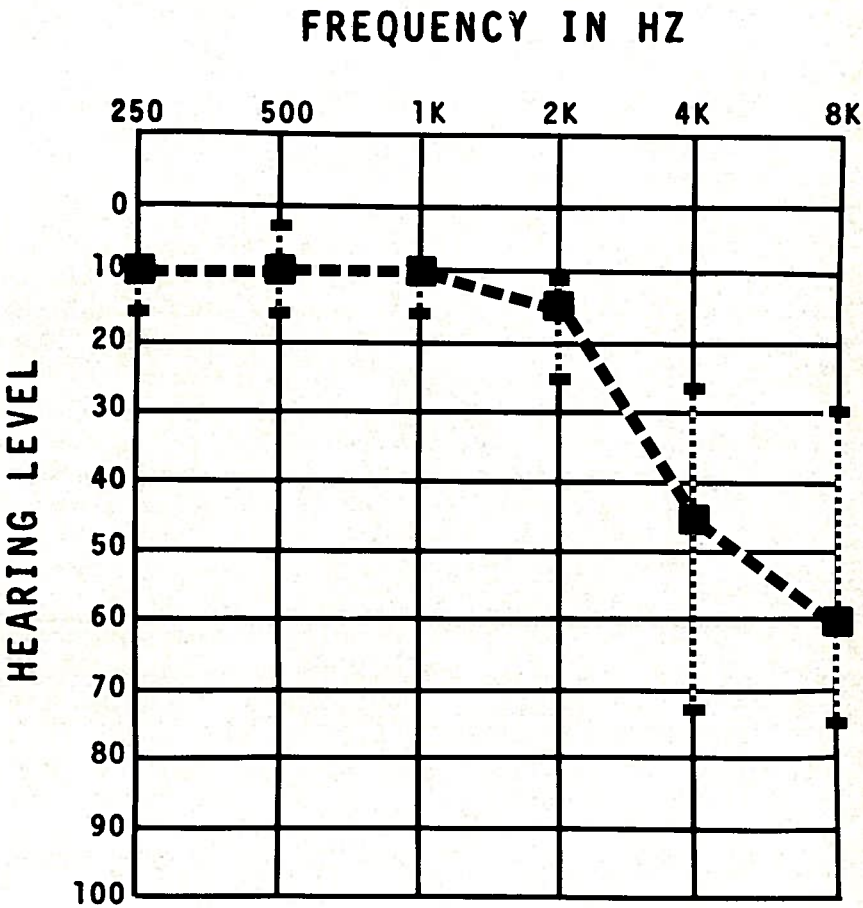
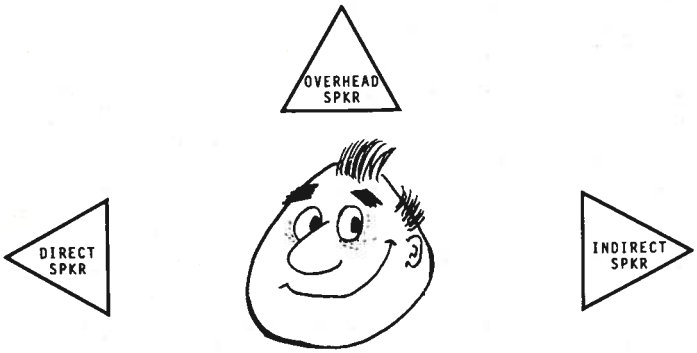


FIGURE 1.—Median pure-tone threshold levels (ISO–1964) and interquartile ranges for the better ears of the experimental subjects.

The revised Lehiste-Peterson Consonant-Nucleus-Consonant (CNC) word lists were used as the experimental stimuli. The CNC words were recorded on one track of magnetic tape with a competing signal, cafeteria noise, recorded on the second track. The taped materials were presented to the subjects via a dual channel tape recorder, through necessary amplifiers and attenuators, and finally to three loudspeakers. The loudspeakers and the subject were located in a sound treated room; the remainder of the equipment was located in an adjacent control room.

Figure 2 is a simplified display of the nature of the loudspeaker placement and description of the conditions which were achieved. The scale here, incidentally, is somewhat distorted. The subject was seated in the center of the test room directly between two loudspeakers and approximately four feet from each. The third loudspeaker was mounted directly over his head. The CNC words were presented from either of the two side speakers, but never from overhead; while the noise could be presented from any of the three speakers.

The conditions we employed are indicated at the bottom of Figure 2. They were specified on the basis of the relationship of the loudspeakers to the unimpaired ear. The direct loudspeaker was the one adjacent to the



CONDITION	STIMULUS		
	DIRECT LOUDSPEAKER	INDIRECT LOUDSPEAKER	OVERHEAD LOUDSPEAKER
SD--NI	Speech	Noise	---
SD--NO	Speech	---	Noise
SF--NO	Speech*	---	Noise
SI--NO	---	Speech	Noise
SI--ND	Noise	Speech	---

*Subject turned to face loudspeaker.

FIGURE 2.—Representation of loudspeaker placement and test conditions which were achieved. Direct speaker refers to loudspeaker located on the side adjacent to subject's better ear.

better ear and the indirect speaker was adjacent to the poorer ear. In the case of the figure, the right ear would be the good ear and the left the impaired ear. The conditions were: a. Speech Direct—Noise Indirect, b. Speech Direct—Noise Overhead, c. Speech Indirect—Noise Direct, d. Speech Indirect—Noise Overhead, and e. a fifth condition was achieved by turning the subject to face one loudspeaker. In that instance, the competition noise was presented by the overhead speaker.

Each subject was tested both unaided and aided under each of the five conditions with appropriate precautions to avoid systematic order effects. We employed two commercially available moderate gain CROS-type hearing aids coupled to the unimpaired ear by modified soft plastic inserts.

The CNC lists were presented at 70 dB sound pressure level (SPL) with a nominal signal-to-noise ratio of +8 dB. Both the presentation level and the signal-to-noise ratio were specified at the point in space to be occupied by the subject's head, but with the subject absent from the field. For the aided conditions the subject adjusted the gain of the CROS aid to a comfortable loudness in the presence of running discourse which was presented from the indirect loudspeaker, that is, from the speaker adjacent to the hearing-aid microphone and opposite the good ear.

The speech intelligibility scores obtained under the five unaided and five aided conditions were converted to deterioration scores relative to better ear discrimination in quiet. These results are displayed in Figure 3. On this graph the black bars represent the mean unaided performance for the group, and the white bars represent the mean aided performance. The height of each bar indicates the decrease in discrimination for that condition relative to discrimination in quiet under phones.

For two of the conditions, differences between unaided and aided performances were not statistically significant using the Wilcoxon matched-pairs signed-ranks test. On the speech direct—noise overhead condition and the speech from the front—noise overhead condition (simulating face-to-face communication) discrimination was about the same whether or not the hearing aid was employed, the decrease from discrimination under earphones being about 20 to 30 percent. This is consistent with the contention that routine audiometry might fail to distinguish between unaided and aided performance.

On the three remaining conditions, the differences between unaided and aided discrimination were more marked and were statistically significant beyond the .05 level using the Wilcoxon. For the speech indirect—noise overhead condition, we found a relative improvement of 15 percent through the use of CROS. Here, unaided scores deteriorated 37 percent re discrimination under phones while aided performance deteriorated only 22 percent.

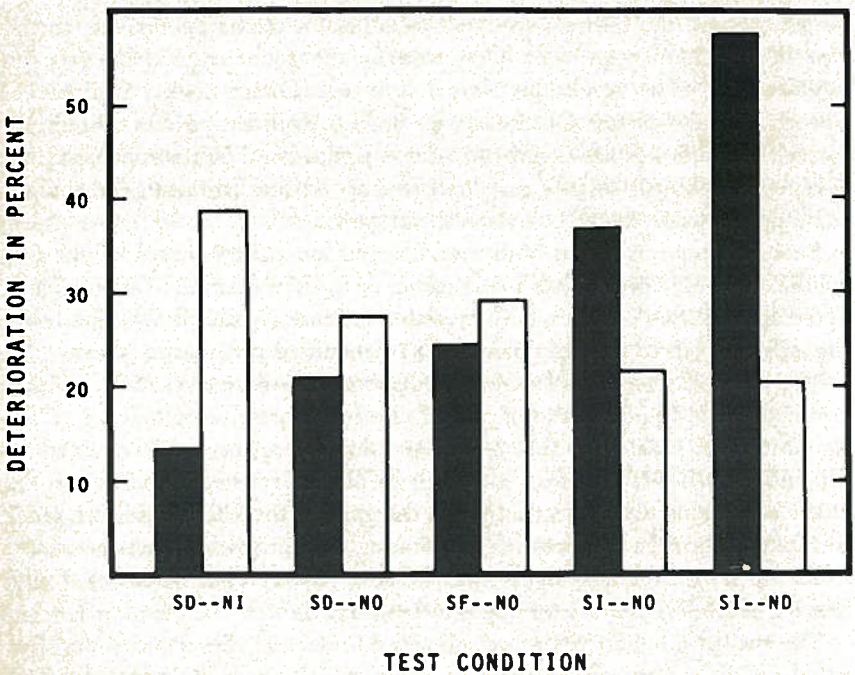


FIGURE 3.—Deterioration in intelligibility (reference discrimination in quiet) as a function of test conditon. Black bars represent mean unaided performance and white bars represent aided performance.

The speech indirect—noise direct condition and the speech direct—noise indirect condition tended to show the CROS aid at its best and its worst, respectively. In the speech indirect—noise direct condition, the unilaterally impaired subject found himself in the circumstances generally most difficult for him: namely, a noisy environment with speech coming to him from his bad side. Mean unaided performance in this situation decreased 58 percent from discrimination in quiet. Using the CROS aid resulted in a relative improvement of 38 percent.

Reversing this situation, that is, presenting speech from the side of the better ear and cafeteria noise from the side of the poorer ear, resulted in the relationship shown on the far left of the chart.

The unaided scores are better than under any other condition. This is not surprising, as the speech was delivered directly to the better ear while the effectiveness of the noise in masking that speech was reduced by the head shadow effect.

Wearing the hearing aid in this condition yielded a decrease in intelligibility of approximately 25 percent. Here, the aid served to amplify the masking noise which had been attenuated by the head baffle effect. Thus,

under the most favorable condition for use, the aid provided a relative increase in performance of 38 percent and in the least favorable condition, a relative decrease of 25 percent.

The simple injunction to the user that he turn on his hearing aid in one situation and turn off his hearing aid in another appears to be a bit too simple. It is in just those circumstances such as meetings or group discussions in which the individual receives speech from a number of sources that he most requires the aid to attend to speech directed to his poorer ear. Similarly, it is in those same situations that the aid may be providing amplified masking when he desires to attend to speech emanating from his good side.

Although the CROS aid reduces the problems created by a unilateral loss on one side, it may under some circumstances create the effects of such a loss on the other side.

It should be mentioned that, almost without exception, the subjects in this study were highly enthused about the CROS aid after using it. This occurred despite the fact that performance with the aid was at times severely impaired.

It seems that the pair of conditions we labeled speech direct—noise indirect and speech indirect—noise direct (i.e., speech to the good side, noise to the bad; and speech to the bad side, noise to the good) may prove useful in further attempts to evaluate CROS-type hearing aids. The conditions are easily achieved and demonstrate both the advantages and disadvantages to be obtained from this type of amplification. It remains to be seen whether objective test scores such as these will prove satisfactory for determining the usefulness of CROS aids or in differentiating one CROS aid from another.

REFERENCES

1. Harford, E. and E. Dodds: The Clinical Application of CROS. A Hearing Aid for Unilateral Deafness. Arch. of Otolaryng., 83:455–464, 1966.
2. Harford, E. and J. Barry: A Rehabilitative Approach to the Problem of Unilateral Hearing Impairment: The Contralateral Routing of Signals (CROS). J. Speech & Hearing Dis., 30:121–138, 1965.

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