Bi-Sensory Articulation Functions for Normal Hearing and Sensorineural Hearing Loss Patients

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INTRODUCTION

This study was designed to determine the relative contribution of auditory and visual cues for discrimination of monosyllabic words. The idea for this study evolved from a dissatisfaction with traditional approaches of testing lipreading ability of hearing-impaired adults and also from the need for quantifying bi-sensory (auditory-visual) speech reception in controlled listening conditions.

Several authors have reported that an auditory-visual (AV) presentation of speech would yield the best possible discrimination score for the hearing impaired client. Siegenthaler and Gruber (1969) recommended AV presentations of speech materials in order to obtain realistic assessments of speech discrmination. Dodds and Harford (1968) suggested that AV presentations of sentence materials in hearing aid evaluations would yield additional information about how hearing impaired persons may understand general conversational speech. Krug (1960) determined bi-sensory discrimination scores at various relative intensity levels and found that the listeners obtained maximum intelligibility at 15 dB sensation level.

From the information presented above it would seem reasonable that individuals who are considered candidates for aural rehabilitation should receive discrimination tests under three different presentation modes: 1) Auditory-only, 2) Visual-only, and 3) Auditory-Visual. The auditory-only scores would reveal information about a person's speech discrimination ability as obtained by conventional speech audiometry. The visual-only scores would reveal the person's lipreading ability for inaudible presentations of low redundancy materials. Finally, the auditory-visual scores might suggest how individuals will receive person-to person speech in general conversational situations. These scores might also reveal information helpful in planning aural rehabilitation therapy and measuring improvement following treatment.

PROCEDURE

Fifteen normal hearing subjects were included in the preliminary portion of this study. Eight males and seven females ranging in age from 23 - 37 years, with a mean age of 28.13 years, comprised this group. They all demonstrated normal hearing by passing a 15 dB screening test (1969 ANSI norms) for frequencies 250 - 4000 Hz. No subject had a visual defect which would interfere with viewing the monitor and none had participated in any previous lipreading or speech intelligibility study.

The speech materials used in this study were: 1) Twenty selected spondees from the list of 36 utilized by Hirsh et al. (1952) were used to establish a free-field speech reception threshold; and (2) Lists 1A, 2A, 3A, 4A, 1B, and 2B each consisting of 50 consonant-vowel-consonant monosyllables from the Northwestern University Auditory Test No. 6, as reported by Tillman and Carhart (1966) comprised the stimulus items. These speech materials were recorded on an Ampex VR-7000 video-tape recorder by a male speaker who monitored the carrier phase "Write the word" at a constant level by watching the VU meter of a Bruel and Kjaer sound level meter (Type 2203).

During the test conditions, both the spondees and monosyllables were delivered from the video-tape unit through a calibrated speech audiometer (Grason-Stadler 162) and presented through a sound field speaker placed 6 feet from the listener. The visual portion of the video-tape was eliminated fro the auditory-only condition. For the auditory-visual portion of the test a Magnavox 13" TV monitor was placed on the sound field speaker to coordinate the source of speech with the lips of the speaker as closely as possible.

Each subject was tested individually in a 400 series IAC sound suite. Prior to presentation of monosyllables a freefield speech reception threshold was established from the list of twenty spondees. For speech discrimination of the monosyllabic words the subjects wrote their responses on prepared answer sheets. In establishing articulation functions the order of auditory-only and auditory-visual was alternated for each subject and the order of list presentation was randomized to minimize list differences and learning factors.

The levels of presentation always proceeded from lowest to highest. These levels were O dB, 8 dB, 16 dB and 24 dB sensation level (SL) for the auditory-only condition and -20, 0, 8 and 16 dB SL for the auditory-visual condition.

RESULTS

The articulation function for the auditory-only condition for normals is consistant with that obtained by Tillman and Carhart as shown in Figure 1. Both groups demonstrate a linear portion with a saturation level after which the curve approaches its asymptote. The function obtained from the present study is slightly less steep than that of Tillman and Carhart: 4.8% per dB in the present study compared to 5.6% per dB reported by Tillman and Carhart. The standard deviations computed in each study were very similar (see Table 1). That is, higher standard deviations were calculated at lower presentation levels in both investigations. The difference in mean discrimination scores for the two studies is considered to be related to speaker and/or equipment differences.

The data obtained for auditory-only and auditory-visual conditions are shown in Figure II. The auditory only articulation function demonstrates speech intelligibility of 21% at 0 dB SL, 59% at 8 dB SL, 80% at 16 dB SL and 94% at 24 dB SL. This is considered to be near the asymptote of the function although it would be interesting to have data for the 32 dB SL condition. Future research will include this presentation level.

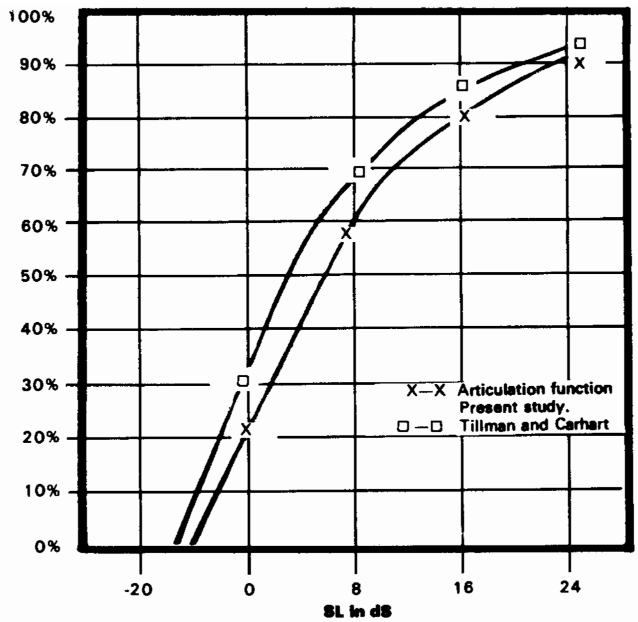

FIGURE I

Articulation function curves for auditory-only in present study compared to Tillman and Carhart curve. Scores are mean scores for percent correct.

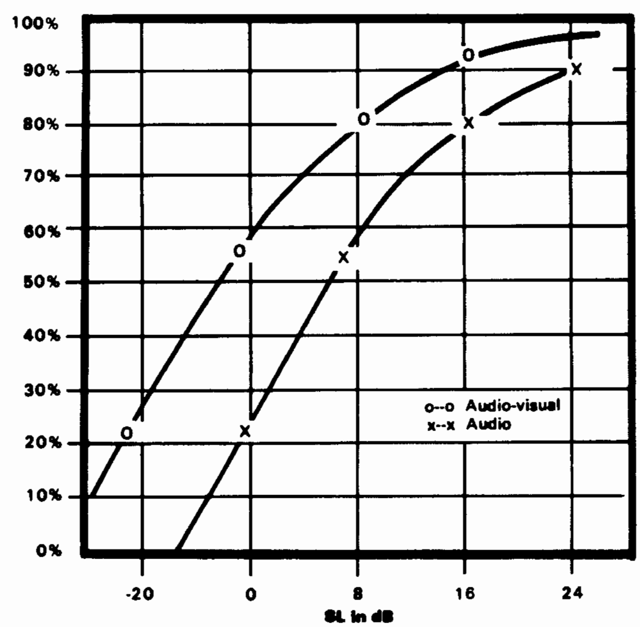

FIGURE II

Mean discrimination scores of normal hearing subjects for audio-visual and audio-only conditions.

TABLE I

Median (Mdn.), mean (x), and standard deviations (s) of discrimination scores of normal hearing subjects. Scores represent percent of items correct.

SENSATION LEVEL OF PRESENTATION*	AUDITORY			AUDIO-VISUAL		
	Mdn.	x	s	Mdn.	x	s
-20	-	-	-	23.75	22.66	11.58
0	15.75	20.53	14.22	58.25	56.66	15.82
8	63.75	58.93	15.81	82.25	84.66	6.76
16	81.75	80.26	11.54	94.00	93.73	3.17
24	95.60	94.26	3.33	-	-	-

* re: free-field SRT

The auditory-visual articulation function parallels the auditory-only function quite consistently although it is steeper and displaced to the left demonstrating the influence of visual cues. The -20 dB SL condition represents the amount of information this group of 15 normal hearing subjects could recognize through lipreading. A mean percentage score of 23% suggests that only a limited number of monosyllables could be recognized through visual attention to articulatory movements. At 0 dB SL the auditory-visual score is 57% which is approximately 36% points greater than the auditory-only score for the same SL. At 8 dB SL the auditory-visual score is 85% compared to the auditory-only score of 59%, a difference of 26%. At 16 dB SL the difference between the auditory-visual score of 94% and the auditory score of 80% is only 14%.

It is suggested that at low sensation levels there may be an interaction between auditory and visual cues. This interaction results in numerically greater scores for the auditory-visual condition than for the sum of the separate auditory and visual conditions. This interaction effect appears to decrease at the higher sensation level of 8 dB and beyond because at higher sensation levels there is progressively more intensity available for speech discrimination and the visual cues tend to contribute a smaller increment to speech intelligibility.

Some sensori-neural hearing loss patients were tested but group data are not available because the scores have demonstrated much variability depending upon the audiometric configuration. Consequently, two individual cases will be reported here.

The audiogram for one sensori-neural hearing loss case is shown in Figure III. This 65 year old college professor demonstrates a moderate, bilateral sensori-neural hearing loss. The pure-tone configuration is fairly flat between 250 and 4000 Hz. He is wearing a hearing aid in his left ear and demonstrates an aided SRT of 28 dB. The auditory-only and auditory-visual articulation functions for this case are shown in Figure IV. His auditory-only function progresses from 20% at 0 dB SL to 78% at 24 dB SL. The auditory-visual curve demonstrates a lip-

FIGURE III

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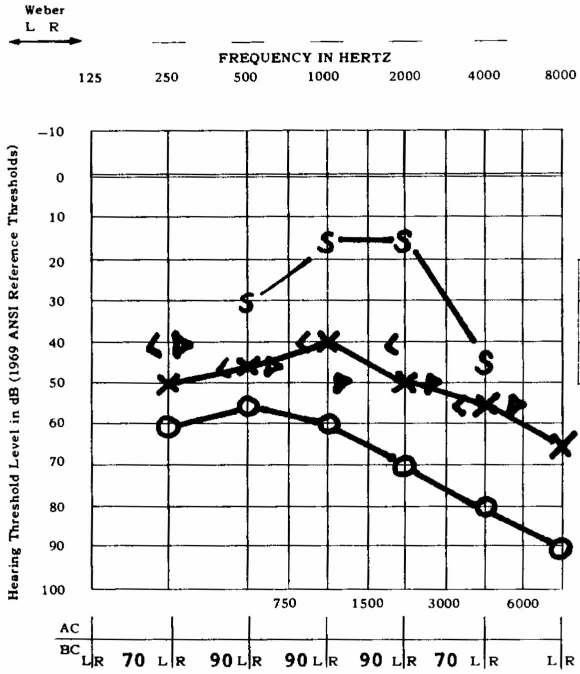
AUDIOMETRIC EVALUATION

Date Jan. 18, 1969

Name H. K. (S-N Case #3) Address ______ Sex M Age 65

Audiometer Bel Model 15CX Estimated Accuracy Good Audiologist CB

PURE TONE AUDIOGRAM



MASKING LEVEL IN NON-TEST EAR

AUDIOGRAM CODE

Ear	Air Un-masked	Air Masked	Bone Un-masked	Bone Masked	
R	O	Δ	>	▷	Red
L	X	□	<	◁	Blue

PURE TONE AVERAGE (500–2000 Hz)

Ear	Air Un-masked	Air Masked	Bone Un-masked	Bone Masked
R	62			
L	45			

SPEECH AUDIOMETRY

	L	L Masking	R	R Masking	SF	LV or Rec
SRT	44		58		28	
PB in Quiet	82 / SL 30	ML / SL	86 / SL 30	70 ML / SL		
PB in Noise	SL	ML / S/N	SL	ML / S/N		
MCL						
UCL						

Remarks: S-S Aided sound field warble tones (LE)

Comments:

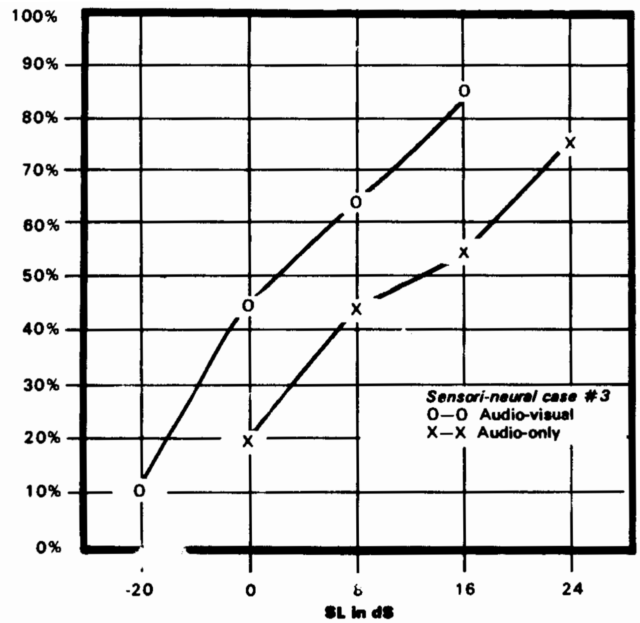


FIGURE IV

Auditory-visual and auditory-only articulation functions for sensori-neural case #5.

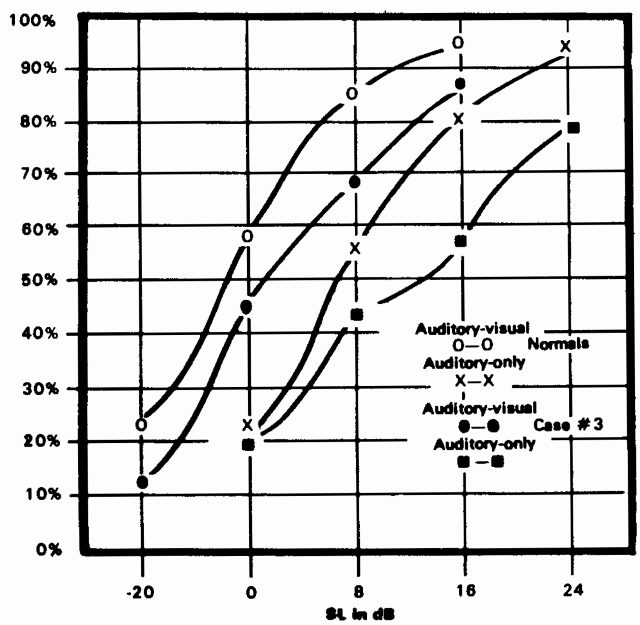


FIGURE V

Comparison of articulation functions for normal hearing subjects and Case #3.

reading score of only 12% at the -20 dB SL condition. A score of 46% was recorded for the A-V condition at 0 dB SL, 68% at 8 dB SL and 86% at 16 dB SL. The speech intelligibility scores are consistently better for the auditory-visual condition and bi-sensory presentation is best at 16 dB. When the articulation function curves for this sensori-neural hearing loss case are compared to those for normal hearing subjects (Figure V) it will be seen that the scores for the sensori-neural hearing loss case are not as good as for normal hearing subjects for the auditory-only condition. This discrimination loss for speech is reduced, in part, when he can utilize visual cues although his auditory-visual score is not quite as good as the auditory-visual scores for normal hearing subjects at any SL. It would be interesting to determine if lipreading and auditory training would yield better discrimination scores by virtue of his articulation function becoming more steep. Possibly the best starting point for therapy for this individual would be the bi-sensory presentation of materials at 16 dB SL or more and then to decrease the SL as he became more proficient at the selected starting point.

The next figure (Figure VI) shows the audiogram of a 57 year old male who has had a hearing loss since he was approximately five years old. He wears a body type hearing aid in his right ear. This precipitous high-frequency hearing loss has produced a severe discrimination loss for speech. He reported that he must rely on visual cues to understand general conversational speech. He obtained an aided SRT of 38 dB although an aided speech detection threshold was recorded at 25 dB

His articulation functions are shown in Figure VII. His discrimination loss for speech is clearly demonstrated in this figure. The best discrimination score for auditory-only conditions was obtained at 16 dB SL and was 54%. The articulation function for auditory-visual listening conditions shows the influence of visual cues. His speech intelligibility score under this condition is approximately 80% at 8 and 16 dB SL. It would be interesting to determine if an integrated approach of lipreading and auditory training would improve his A-V score at 16 db SL.

Auditory and audio-visual discrimination scores for other sensori-neural hearing loss subjects are shown in Table II. The auditory discrimination scores show a steady improvement with increases in presentation level reaching the low to mid 80% level at the 24 dB sensation level for three subjects. Only one subject reached 94% at 24 dB SL while the other had poor auditory speech discrimination (36%) at 24 db SL. The lipreading scores (-20 dB SL) for the five subjects range from 8 - 22% yielding an average score of 14.80% which is below the lipreading score for the normal hearing subjects. However, it is interesting to note the relatively good audio-visual speech discrimination scores obtained by the sensori-neural subjects at 16 dB SL. The poorest score for the monosyllabic words was 74% while the best score was 98%. As a group, the average audio-visual speech discrimination score at 16 dB SL was 85.60%. This really is a very good

FIGURE VI
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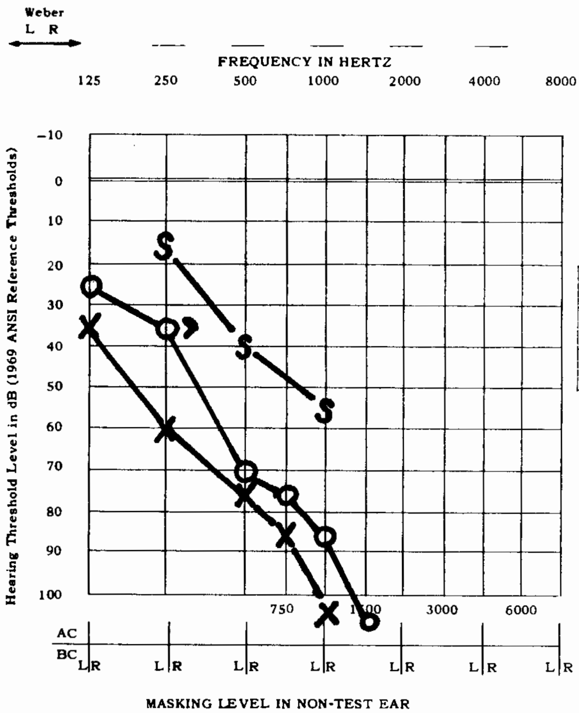
AUDIOMETRIC EVALUATION

Date Nov. 7, 1968

Name J. D. (S-N Case #5) Address ______ Sex M Age 57

Audiometer Bel Model 15CX Estimated Accuracy Good Audiologist CB

PURE TONE AUDIOGRAM



AUDIOGRAM CODE

Ear	Air Un-masked	Air Masked	Bone Un-masked	Bone Masked	
R	O	Δ	>	▷	Red
L	X	□	<	◁	Blue

PURE TONE AVERAGE
(500–2000 Hz)

Ear	Air Un-masked	Air Masked	Bone Un-masked	Bone Masked
R	*77			
L	*90			

SPEECH AUDIOMETRY

	L	Masking	R	Masking	Aided SF	LV or Rec
SRT	80		60		38	
PB in Quiet	16 / 20	80 ML / SL	40 / 30	ML / SL		
PB in Noise	SL	ML / S/N	SL	ML / S/N		
MCL						
UCL						

Remarks: S-S=Aided sound field warble tones (RE)

Comments: *Two frequency ave.

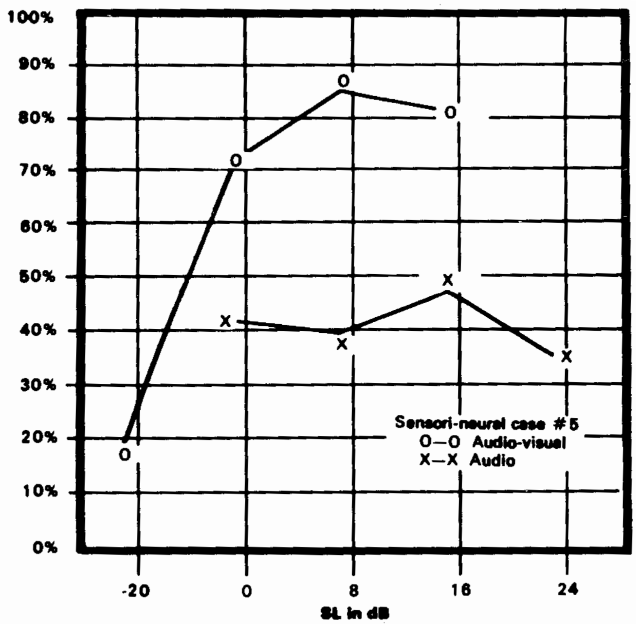


FIGURE VII

Auditory-visual and auditory-only articulation functions for sensori-neural Case #5.

TABLE II

Auditory and audio-visual discrimination scores for sensori-neural hearing loss subjects.

AUDITORY

SENSATION LEVEL OF PRESENTATION*	Sensori-neural loss cases #1	#2	#3	#4	#5	Mean scores for normals
0	30%	22%	20%	46%	42%	21%
8	64%	40%	46%	86%	38%	59%
16	74%	62%	60%	90%	54%	80%
24	84%	84%	78%	94%	36%	94%

AUDIO-VISUAL

SENSATION LEVEL OF PRESENTATION	Sensori-neural loss cases #1	#2	#3	#4	#5	Mean scores for normals
-20	22%	14%	12%	8%	18%	23%
0	66%	58%	46%	76%	72%	57%
8	70%	76%	68%	84%	84%	85%
16	88%	82%	86%	98%	74%	94%

* re. Sound field SRT.

score and would be even higher with highly redundant speech materials, i.e., sentences, presented in a person-to-person communication situation.

DISCUSSION

The data in this study clearly demonstrate that the best intelligibility score is obtained for auditory-visual presentations for lower sensation levels. The concept of articulation function appears to have practical application to aural rehabilitation. The construction of auditory-only and auditory-visual articulation functions will reveal the maximum discrimination score obtained for each individual in these respective listening conditions. The level at which the best auditory-visual score is obtained may serve as the starting point in aural rehabilitation. This optimum listening condition for each individual can be controlled with either group or individual auditory training units, depending upon the therapy situation. Phonetic analyses of errors into confusion matrices for both auditory-only and auditory-visual conditions will assist the therapist in the plan of therapy.

Ideally, after training we would like to see the articulation curves become steeper and displaced to the left with better intelligibility scores. The curves obtained prior to training will serve as the baseline for comparison of scores after training.

This study only demonstrated scores for monosyllabic words and obviously additional information is needed for other types of variably redundant speech materials, especially sentences. Articulation functions for sentence material are currently being constructed to quantify further auditory-visual relationships and their application to lipreading instruction.

REFERENCES

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