QUANTIFICATION OF PSYCHOLOGICAL VARIABLES PERTINENT TO AURAL REHABILITATION

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INTRODUCTION

Audiologists interested in aural rehabilitation have long felt a need for a test battery that could quantify those elusive psychological variables that so determine the success or failure of the rehabilitative effort. One of those psychological variables is the appropriateness of the individual's confidence in his ability to identify the signal correctly.

If the individual lacks confidence, he will tend to guess less than he should and thereby have less success in synthesizing the message from the available signal. If the individual is overconfident in his ability to process the signal, he will tend to misinterpret many messages. The behavior of the individual with a lack of confidence may be marked by withdrawal, the standard smile and affirmative nod, constant requests for repetition, etc. The behavior of the overconfident individual may be marked by such inappropriate responses as, "four o'clock" to the question, "Do you have a dime?" (interpreted as: "Do you have the time?"), seldom or never asking for clarification or repetition, and, again, the standard smile and affirmative nod.

The behavior resulting from either extreme level of confidence is at times similar. At best, the skillful and experienced rehabilitative audiologist must make highly intuitive judgments concerning the client's level of confidence in his ability to identify a signal and how that client's confidence affects his ability to listen effectively. If the rehabilitative audiologist were to have the good fortune to correctly assess his client's level of confidence, he lacks a metric by which to plot behavioral changes that may result from his therapy.

Standard speech discrimination tests are inadequate metrics for purposes of aural rehabilitation. Speech discrimination tests were originally developed to evaluate communication systems (Fletcher, 1929; Egan, 1948; House *et al.*, 1965). With the development of clinical audiology, many speech discrimination tests were adapted and others developed for use in evaluating the discrimination ability of human observers (Hudgins *et al.*, 1947; Hirsh *et al.*, 1952; Black and Haagen, 1963; Tillman *et al.*, 1963; Tillman and Carhart, 1966; Berger, 1967; Kruel *et al.*, 1968). A simple input-output model adequately defined telephone and military communication systems. This model, however, has not fit the human processor well. It became apparent that human observers with the same sensitivity and the same materials to discriminate performed differently under difficult listening conditions (Abrams *et al.*, 1942; Karlin *et al.*, 1944).

Sensori-neural hearing impairment creates a difficult listening situation. It creates less than optimal physiological conditions for the discrimination of speech. However, the difficulty in discriminating speech by those with a sensori-neural hearing impairment is not the effect of modified physiological status alone (Young and Gibbons, 1962). In addition to poor correlation between measures of the physiological sensitivity for sound and the discrimination of speech, the psychological problems resulting from poor adjustment to hearing impairment seem to intensify the effect of the physical disability (Levine, 1960). Obviously, there are variables among observers that are not accounted for by the percent correct discrimination score.

The model that is the basis of the Theory of Signal Detection (TSD) provided the insight that discrimination performance may differ among observers as a result of individuals assuming different criterion (Swets, 1964; Green and Swets, 1966). Schultz and Kraat (1970) employed a signal detection paradigm in a study of hearing-impaired discrimination ability and demonstrated that the criteria for response does indeed affect discrimination performance. They suggested improving discrimination performance in hearing-impaired observers by teaching the observer "better use of the discrimination cues he already has" (p. 42), which is clearly a reference to the interplay in discrimination of various psychological factors.

Comparison of confidence ratings of identification responses made by normal hearing and hearing-impaired observers should yield insight into the effect of hearing impairment on the observer's confidence. The observer's confidence would naturally affect his criterion for response and thereby his discrimination performance. Discrimination scores must, of necessity, be equated for the differences between groups in the appropriateness of their confidence to become apparent. Further, Signal Detection analysis of those confidence ratings should yield a method to quantify the appropriateness of the hearing-impaired observer's confidence in his ability to correctly identify a signal and, thereby, the overall appropriateness of his communicative responses. Confidence rating techniques in TSD have been employed by Pollack and Decker (1958), Egan *et al.*, (1959) and others. TSD analysis of confidence ratings in identification responses produce the Type II Receiver Operating Characteristic (ROC) (Clarke *et al.*, 1959). A measure of the observer's confidence in his identification responses, d_r, is obtained from the Type II ROC curve (Pollack, 1959). For this study, the strong assumption was made that the underlying distributions on a scale of confidence were normal-normal with equal variance.

This experiment equated initial discrimination performance of hearing-impaired and normal hearing observers and compared their Type II ROC curves under different conditions of context and payoff.

This study outlines a relatively objective procedure for determining the appropriateness of the hearing-impaired observer's confidence in his ability to auditorily discriminate the speech signal under varying conditions of context and payoff. Context variations were introduced to determine how appropriately this group of hearing-impaired subjects utilized contextual cues. Variations in payoff were introduced to determine if this group of hearing-impaired observers were operating at an optimal level or if their performance could be improved. An optimal level of performance, then, is defined operationally as no significant change upward in the d_r scores.

METHODOLOGY

Subjects

The subjects consisted of two groups of observers (*O*s): fifteen normal hearing and fifteen clinically diagnosed, bilaterial sensori-neural hearing-impaired *O*s. Hearing-impaired *O*s were adults ranging in age from twenty-two to fifty-nine years with a mean age of forty-three years. Normal hearing *O*s were adults ranging in age from twenty to forty-five years with a mean age of twenty-three years. No congenitally hearing-impaired persons were included among the *O*s in the hearing-impaired group.

Procedure

Four experimental test conditions were administered to each *O* in the following order: 1) context condition 1 under payoff condition 1 (C1P1), 2) context condition 2 under payoff condition 1 (C2P1), 3) context condition 1 under payoff condition 2 (C1P2), and 4) context condition 2 under payoff condition 2 (C2P2). A randomized presentation order was not used because it was felt such an order might cause *O*s to perform differently in payoff condition 1 if they had received payoff condition 2 first. In all four conditions the *O*s task was to: 1) mark the word he thought he heard, and 2) to rate his confidence in his identification response. The *O* was instructed to assign a plus (+) rating when he had confidence in his identification response and a minus (-) rating when he did not have confidence in his identification response. Each *O* was seated at a table in a double-walled IAC sound treated booth. He was provided with a test booklet containing instruction, practice items, and the appropriate response forms before each experimental test condition. The recorded materials were presented to his better ear through a high quality audio system. The level at which the speech materials were presented was 40 dB Sensation Level (SL) above the Speech Reception Threshold. This level was a comfortable level for listening to speech for all *O*s.

By providing two different context conditions to the *O*s, it was possible to measure their confidence in their identification responses under varying contextual conditions. The Modified Rhyme Test (MRT) materials (House *et al.*, 1965) were adapted to provide the two context conditions: words with a neutral carrier phrase (context condition 1) and words in sentences (context condition 2). *O*s were familiarized with the MRT materials prior to testing. On any given trial, only the signal word and five alternatives within the closed response set were available for possible response. There were one hundred trials per condition. The sentences were constructed such that only one word per response ensemble was appropriate (Kelly, 1971). The sentence conditions, therefore, were highly contextual compared to the word conditions. All stimulus items were preceded by the notation phrase, "Number_____is." All test conditions were programmed on tape by a single speaker of General American Dialect. The recorded materials were edited to meet pre-established intensity and quality criteria.

Different payoff conditions were designed to determine if paying the *O*s to adjust the costs and gains of the various responses open to them would result in a change in their confidence in their identification responses. In payoff condition 1, the *O*s confidence in his identification responses was neutrally structured by a balanced payoff matrix. In this balanced payoff matrix, the *O* received plus one point for a correct response rated confident and minus one point for an incorrect identification response rated confident. It was assumed that the cost of a correct identification response rated minus was equal in value to the cost to an incorrect identification response rated minus. It was assumed that under payoff condition 1 the *O*s would employ the confidence in their identification responses that was most typical for them. In payoff condition 2, the *O*s received plus two points for a correct identification response rated confident and lost one point for an incorrect identification response rated confident. It was assumed that under payoff condition 2 the *O*s would employ more positive confidence ratings than they would under payoff condition 1.

Prior to administering the four test conditions, control procedures were initiated for the following variables: 1) differences between the hearing-impaired and normal hearing *O*s in discrimination scores, 2) differences among the *O*s attributable to familiarity and practice effects, and 3) differences among the *O*s attributable to motivation. A Speech-to-Noise Ratio (SN Ratio) at which 50% intelligibility was attained for each *O* was used throughout the experimental test conditions. This SN Ratio was established by maintaining MRT words at a 40 dB SL and varying the intensity of the noise in relation to the speech. All *O*s could be considered to be performing at equal intelligibility levels. Pretest discrimination scores in noise, indicating the degree of equalization for the two groups, were 49% (S. D. 3.01) for the hearing impaired and 51% (S. D. 3.34) for the normal hearing groups. The SN Ratio Level for the hearing-impaired group was -10 dB (S. D. 1.99). For the normal hearing group it was -14 dB (S. D. .85).

It is known that adequate practice and motivation reduce the effects of familiarity, learning, attention, and motivation as causes of variation in the speech discrimination score (Licklider and Miller, 1951). The *O*s were paid a penny a point for their behavior in the experimental conditions. In addition, all *O*s were informed at the beginning of the test conditions that the *O* having earned the most points would receive a ten dollar bonus. Payment was used to motivate the *O*s. Practice and familiarity effects were reduced by familiarizing the *O* with the MRT materials and by the close-response set nature of the tasks.

RESULTS

Discrimination Scores

Table 1 is a tabulation of discrimination scores for each *O* by group in each context-payoff condition. As seen in Table 1, both groups scored higher in context 2 conditions than they did in context 1 conditions. This was expected. Also, both groups appeared to score higher

Table 1. Percent Correct Scores For Os in Each Context-Payoff Condition.

Group	Os	C1P1	C2P1	C1P2	C2P2
	SC	58	98	78	98
	GH	45	83	49	78
	JK	46	60	43	61
	CK	45	50	44	57
	MM	45	83	58	76
Hearing Impaired	JD	54	92	67	91
	KW	48	75	42	74
	RK	70	90	60	94
	WG	33	63	38	59
	MI	58	92	64	98
	HQ	48	89	50	91
	FF	55	88	63	87
	DC	63	89	59	91
	JG	54	88	51	88
	PM	62	78	58	81
	Mean Score	52.27	81.20	54.93	81.60
	S. D.	9.29	13.67	10.94	13.81
	JP	51	87	53	74
	SK	53	83	56	79
	KP	54	90	55	89
	SP	56	83	57	87
	AF	57	84	53	89
Normal Hearing	HB	50	86	51	88
	BA	48	86	54	79
	EP	59	84	53	82
	RB	52	77	52	79
	JO	48	85	61	78
	PM	42	80	56	90
	DC	44	73	39	61
	MP	59	90	64	84
	EB	53	90	63	86
	EW	50	85	59	81
	Mean Score	51.73	84.20	55.07	81.73
	S. D.	4.99	4.74	5.96	7.52

in C1P2 than they did in C1P1. This interaction between payoff and context was not expected. Analysis of variance indicated both the main effect for context and the interaction between payoff and context were significant beyond the .05 level. Upon closer examination, the interaction between payoff and context was found to be contaminated by an experimental artifact. The first list used in C1P2 was another randomized ordering of the same list that all *O*s received to establish their discrimination scores in quiet immediately prior to the experiment. Therefor, all *O*s may have done a little better on C1P2 because of a familiarity effect.

Table 2. The number of plus ratings for Os in each context-payoff condition.

Group	Os	C1P1	C2P1	C1P2	C2P2
	SC	85	100	94	99
	GH	74	80	81	76
	JK	63	68	65	71
	CK	39	33	50	63
	MM	44	84	44	79
	JD	86	93	73	87
	KW	46	68	30	69
Hearing Impaired	RK	82	90	81	96
	WG	93	98	97	95
	MI	49	83	51	87
	HH	97	93	87	91
	FF	84	88	91	85
	JH	48	75	48	86
	JG	77	89	94	95
	PM	64	71	47	80
	Mean Score	68.73	80.87	68.87	83.93
	S. D.	19.54	16.74	22.23	10.77
	JP	56	80	50	63
	SK	46	75	50	72
	KP	61	84	64	84
	SP	63	80	63	87
	AF	54	82	58	79
	HB	79	93	76	87
	BA	66	86	60	78
Normal Hearing	EP	8	55	39	67
	RB	65	74	62	73
	JO	57	77	68	74
	PM	78	80	76	90
	DC	54	70	52	62
	MP	65	86	57	62
	EB	57	86	57	82
	EW	75	84	74	75
	Mean Score	60.27	79.47	60.40	75.67
	S. D.	12.83	8.88	9.71	9.34

Confidence Ratings

Table 2 is a tabulation of the number of plus ratings used for each *O* by group in each context-payoff condition. The hearing-impaired group used more plus ratings than the normal hearing group. Both groups used more plus ratings in context 2 conditions than they did in context 1 conditions. The hearing-impaired group used more plus ratings in C2P2 than they did in C2P1, while the normal hearing group used fewer plus ratings in C2P2 than they did in C2P1. Analysis of variance indicated that only the main effect for context and an interaction of groups-by-payoff was significant beyond the .05 level.

Table 3. The d_r scores for Os in each context-payoff condition.

Group	Os	C1P1	C2P1	C1P2	C2P2
Hearing Impaired	SC	.832	.000	.965	2.326
	GH	.475	1.835	.669	1.988
	JK	.106	1.380	.588	1.509
	CK	.633	1.808	.226	1.008
	MM	.971	1.480	.820	1.543
	JD	.499	1.419	.790	2.871
	KW	.587	1.836	.752	1.411
	RK	.602	2.004	1.020	2.326
	WG	.540	.173	.682	1.151
	MI	.693	2.353	1.212	3.553
	I Q	.772	1.138	.979	1.902
	FF	.863	1.757	.650	2.681
	JH	1.012	2.295	.883	1.587
	JG	.295	2.321	.772	1.886
	PM	.266	1.996	.484	2.119
Mean Score		.611	1.586	.766	1.990
S. D.		.068	.498	.057	.468
Normal Hearing	JP	1.092	1.622	.771	2.745
	SK	.830	2.042	1.081	2.251
	KP	1.000	2.182	.538	1.954
	SP	.700	2.730	.449	2.620
	AF	1.107	2.771	1.219	2.042
	HB	.993	1.695	.695	1.678
	BA	.954	2.198	.683	2.433
	EP	.896	1.913	1.054	2.033
	RB	.689	2.531	.839	1.434
	JO	-.051	1.968	.277	2.197
	PM	1.036	1.726	.947	1.555
	DC	.329	2.104	.949	1.411
	MP	.512	2.836	.614	2.168
	EB	.701	2.836	.667	2.556
	EW	1.028	2.168	.153	2.221
Mean Score		.787	2.221	.729	2.086
S. D.		.104	.178	.089	.176

Table 3 is a tabulation of the d_r scores for each *O* by group in each context-payoff condition. The hearing-impaired group had lower d_r scores than the normal hearing *O*s under all conditions but C1P2. Both groups had higher d_r scores in context 2 conditions than they did in context 1 conditions. The hearing-impaired group had higher d_r scores in payoff 2 conditions thatn they did under comparable context conditions in payoff condition 1, while the normal hearing group had lower d_r scores in payoff 2 conditions than they did under comparable context conditions in payoff condition 1. Analysis of variance indicated main effects for groups and context and the interaction between groups-by-payoff to be significant beyond the .05 level.

DISCUSSION

Three things were apparent from the comparison of hearing-impaired and normal hearing discrimination data: 1) the two groups performed similarly, 2) both groups had equally higher discrimination scores with the addition of contextual cues, and 3) changing payoff did not affect the discrimination score. These data indicated that it was possible to equate normal hearing and hearing-impaired discrimination performance across varying conditions of context and payoff by establishing an initial SN Ratio that yielded 50% correct discrimination responses. Yet, with discrimination scores equal across groups and payoff conditions, differences were observable with the d_r metric.

Four things were apparent from the comparison of hearing-impaired and normal hearing confidence rating data. First, the two groups did not differ in the number of plus ratings used but, in general, the hearing-impaired group assigned confidence ratings to identification responses less appropriately than the normal hearing group. An appropriate rating would be a plus rating for a correct identification response and a minus rating for an incorrect identification response. This finding indicates that therapy might concentrate on increasing the confidence of this group of hearing-impaired observers in whatever discrimination ability they have. Second, for both groups, confidence in their discrimination ability was greater and more appropriately assigned with the addition of contextual cues. This finding indicates that therapy methods for the hearing-impaired group might do well to make use of highly contextual materials. Third, both groups performed with similar ability to appropriately assign their confidence ratings under payoff 2 conditions. It may be possible to increase the communicative ability of the hearing-impaired observer to be more confident. The normal observer, however, was already operating optimally and when paid to do better, could not do so. Fourth, the information added by Signal Detection analysis of confidence ratings can be used to supplement the information gained from discrimination scores. Speech discrimination performance and success in communication is not dependent on signal processing ability alone.

Information on an individual client's signal processing can and should be obtained on the phonological level, visually, auditorily, and with vision and audition combined. The individual's ability to utilize contextual cues should be evaluated, visually, auditorily, and with vision and audition combined. The appropriateness of the individual's confidence in his ability to process the signal should be evaluated visually, auditorily, and with the combination of vision and audition. The adaptation of the MRT materials used in this study are useful for auditory quantification. Suitable and similar materials need to be developed for visual and combined modality testing. With this additional information, a profile of an indiviaual client's receiver operating characreristics can provide a more objective and a quantitative means of determining his therapy needs. Through pre- and post-testing, the success of the intervening therapy can be determined.

It was clear that it was possible to change the payoff and cause the two groups to adopt more similar confidence performance. It was not clear what significance the group-by-payoff interaction has for therapy methodology. It may be possible to reward hearing-impaired *O*s so that they may more appropriately assign their confidence ratings and, thereby, perform in a manner more nearly like the normal hearing *O*. It may be that such therapy would carry over outside the clinical setting. It may be that the observed statistically significant interaction between groups-by-payoff has no real significance for aural rehabilitation. The answer must await further investigation.

Norms for normal hearing behavior in these tasks need to be established so that the appropriateness of hearing-impaired behavior can be determined.

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REFERENCES

Abrams, M. H., Karlin, J. E., et al. *The problem of selecting and training personnel for communication in intense noise.* OSRD Report 987, Psycho-acoustic Laboratory, Harvard University, 1942 (PR 19785).

Berger, K. W., The K. S. U. *Speech Discrimination Test.* Kent, Ohio: Kent State University, 1967.

Black, J. W. & Haagen, C. H., Multiple-choice intelligibility tests, forms A and B. *J. Speech Hearing Dis.*, 1963, 28, 77-86.

Clarke, F. R., Birdsall, T. G., & Tanner, W. P., Jr., Two types of ROC curves and definitions of parameters. *J. Acoust. Soc. Amer.*, 1959, 31, 629-30.

Egan, J. P., Articulation testing methods. *Laryngoscope,* 1948, 58, 955-91.

Egan, J. P., Schulman, A. I., & Greenberg, G. Z., Operating characteristics determined by binary decisions and by ratings. *J. Acoust. Soc. Amer.*, 1959, 31, 768-73.

Fletcher, H., *Speech and Hearing.* New York: Van Nostrand, 1929.
Green, D. M., & Swets, J. A., *Signal Detection Theory and Psychophysics.* New York: Wiley, 1966.
Hirsh, I., Davis, H., Silverman, S. R., Reynolds, E. G., Eldert, E., & Benson, R. W., Development of materials for speech audiometry. *J. Speech Hearing Dis.*, 1952, 17, 321-37.
House, A. S., Willaims, C. E., Hecker, M. H. L., & Kryter, K. D., Articulation-testing methods: consonantal differentiation with a closed response set. *J. Acoust. Soc. Amer.*, 1965, 37, 158-66.
Hudgins, C. V., Hawkins, J. F., Karlin, J. E., & Stevens, S. S., Development of recorder auditory tests for measuring hearing loss for speech. *Laryngoscope,* 1947, 57, 57-89.
Karlin, J. E., Abrams, M. H., et al., Auditory tests of the ability to hear speech in noise. OSRD Report 3516, Psycho-acoustic Laboratory, Harvard University, 1944 (PB 22847).
Kelly, B. R., *An Evaluation of Listener Response Strategy in Speech Discrimination Tasks.* Unpublished doctorial dissertation, Case Western Reserve University, 1971.
Kreul, E. J., Nixon, J. C., Kryter, K. D., Bell, D. W., & Lang, J. S., A proposed test of speech discrimination. *J. Speech Hearing Res.*, 1968, 11, 536-52.
Levine, E., *The Psychology of Deafness.* New York: Columbia University Press, 1960.
Licklider, J. C. R., & Miller, G. A., The perception of speech. In S. S. Stevens (Ed.) *Handbook of Experimental Psychology.* New York: Wiley, 1951, 1040-74.
Pollack, I., On indices of signal and response discriminability. *J. Acoust. Soc. Amer.*, 1959, 31, 1031.
Pollack, I. & Decker, L. R., Confidence ratings, message reception, and the receiver operating characteristic. *J. Acoust. Soc. Amer.*, 1958, 30, 286-92.
Schultz, M. C., & Kraat, A. W. A metric for evaluating therapy with the hearing impaired. *J. Speech Hearing Dis.*, 1970, 35(1), 37-43.
Swets, J. A. (Ed.)., *Signal Detection and Recognition by Human Observers: Contemporary Readings.* New York: Wiley, 1964.
Tillman, T. W., & Carhart, R., An expanded test for speech discrimination utilizing CNC monosyllabic words (N. U. Auditory Test No. 6). *USAF School of Aerospace Medicine Report,* June, 1966, 55-66.
Tillman, T. W., Carhart, R., & Wilber, L., A test for speech discrimination composed of CNC monosyllabic works (N. U. Auditory Test No. 4), *USAF School of Aerospace Medicine Report,* January, 1963, 62-135.
Young, M. A., & Gibbons, E. W., Speech discrimination scores and threshold measurements in a non-normal hearing population. *J. Aud. Res.*, 1962, 2(1), 21-33.