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Some Effects on Intelligibility as the Sidetone Level and the Amount of Sidetone Delay Are Changed*

By CHESTER J. ATKINSON

INTRODUCTION

It is easy to ascribe the control of several aspects of speech to the monitoring function of the ear. Among these aspects are control of the rate, the sound pressure level, and the intelligibility of speech. The level of amplified sidetone has been shown to affect the intelligibility of speech under certain conditions. Delayed sidetone has been shown to affect the production of speech in several aspects. Most studies of delayed sidetone measure speech in terms of rate and sound pressure. The effects of delayed sidetone on correctness of reading a passage has been studied, as well as the effect of delayed sidetone on intelligibility. This study presents the results of testing the intelligibility of talkers as the level of the sidetone of the talker is changed and the amount of delay of the sidetone is also changed.

STATEMENT OF THE PROBLEM

An answer to the following question was sought. Do talkers change the intelligibility of their speech in a noisy environment as the level of their sidetone is changed and the amount of delay in the sidetone is changed? It appears reasonable to hypothesize (1) that increased sidetone level would result in decreased intelligibility scores as research has shown, and (2) that the amount of delay should affect the intelligibility of speech; increasing sidetone delays up to .20 second would yield decreasing intelligibility scores. The second hypothesis is in line with research showing that the maximum effect of delayed sidetone in speech is centered around .20 second delay when rate and sound pressure instead of intelligibility is under test.

PROCEDURE

The data was gathered in what may be called a formal articulation testing method. Seven persons read intelligibility lists to

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each other in a round-robin fashion, one as a talker and six as listeners at a time.

The following were kept constant during the entire period of data collection; (a) the speakers were the same and spoke in every sidetone condition, (b) the listeners were also the same from condition to condition, (c) the level of noise in the listener's headsets was constant, (d) the level of noise in the talker's headsets was constant, (e) the test materials were all drawn from the same group of fifty lists, (f) room temperature and illumination were kept constant, (g) timing of the test words was controlled by an automatic timer.

The variables under test were changes in the sidetone of the talker. The sidetone of the talker was set at one of three levels. The levels were 0, +10, and +20 db above a constant 75 db noise level in the earphones of the talker.

The amount of delay in the talker's sidetone was also changed. The delays were .03, .04, .05, .06, .07, .08, .09, .10, .12, .15, and .27 seconds. Thus, as a person talked his amplified sidetone was returned to him with a given level (maintained by a limiter, a copy of a conventional commercial limiter, one which does not allow a signal, in this instance sidetone, to become greater than a preset level) and with a certain amount of delay (maintained by a delay mechanism, a fairly high quality tape recorder that had a playback head moveable with respect to the record head).

The noise level in the listener's earphones was approximately 80 db sound pressure level. The level was chosen to keep the scores on the intelligibility tests relatively low.

Each person as a talker spoke twice with each condition of level and delay. Because of the control of other conditions, any changes in the score of the group on the intelligibility tests may reasonably be attributed to the change in sidetone conditions.

The order of the combinations of sidetone level and sidetone delay was randomized. The order of talkers was separately randomized within each combination. The list of fifty words each talker read was determined randomly from a group of fifty lists (Harvard fifty word P.B. lists). No more than 28 lists were used in a given day. A separate randomization for each list was accomplished by printing one word on a card, and shuffling the list before it was read.

Before data collection was started, the group practiced for two weeks, three hours per day, taking and giving intelligibility tests. The answers written by the listeners were scored by two people

who checked each other's work periodically for accuracy. The measures taken were percent correct responses for each fifty word list averaged for the six listeners hearing a talker.

RESULTS

The measures of intelligibility were formed into tables for observation of the means and were also analyzed by analysis of variance to assess the difference among the means.

Table I presents the means of the intelligibility measures (percent correct) and shows how the intelligibility (in percent of words correctly understood) of each talker was affected by the level of sidetone. The talkers are presented in rank order of intelligibility. The entry in each cell of the table is a mean representing all the responses to each of the seven talkers as the talkers heard sidetone at each of the three levels. The average means for each talker are presented at the base of each column and the average means for each sidetone level are presented at the right of each column. The mean of the entire table is presented at the lower right hand corner.

Table I
Mean Percent of Words Heard Correctly for Each Talker at Each of Three Levels of Amplified Sidetone

Sidetone level re noise	Talkers in Rank Order							means
	1	2	3	4	5	6	7	
0	82.9	80.9	78.3	72.4	67.4	64.7	61.4	72.6
+10	83.8	79.2	77.3	66.1	61.4	61.4	59.7	69.8
+20	82.2	78.9	78.2	59.6	61.7	55.9	57.7	67.7
means	83.0	79.7	77.9	66.0	63.5	60.7	59.6	70.0

The analysis showed significant differences among the level of sidetone means, and also a significant talkers x levels interaction. This interaction can be seen in the differences associated with levels from speaker #1 through speaker #7. It is also worthy of note that the talkers with high intelligibility were affected less by sidetone level than those with low intelligibility.

Table II shows the data in a comparison of levels of sidetone and delays of sidetone. Each entry is the mean percent of words correctly heard from each of the talkers as they spoke with a given level of sidetone and a given delay of sidetone.

Table II

Means of the Percent of Correctly Heard Words Associated with Sidetone Delay and Sidetone Level

Sidetone level re Noise	Delay											means
	.03	.04	.05	.06	.07	.08	.09	.10	.12	.15	.27	
0	72.6	73.7	72.8	73.7	70.9	73.8	72.6	71.4	72.4	73.3	70.9	72.5
+10	75.0	68.5	70.3	67.6	68.7	71.0	68.3	68.0	73.1	71.4	66.3	69.8
+20	70.3	64.8	71.6	70.5	67.1	66.5	65.0	62.0	68.9	71.2	67.4	67.7
means	72.6	69.0	71.6	70.6	68.9	70.4	68.6	67.1	71.5	72.0	68.2	70.0

The analysis shows significant differences among the delay means.

The rank order of the mean intelligibility scores of Table II due to delay of sidetone plus an indication of the means that are significantly different (at the 5% level of confidence) from each other are included in Table III.

Table III

Rank Order of Delays According to the Intelligibility Associated with Them and an Indication of Significantly Different Delays

Sidetone Delay (sec)	Mean relative intelligibility	Delays that yielded significantly different percent correctly heard words from this delay (t) 5 % level of confidence	
.03	72.6	.10,	.27
.15	72.0		.10
.05	71.6		.10
.12	71.5		
.06	70.6		
.08	70.4		
.04	69.0		
.07	68.9		
.09	68.6		
.27	68.2		
.10	67.1		

The rank order of the results for the various delays gives no predictable pattern, even though the shortest delay produced the highest intelligibility and the longest delay nearly the lowest intelligibility.

An analysis of variance was performed on the data. The analysis is presented in Table IV.

Table IV

Summary of Analysis of Variance: Percent Correctly Heard Words As Affected by Level of Sidetone and Delay of Sidetone, Measured for Seven Talkers

Source	df	MS	Error term	F	Level of confidence
SS _L (levels)	2	891.86	136.30	6.54	5%
SS _D (delays)	10	132.37	48.46	2.73	5%
SS _T (talkers)	6	6,358.43			
SS _{LD} (lev x del)	20	54.85	46.08	1.19	
SS _{LT} (lev x talk)	12	136.30	46.08	2.96	5%
SS _{DT} (del x talk)	60	48.46	46.08	1.05	
SS _{LDT}	120	43.14	46.08	.94	
SS _{WC} (within cells)	231	46.08			

No triple interaction is indicated by the table, and two of the three double interactions were also non-significant. The (F) ratio between WC and LT (levels x talkers) was significant at the 5% level of confidence. This indicates that talkers were affected differentially by levels of sidetone in the percent of their words that were correctly understood.

The mean squares of L (levels) and D (delays) when divided by appropriate error terms produced significant (F) ratios. The results indicated that levels were effective in producing changes in intelligibility and that delays were effective in producing changes in intelligibility.

From the results of observation of the means and the results of the analysis of variance, the following notes may be made:

1. Levels of sidetone affected intelligibility to an extent that would occur by chance only 5% of the time. The higher the level of sidetone, the lower the intelligibility score, as had been hypothesized.

2. Delays of sidetone produced significant differences in the intelligibility of the talker's speech. The effect was not progressive for longer delays, not as had been hypothesized.

3. There was an interaction effect significant at the 5% level of confidence for talkers and sidetone levels. Figure 1 shows this effect as a differential spread between lines (levels of sidetone) at

the points representing the various talkers. This means that the intelligibility of a talker at one level cannot be predicted from his intelligibility at another level.

4. There was a tendency for talkers who were highly intelligible to be less affected by sidetone level than were talkers who were less intelligible.

DISCUSSION

Apparently the easier it is for a talker to hear himself in a noisy environment, the less effort he puts into making his speech intelligible. This may be a confounding factor as far as this experiment is concerned, as well as for the previous research that related talker intelligibility to level of sidetone. One might as easily say, "More intelligible sidetone is associated with less intelligible speech," or "Higher sidetone levels are associated with less intelligible speech." This statement can be made because when the S/N ratio of sidetone is changed from say 0 db to +20 db, the talker hears his own speech 20 db better. For an average listener, an increase in the S/N ratio is an increase in intelligibility. Thus, the least intelligible speech is produced when the talker hears what was presumably the most intelligible sidetone. Further study is needed to clarify this possibility.

The only previous study of intelligibility of speech and delay of sidetone reported that .05 seconds is a favorable sidetone delay for intelligible speech. No one sidetone delay in the present research appeared to afford a decided advantage for intelligibility over delays of approximately the same length. It is unfortunate that no 0.0 delay condition was provided and so no comparison can be made between the effects on intelligibility of delay vs. 0.0 delay in the sidetone.

SUMMARY

A study of the effects of several combinations of sidetone level and sidetone delay is reported. The combinations consist of three levels of sidetone each tested against eleven delays of sidetone. Level of sidetone is shown to be effective on intelligibility by producing relatively more intelligibility for less level of sidetone, a result to be predicted from previous research. A possible ambiguity in the interpretation of the results of 'level' of sidetone is discussed. Delay of sidetone is also shown to affect intelligibility, the manner in which the delays affected intelligibility is not predictable, nor was it possible to see a pattern for the effects of delay on intelligibility.

There appears to be a tendency for the more intelligible of the talkers in this study to be less affected than the less intelligible talkers in this study.

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