INTELLIGIBILITY OF THE PHONETIC ALPHABET WHEN MASKED BY RANDOM WHITE NOISE

INTRODUCTION

The Listen Study (Cunningham, Moler, Sheldon, 1963) was designed to develop and test a training method to increase the ability of Air Force personnel to identify verbal signals masked by jamming. Thirty Air Force personnel were trained each day for ten days by listening for 15 minutes to 65 signals masked by constant or increasing random white noise. Some subjects were trained with visual or auditory cues given just before the spoken signal, other subjects received no cues. Following training, each subject took a 5 minute test, composed of 40 signals imbedded in constant heavy random white noise. For all training and testing sessions the signals included two letters randomly chosen from the current (1956) International Civil Aviation Organization alphabet. This word-spelling alphabet is used by the Air Force, and includes the following words:

alfa	juliet	sierra
bravo	kilo	tango
charlie	lima	uniform
delta	mike	victor
echo	november	whiskey
foxtrot	oscar	x-ray
golf	pappa	yankee
hotel	quebec	zulu
india	romeo	

Also used in each signal were two random numbers, pronounced as follows:

one	six
two	seven
tree	eight
fo-wer	nin-er
fife	zero

Several examples of a complete signal were:

whiskey	sierra	tree	six
pappa	november	zero	one
romeo	juliet	seven	fo-wer

The purpose of the experiment was to discover which training conditions of cueing and noise presentation most enhanced the ability of the subject to discriminate signals. An illustration of the experiment appears on a subsequent page. The basic analysis of the Listen Study data may be found in the document cited above. The analysis, however, uncovered findings not central to the purpose of the experiment. These findings indicated that the words used by the Air Force as symbols for letters varied widely insofar as they were intelligible when masked by random white noise. The purpose of this document is to present and discuss the findings relating to alphabet intelligibility. These findings will be discussed in connection with previous research.

FINDINGS

Table I on the following page lists words comprising the International Civil Aviation Organization word-spelling alphabet. The Table cites the number of times each word was identified correctly or was missed by all subjects in all tests in the Listen Study. The last column in the Table indicates the intelligibility score of each word as the percentage of occasions when the word was correctly identified, in relation to the number of occasions when the word was used throughout the study.

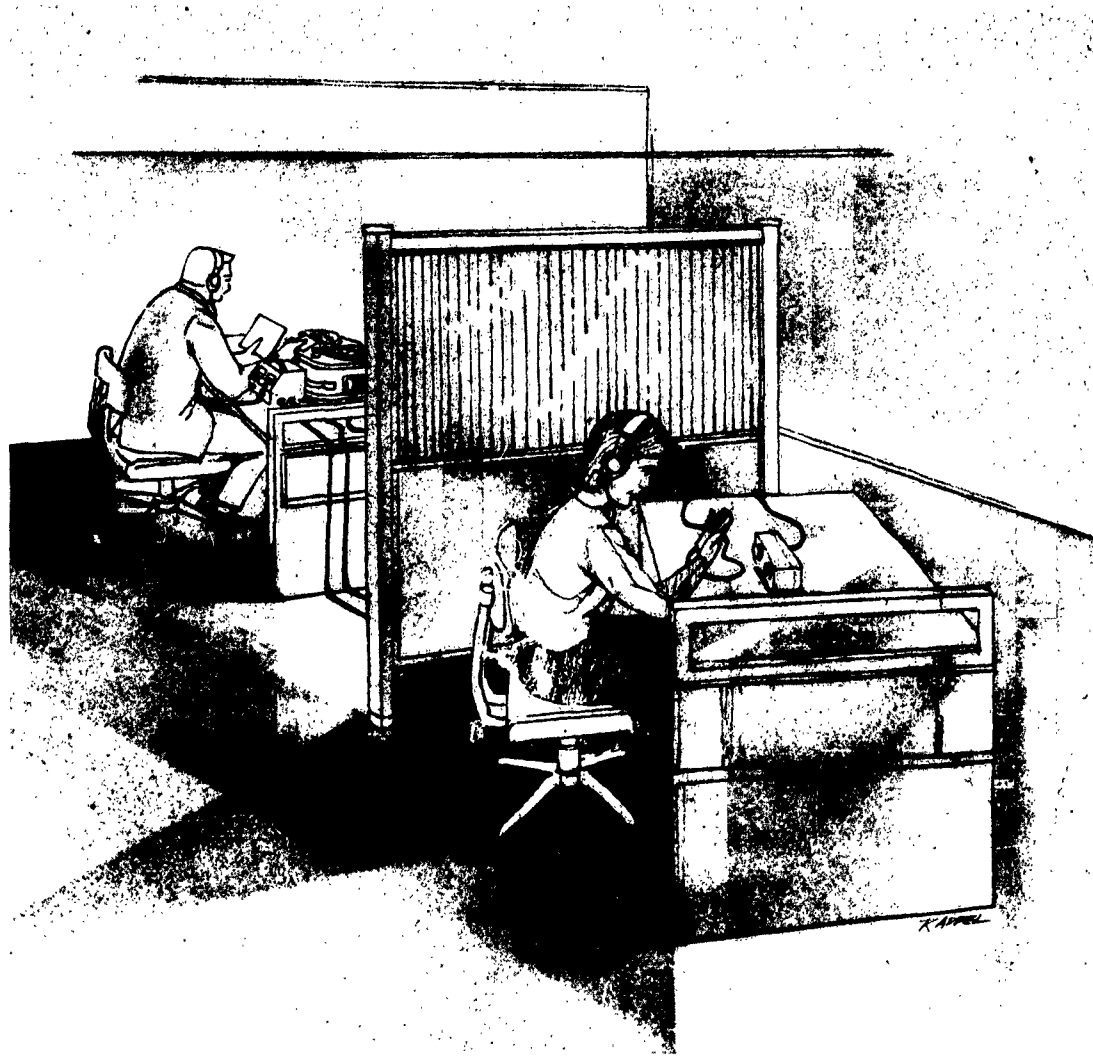

Illustration of the Listen Study

TABLE I

Intelligibility Scores Achieved by the Twenty-Six Alphabet-Spelling Words Used in the Listen Study

Actual Word	Total Correct	Total Wrong	Total Right and Wrong	Intelligibility Score (%)
Alfa	610	500	1110	54.95
Bravo	1108	302	1410	78.58
Charlie	520	200	720	72.22
Delta	489	141	630	77.62
Echo	864	426	1290	66.98
Foxtrot	648	202	850	76.24
Golf	540	390	930	58.06
Hotel	577	263	850	68.69
India	172	428	600	28.67
Juliet	593	367	960	61.77
Kilo	340	200	540	62.96
Lima	902	358	1260	71.58
Mike	886	394	1280	69.22
November	1258	122	1380	91.16
Oscar	794	376	1170	67.86
Pappa	465	195	660	70.45
Quebec	668	352	1020	65.49
Romeo	789	111	900	87.67
Sierra	749	181	930	80.54
Tango	643	197	840	76.55
Uniform	568	152	720	78.89
Victor	282	168	450	62.67
Whiskey	613	107	720	85.14
X-Ray	472	398	870	54.25
Yankee	656	244	900	72.89
Zulu	629	391	1020	61.67
TOTAL	16,835	7,165	24,000	(70.15)

Inspection of the findings in Table I reveals the presence of a very large spread in the intelligibility scores. Table II presents the scores ordered in relation to percentage of intelligibility.

TABLE II

Intelligibility Scores of the Twenty-Six Alphabet Words (ordered from most intelligible to least intelligible)

Words	Per cent of Intelligibility
November	91.16
Romeo	87.67
Whiskey	85.14
Sierra	80.54
Uniform	78.89
Bravo	78.58
Delta	77.62
Tango	76.55
Foxtrot	76.24
Yankee	72.89
Charlie	72.22
Lima	71.58
Pappa	70.45
Mike	69.22
Hotel	68.69
Oscar	67.86
Echo	66.98
Quebec	65.49
Kilo	62.96
Victor	62.67
Juliet	61.77
Zulu	61.67
Golf	58.06
Alfa	54.95
X-Ray	54.25
India	28.67

Table II indicates that the range of intelligibility of the twenty-six letters was from 29% to over 91%; the average intelligibility score was 70%.

MAJOR CONFUSIONS OF SUBJECTS IN IDENTIFYING WORDS

An important source of error in identifying alphabet words was the consistent confusion of certain often-missed words with other words. Table III lists the eight most often-missed words (arbitrarily chosen as representing slightly less than one-third of the sample) together with words with which they were most often confused.

TABLE III

Major Confusions of Subjects in Identifying Alphabet Words

Alphabet Word (with intelligibility score)		Percentage of unintelligibility contributed by confusion (in order of importance) 1st	(%)	2nd	(%)	3rd	(%)
India	(28.67)	Juliet	(32.3)	Lima	(21.6)	Zulu	(20.2)
X-Ray	(54.25)	Oscar	(15.1)	*		*	
Alfa	(54.95)	Delta	(19.2)	Golf	(17.8)	Pappa	(16.7)
Golf	(58.06)	Bravo	(39.2)	Foxtrot	(18.1)	*	
Zulu	(61.67)	Juliet	(48.0)	Lima	(18.8)	India	(18.8)
Juliet	(61.77)	Zulu	(33.3)	India	(23.2)	*	
Victor	(62.67)	Whiskey	(38.0)	X-Ray	(28.7)	*	
Kilo	(62.96)	Zulu	(31.4)	Juliet	(28.6)	*	

*Minor percentages (less than 10%) are not included.

In Table III the percentages relate to the percentage of occasions various words are confused for a word actually used in the tests. On 32.3% of all occasions when the word India was confused, for example, the word heard was Juliet. These percentages do not add up to 100% since only major instances of confusion were included.

Table III reveals that certain consistent reciprocal misidentifications are present. India, the most often-missed word, was often confused with Juliet, Lima, and Zulu. Likewise, Juliet was often confused with Zulu and India. Similarly, Zulu was often confused with Juliet, Lima and India. In addition, the word Kilo was often confused with Zulu and Juliet. This finding suggests that a small group of alphabet words currently employed by the Air Force have the intrinsic defect of resembling each other phonetically in a background of noise.

In a report (Moser, 1959) of an earlier test[1] of the intelligibility of the word-spelling alphabet when masked by random white noise, findings were presented which the present results tend to confirm. Although conditions in the two studies were dissimilar[2] many of the reciprocal misidentifications noted above were also noted in one phase[3] of the early study. This similarity can be demonstrated by listing the four words discussed above, together with words they were most often misidentified with in both studies. Thus:

TABLE IV

Ohio State Study

India - Union - Juliet - Zulu
Juliet - Zulu - Union - India
Zulu - Union - Juliet - Kilo - India
Kilo - Zulu - Union - Juliet

Present Study

India - Juliet - Lima - Zulu
Juliet - Zulu - India
Zulu - Juliet - Lima - India
Kilo - Zulu - Juliet

[1] At the Ohio State University Research Foundation.

[2] The earlier study was designed for the purpose of testing international word-spelling alphabets. Subjects were both foreign and American, and the speech level was attenuated to achieve progressively more difficult reception conditions. The signal/noise ratio in the two experiments was also different. In the Listen Study only one voice was used.

[3] It should be pointed out that the Ohio State experiment made several tests of word-spelling alphabets. In the phase of the experiment with which the Listen Study was compared the word "Union" was tested. Other different words tested in this phase were: coca, metro, nectar, and extra.

In examining the comparisons made in Table IV it must be again pointed out that the phase of the earlier research under consideration tested the word "Union," rather than the word "Uniform," which was used in the Listen Study. Aside from the fact that the word Union was not tested in the Listen Study it can be seen that in most cases the two studies reveal somewhat similar findings regarding chronic patterns of confusion. Three words, India, Juliet, and Zulu, are consistantly confused with each other. In addition, both studies indicate that the words Zulu and Juliet are often confused with the word Kilo.

Table V lists the number of times subjects thought they heard a word which was not actually used in the test.

TABLE V

Words Confused by Subjects

Words Subjects thought they heard	Times the words were identified by Subjects (but were not correct)
Juliet	377
Zulu	331
Golf	316
Delta	274
Foxtrot	235
Pappa	204
Yankee	174
Lima	163
India	136
Alfa	136
Tango	132
Victor	130
Mike	126
Uniform	126
Whiskey	120
X-Ray	119
Bravo	119
November	118
Echo	117
Quebec	110
Oscar	104
Hotel	97
Kilo	71
Romeo	64
Charlie	33
Sierra	31

As shown in the list in Table V, the words Juliet and Zulu consistently contributed to error in identifying alphabet letters masked by random white noise. Another major contribution to unintelligibility was the fact that the words Victor and X-Ray were often confused with the word Whiskey. These findings were also noted in the earlier experiments conducted at the Ohio State University Research Foundation.

The preceding presentation indicated that some words seem to be inherently less intelligible and more confusing than other words, when masked by noise. The following analysis is designed to shed some light on why some words are far less intelligible than others. For purposes of analysis the eight most often missed alphabet words, together with the eight least often missed words, were selected. As was stated earlier, this selection was arbitrary; each group of eight represents slightly less than one-third of the sample. The middle group of ten words was eliminated from analysis in an attempt to isolate factors which might have bearing on the wide variation in intelligibility scores. The words chosen for analysis were:

TABLE VI

Most Often Missed	Least Often Missed
India	November
X-Ray	Romeo
Alfa	Whiskey
Golf	Sierra
Zulu	Uniform
Juliet	Bravo
Victor	Delta
Kilo	Tango

EFFECT OF THE POSITION OF THE SIGNAL IN THE TEST

Before proceeding with the analysis it was felt that an investigation of whether or not more words were missed at the end or at the beginning of the test would rule out whether a fatigue effect might have caused subjects to miss more words in the final portion of the test, and whether often-missed words might by chance be clustered at the end of tests. To find out whether subjects tended to make more mistakes at the end of the test, the tests were examined to discover how errors were distributed. These findings appear in Table VII.

TABLE VII

ERROR DISTRIBUTION

Percentage of Errors Occurring

Between 1st and 10th Signal (%)	Between 11th and 20th Signal (%)	Between 21st and 30th Signal (%)	Between 31st and 40th Signal (%)
24.8	27.5	23.4	24.3

Inspection of these figures reveals that errors made by subjects in identifying signals were distributed evenly throughout the tests. No "fatigue effect" was discernible; it was concluded that the position of various words in the test had no effect on the outcome.

ANALYSIS OF SYLLABLE CONTENT OF THE TWELVE WORDS MOST CONSISTENTLY CONFUSED

An analysis was made of the number of syllables in the most and least frequently missed words. This analysis is illustrated in Table VIII.

TABLE VIII

Number of Syllables in Most and Least Missed Words

Group	Word Contains One Syllable	Word Contains Two Syllables	Word Contains Three Syllables	TOTAL
Most missed words	1	5	2	8
Least missed words	0	4	4	8

Table VIII demonstrates that four of the least missed group of alphabet words contain three syllables. In two of these words the stress is on the second syllable (Sierra, November). The most missed group of alphabet words, however, has only two three-syllable words, both of which were pronounced with stress on the first syllable. None of the least missed group has only one syllable. These findings indicated that there is a tendency for the least most often missed words used in the Listen Study to have more syllables than the most often missed words. The findings are consistent with an earlier study (Hirsh, Reynolds, and Joseph, 1954) which demonstrated that words with more syllables were more intelligible in noise.

RELATIVE PHONETIC POWERS OF THE FUNDAMENTAL SPEECH SOUNDS OF THE MOST AND LEAST FREQUENTLY MISSED ALPHABET WORDS

It has been concluded (Fletcher, 1953) that there is a range of 28 decibels between the weakest and the most powerful speech sounds in terms of mean power. Gerber (1960) has prepared a list of relative phonetic powers of the fundamental speech sounds, ranging from 1 to 680. The actual range covered is 28 decibels. The Gerber list is included in Table IX.

TABLE IX

Relative Phonetic Powers
of the Fundamental Speech Sounds

Sound (Vowel)	Relative Power	(Semi-Vowel)	Relative Power	Sound (Consonant)	Relative Power
As in talk	680	As in rain	210	As in shot	80
top	680	let	100	chief	42
ton	510	ring	73	jot	23
tap	490	(w)	(not given)	azure	20
tone	470	(j)	(not given)	zip	16
took	460	me	52	sit	16
tape	370	no	36	tap	15
ten	350			get	15
tool	310			cat	13
tip	260			vat	12
team	220			that	11
				bat	7
				dot	7
				pat	6
				phone	5
				thin	1

In Table IX it will be noted that the relative power of the consonant "th" as in thin is valued at one; this contrasts with the relative power of the vowel in talk which is valued at 680.

Table IX has been arbitrarily used to analyze the relative power value of that part of each of the most and least frequently missed alphabet words which received primary stress, e.g., India. The technique utilized was to make a simple addition of the power values of each component of the stressed syllables. It must be kept in mind that such an analysis is not based upon actual acoustical measurements of the words spoken against a noise background. What has been done is to isolate the stressed portion of the word, and present a simple statement concerning the relative power value of the letters comprising the word. No attempt has been made to take into consideration the effect upon intelligibility of the transition from one speech sound (or letter) to another.

TABLE X

Relative Power Values of the Stressed Syllable in Each of the Eight Most Frequently Missed and Eight Least Frequently Missed Alphabet Words

Most Missed Words			Least Missed Words		
Stressed Syllable	Power of Units in Syllable	Total Relative Power of Syllable	Stressed Syllable	Power of Units in Syllable	Total Relative Power of Syllable
India	260.36	296	November	12.350.52	414
X-Ray	350.13.16	379	Romeo	210.470	680
Alfa	490.100	590	Whiskey	460.260.16	736
Golf	15.680.100.5	800	Sierra	350.210	560
Zulu	20.310	330	Uniform	260.310.36	606
Juliet	80.310	390	Bravo	7.210.680	897
Victor	12.260.13	285	Delta	7.350.100	457
Kilo	13.220	233	Tango	15.490.73	578
TOTAL		3303	TOTAL		4928

It will be observed that Table IX contains no relative power value for the letter "w". To arrive at a power value for the syllable "whis" in the word Whiskey, the letter "w" was interpreted as being composed of two sounds, the "oo" sound as in the word Took, plus the "ih" sound as in the word Tip. Other decisions of this sort were made in relation to the words Uniform, and X-Ray.

Table X indicates that the least missed alphabet words have more relative power distributed among their stressed syllables. Least missed words have a total stressed syllable value of 4928, while most missed words have a value of 3303. This is a difference of approximately 20%.

Another way the Relative Power Value Table may be arbitrarily used is to compare the total relative power values for each word in the most and least missed word groups.

TABLE XI

Total Relative Power Values of Each of the Eight Most Frequently Missed and Eight Least Frequently Missed Alphabet Words

Most Missed Words		Least Missed Words	
Word	Total Relative Power	Word	Total Relative Power
India	1073	November	1647
X-Ray	959	Romeo	1422
Alfa	1105	Whiskey	969
Golf	800	Sierra	1306
Zulu	740	Uniform	1603
Juliet	1075	Bravo	1379
Victor	980	Delta	982
Kilo	803	Tango	1048
TOTAL	7535	TOTAL	10356

Table XI reveals that the total relative power value of the least missed words is 18% greater than the power value of the most missed words. On the basis of an arbitrary use of a list of relative power values it can be stated that the stressed syllables of the most frequently missed alphabet-spelling words have about 20% less relative power than the least missed words. In relation to the entire word the difference is about 18%.

RELATIVE CONTRIBUTION OF VOWELS AND CONSONANTS TO SPEECH INTELLIGIBILITY

It has been said (Gerber, 1960) that consonants contribute ninety-five percent of speech intelligibility. This hypothesis receives reinforcement when alphabet words are analyzed in relation to their comparative intelligibility when only vowels or only consonants are included. In the following analysis semivowels, such as r, l, w, m, and n, and letters such as x and y are included as consonants.

TABLE XII

Vowels Only

Most Missed	Least Missed
I--IA	-O-E--E-
--A-	-O-EO
A--A	--I--E-
-O--	-IE--A
-U-U	U-I-O--
-U-IE-	--A-O
-I--O-	-E--A
-I-O	-A--O

Consonants Only

-ND--	N-V-MB-R
XR-Y	R-M--
-LF-	WH-SK-Y
G-LF	S--RR-
Z-L-	-N-F-RM
J-L--T	BR-V-
V-CT-R	D-LT-
K-L-	T-NG-

Obviously it is easier to decipher words which have only the consonants included. An analysis of the most and least missed words in the Listen Study indicates that the eight least missed words contained slightly more consonants or semi-vowels and more vowels than did the eight most missed words. Certain letters, such as w and x were interpreted as being composed of several vowel or consonant sounds.

TABLE XIII

Consonant-Vowel Composition of the Most and Least Missed Words

	Total Consonants or Semi-Vowels	Total Vowels	TOTAL
Most missed words	22	17	39
Least missed words	26	21	47

These findings indicate that the presence of more consonants (containing more information value) together with the presence of more (higher relative power) vowels was characteristic of the eight words in the least missed group.

ANALYSIS OF THE INFLUENCE OF THE PRESENCE OF THE NASAL LETTERS IN THE ALPHABET WORDS

There are three letters which are known as "nasals", "m", "n", and the "ng" sound, as in "sing". These sounds have great relative duration, and are relatively more powerful than consonants (see Table IX, listing relative power values). Analysis has indicated that six of the three nasals are present in the eight alphabet words least often missed, whereas only one nasal is present in the eight alphabet words most often missed.

TABLE XIV

Presence of the Nasals ("M", "N", or "NG") in the Alphabet Words

Nasal	Most Missed Group	Least Missed Group
m		3
n	1	2
ng		1

These findings furnish more evidence relating to the comparatively different intelligibility scores of the 16 alphabet-spelling words under consideration in the present analysis.

ANALYSIS OF THE INTELLIGIBILITY OF TEN NUMBERS USED IN THE LISTEN STUDY

It will be remembered that each of the 40 masked signals used in all tests in the Listen Study was made up of two alphabet words and two numbers. A matrix may be found on a subsequent page which gives data relating to the number of times numbers were correctly identified, were confused for other numbers, or were left unidentified by subjects.

In the Listen experiment the ten numbers achieved the following intelligibility scores:

TABLE XV

Intelligibility Scores Achieved by the Ten Numbers Used in the Listen Study

(Ordered in relation to decreasing rate of intelligibility)

Numbers	(% of occasions on which numbers were correctly identified)
4 (fo-wer)	94.02
8	87.75
2	81.95
6	80.37
7	79.82
1	79.25
0 (zero)	77.41
5 (fife)	74.26
3 (tree)	62.79
9 (nin-er)	62.60

TABLE XVI

NUMBER CONFUSION MATRIX

(Numbers Identified Correctly and Numbers Confused for Other Numbers)

NUMBER REPORTED BY THE SUBJECT

Actual Number used in Test	0	1	2	3	4	5	6	7	8	9	No Answer	Other Response	(Total Wrong)	Total Right and Wrong	Intelligibility Score (%)
0 (Zero)	1463	68	33	16	165	0	12	28	10	2	93	0	(427)	1890	77.41
1	8	2219	9	17	81	15	54	137	18	84	238	0	(661)	2880	79 25
2	9	6	2733	133	17	2	58	7	125	1	244	0	(602)	3335	81.95
3 (Tree)	19	4	277	1129	5	4	96	4	103	15	142	0	(669)	1798	62.79
4 (Fo-wer)	7	1	1	0	2059	21	3	7	3	7	81	0	(131)	2190	94.02
5 (Fife)	4	82	6	3	27	1581	17	46	64	89	210	0	(548)	2129	74.26
6	4	29	11	17	35	9	1831	46	17	5	276	0	(449)	2280	80.37
7	3	87	3	3	41	23	219	2346	9	1	204	0	(593)	2939	79.82
8	4	11	32	46	8	5	13	4	1898	11	134	0	(268)	2166	87.75
9 (Nin-er)	28	93	48	38	96	50	26	66	127	1498	321	2	(895)	2393	62.60
TOTAL	1549	2600	3153	1402	2534	1710	2329	2691	2374	1713	1943	2	(5243)	24000	78.2

The preceding Table indicates that the numbers nine (pronounced "nin-er"), three (pronounced "tree"), five (pronounced "fife"), and zero (pronounced "zero", rather than "oh") were the four words which were missed most often by subjects.

In an earlier experiment (Moser, 1960) conducted at the Ohio State Research Foundation, a study was conducted of the intelligibility and confusability of 16 variants of the English numbers. The digits were tested in sufficient noise to produce about 50 percent error; ten speakers pronounced the words. One significant finding in the earlier study was that:

> "Of the common variants for the digits studied, those which are most intelligible are: Oh, One, Two, Three (or Free), Six, Seven, Eight, and Nine. Those which are less intelligible are: Zero, Tree, Fow-er, Fife, and Nin-er. The above findings hold true for the majority of speakers, but not for all speakers."

Although the experimental conditions in the earlier test and in the Listen Study were different (only one noise level and one speaker was used in the present experiment), the new data tend to confirm the earlier finding relating to the comparatively inferior intelligibility of the irregularly pronounced numbers "Zero", "Tree", "Fife", and "Nin-er". (The present study used the pronunciation "Fo-wer", rather than the pronunciation "Fow-er".) These findings indicate that some of the "irregular" pronunciations currently employed by the Air Force to tell numbers are not of maximum intelligibility.

MAJOR CONFUSIONS MADE BY SUBJECTS IN IDENTIFYING NUMBERS

In addition to testing the comparative intelligibility of the ten digits an analysis was made of the confusions made by subjects in identifying numbers. Table XVII, on a subsequent page, indicates the major number confusions which were noted, together with a percentage indicating the part played by the confusion in relation to the total number of times the number was missed. Inspection of the Table reveals the following outstanding sources of confusion:

confusing "Four" for "Zero"
confusing "Seven" for "One"
confusing "Three" for "Two"
confusing "Two" for "Tree"
confusing "Nine" for "Fife"
confusing "Six" for "Seven"
confusing "Three" for "Eight"

TABLE XVII

Major Confusions for Each of the Numbers

Number Used in Test	Major confusion (in order of importance) First	(%)	Second	(%)	Third	(%)
Zero	Four	(38.6)	One	(15.9)	*	
One	Seven	(20.7)	Nine	(12.7)	Four	(12.3)
Two	Three	(22.1)	*		*	
"Tree"	Two	(41.4)	Eight	(15.4)	*	
Fo-wer	no major confusions					
"Fife"	Nine	(16.24)	One	(14.9)	*	
Six	Seven	(10.2)	*		*	
Seven	Six	(36.9)	One	(14.7)	*	
Eight	Three	(17.2)	Two	(11.9)	*	
"Nin-er"	Eight	(14.2)	Four	(10.7)	One	(10.4)

*Minor percentages (less than 10%) are not included.

It should be pointed out that the seven outstanding sources of confusion reported above are cited as major contributors to the unintelligibility of numbers in the earlier research conducted at the Ohio State University (Moser, 1960). The significance of these findings lies in the fact that the pronunciation of certain numbers, on the basis of the present evidence, typically tends to cause confusion between those numbers and certain other numbers. Whether different pronunciations of the words would alleviate some of the confusion cannot be answered in this paper.

SUMMARY AND CONCLUSIONS

In the Listen Study it was found that there was widespread variation in the percentage of times the 26 words used in the military alphabet were missed when masked by random white noise. The word November was missed on only 9% of the occasions it was used, while India was missed on about 71% of the occasions. The most successful words were:

November	Sierra	Delta
Romeo	Uniform	Tango
Whiskey	Bravo	

The least successful words were:

India	Alfa	Zulu	Victor
X-Ray	Golf	Juliet	Kilo

Analysis revealed that some of the least successful alphabet words such as India, Juliet and Zulu, were continually confused for each other. In addition, major sources of error were the confusion of the words Zulu and Juliet for the word Kilo. Another major confusion were the words Victor and X-Ray for the word Whiskey. These findings relating to the consistent confusion of certain words for other words agreed with data obtained earlier in one phase of a research project at the Ohio State University Research Foundation.

Analysis indicated that four of the least missed group of alphabet words contained three syllables. On the other hand the most missed group contains only one three-syllable word. A tendency existed for the least missed words to have more syllables. This finding is consistent with an earlier study (Hirsh, Reynolds, and Jacobs, 1954) who found that words with more syllables were more intelligible in noise. Using a Table prepared by Gerber (1960), an analysis was made of the relative power values of the vowels and consonants in the eight most successful and eight least successful words. Previous studies have indicated that vowels have more power (capacity to produce more acoustical energy) than do consonants. The "a" sound in "talk", for example, has the capacity to generate 680 times the relative power of the "th" sound in "thin". Analysis revealed that the stressed syllables in the least missed words have about 20% more relative power than stressed syllables in the most missed group of alphabet words.

Previous research has demonstrated the importance of the presence of consonants in creating intelligibility. It has been suggested that identification of a word is easier if only the consonants are known than if only the vowels are known (contrast N-v-mb-r (November) with I--ia (India)). In the group of eight least missed words there were 26 consonants; in the group of eight most missed words there were 22 consonants.

Previous research in speech communication has demonstrated the relatively greater power value of the three letters which are nasals (pronounced nasally). These are: "m", "n", and "ng". The nasally pronounced words also have greater duration. An important finding was that the eight words least often missed made use of six nasally pronounced letters. The most often missed group of words made use of only one nasally pronounced letter.

It was discovered that four of the numbers which were pronounced differently (i.e., "nin-er", "tree", "fife", and "zero", rather than "oh") were less intelligible in noise. These findings agree with an earlier study conducted by Moser (1960) who also found that the pronunciations "nin-er", "tree", "fife", and "zero" were not as intelligible as "nine", "three", "five", and "oh".

It must be pointed out that the preceding data were gathered in a single experiment, the Listen Study. Experimental conditions were determined by needs basic to the central purpose of that study, i.e., to develop a training program to enhance the ability of Air Force personnel to read signals through noise. One constraint imposed on the data presented in this paper was the fact that only one voice pronounced the words. It might be desirable to have different voices involved to test the importance of the voice variable. In addition, the use of different types and patterns of noise and different signal-to-noise ratios would be desirable. The present document has indicated that there were specific reasons why some alphabet words "failed". Using these reasons as criteria, other Air Force words and command phrases might be selected and tested.

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Supersedes TM-886. Reports that the Listen Study (Cunningham, Moler, Sheldon, 1962) was designed to develop and test a training method to increase the ability of Air Force personnel in identifying verbal signals masked by jamming. Presents and discusses the findings relating to alphabet intelligibility. Concludes that in the Listen Study it was found that there was widespread variation in the percentage of times the 26 words used in the military alphabet were missed when masked by random white noise.

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